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RAINBO

Comune di Bologna

lepidaspa

arpae emilia-romagna

NIER INGEGNERIA

MEEO Meteorological Environmental Earth Observation

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Document Code	Task 1.3 + task 1.4
Title of Document	Specification of RainBO platform requirements
Reference Action	C1
Dissemination Level	CO
Date of Preparation	30/12/2016
Author(s)	NIER Ingegneria SpA
Editor(s)	NIER Ingegneria SpA
Document Location	https://drive.google.com
Project Coordinator	Franco Cima

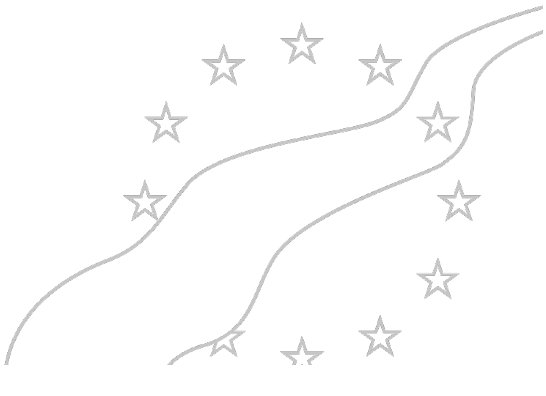
Version History

Version 0.01		*First Version – NIER Ingegneria SpA*

Document Summary

The present document relates the RainBO project results concerning the two following tasks:
1.3 Specification of monitoring infrastructure requirements;
1.4 Specification of RainBO platform requirements.
In particular, the aim of the first task concerns the identification of the monitoring system and devices already available and used and of their limits and the specification of the performance to be fullfilled by the monitoring.
These information are provided in the deliverable "Collection of user needs and review of the state of the art" while in the present document they are taken up as functional and "non functional" requirements of RainBO system.
The four task of C1 activity aims at producing a complete set of consistent and coherent requirements that will be development in RainBO system starting from user needs.
The requirements should specify:

- data to be stored by the implemented data based;
- functionalities to be implemented by software modules;
- constraints to be fulfilled in the integration of database and modules within the whole platform
- main features of the graphical user interface.



Index

Annex List

Annex List

1. RainBO overall description

1.1. Main functionalities of RainBO platform

RainBO project is a follow up of BLUEAP Life project[1], which showed extreme rain phenomena as a critical consequence of climate changes in urban areas. RainBo will also consider some results of T-Rain[2], a Climate-KIC project to improve an innovative monitoring system based on big data coming from cellular networks.

The high-level objective of RainBO is the improvement of knowledge, methods and tools for studying and forecasting extreme rain events in small basin and their potential impacts in urban areas (flash flooding).

In particular, the focus of the project is to analyze the potential consequences concerning two types of events:

- Extreme rainfall events;
- Heavy rainfall occurring when soil is saturated, typically in winter or spring season, after a period of continue precipitations or after a snow melting period.

RainBO will contribute to the local resilience both in the planning phase (without events) and in the emergency phase (warning), allowing:

- Territorial planning activities and emergency response support;
- Reliable system for early warning and monitoring system to follow the scenario evolution.

The key characteristics of RainBO system are:

- **Web-based** platform;
- **Open architecture**: RainBO will be created as open-source software without any proprietary constraints;
- **Modular structure**: the system will be divided into smaller blocks, the modules, which can be independently created and used.

The key functions of RainBo address the following (user) needs:

- Acquisition of hydro-meteorological sensors collecting the extreme rainfall data;
- Improvement of an innovative monitoring technology of the meteorological conditions based on microwaves analysis
- Definition of a reliable Early Warning system
- Acquisition and elaboration of the results of hydrogeological Simulation models;
- Availability of territorial data included risk maps
- Interoperability and integration with other existing systems.

RainBO platform prototype will be validated in two pilot cases:

- Bologna Municipality: Ravone creek;
- Parma Municipality: Parma River.

The system can be used in two modalities:

- **OFF - LINE modality,** for: - planning activities about mitigation actions to reduce hydraulic risk; -emergency plans definition; - territorial organization; - data consultation and update.

[1] http://www.blueap.eu/site/en/
[2] http://www.climate-kic.org/projects/t-rain/

The system will be able to simulate different scenarios, based on climate models, hydrological models, territorial data and vulnerability model, in order to assess the potential impacts of intense rainfall in small basins, in urban area.

- **ON - LINE modality**, to provide early warnings monitoring the different possible scenarios. In particular, the system will monitor the scenario evolution to detect forerunners, in order to increase the ability of diagnosis of weather condition and to support emergency management in case flash flood situation.

In OFF - LINE modality, the RainBo allows the following actions:

- Displaying, consulting and modifying / updating vulnerability maps;
- Displaying and consulting hazard maps;
- Consulting simulation scenario (outputs of Simulation Module);
- Uploading new simulation scenarios;
- Overlaying of hazard and vulnerability maps in order to generate risk maps;
- Displaying, consulting and modifying / updating territorial data and information;
- Displaying, consulting and updating historical events Database;
- Consulting weather forecast;
- Consulting previous data from monitoring sensors network. **Inserire l'elenco delle reti di sensori di monitoraggio utilizzati (radar, microwaves, tradizionali, crowd sourcing etc)**

The following table summarizes the main RainBO functionalities for - OFF-LINE modality.

OFF-LINE Functionalities	**Overall description**
Support to warning threshold test and upgrading	The simulation models 'application and the monitoring network (both traditional sensors and innovative ones) can allow the testing of existing warning thresholds and, if necessary, the definition of new local warning criteria.
Support to risk maps creation	The outputs of simulation module **(specificare che l'output del sistema di simulazione è un dato puntuale di livello idrico in punti specifici dell'alveo osservato e non direttamente la mappa di pericolosità idraulico.)** and of vulnerability module can be integrated for generating detailed risk maps. The user can make advanced query to consult these maps and the associated database. The vulnerability maps can be modified and updated by users (depending on their role).
Support to emergency planning	By system database, the user will have availability of most of data and information necessary for defining an

	emergency plan (by only platform). In particular, for example, the user can be supported by RainBO in the following activities: - Individuation of critical elements (structures /infrastructures) exposed to hydrogeological risk; - Analysis of reference scenarios based on simulation and historical data; - Analysis of interactions between heavy rain events and critical infrastructures; - Definition of warning procedures; - Definition of communication plan (for citizens).
Support to territorial planning	By system database, the user will have availability of most of data and information necessary for territorial planning on only platform. For example, the users, by consulting RainBO territorial DB and GIS, can get the information useful to define mitigation actions or city plan restrictions. The effects of territorial interventions strategy can be evaluated through vulnerability module and planning module.
DB consulting, modifying and updating	Four different database will be connected to RainBO platform: - Simulation DB - Monitoring DB - Historical DB - Territorial DB The Simulation, Historical and Territorial DB will be consulted in both “OFF and ON line” use, but they can be updated and modified only in “OFF-LINE” modality. The monitoring DB can be updated and modified also in “ON-LINE” modality.

In ON – LINE modality, RainBO allows the following actions:

- Monitoring the data from traditional sensors network;
- Monitoring the data from innovative sensors network (microwaves cellular network disturbs);
- Monitoring the data from crowd sourcing app
- Identifying and updating the reference scenarios by Data mining Module;
- Getting early warning (when critical thresholds are exceeded);
- Displaying and consulting database and risk maps (of reference scenario);
- Consulting weather - forecast;
- Getting alert thresholds.

The following table summarizes the main RainBO functionalities for - ON-LINE modality.

ON-LINE Functionalities	**Overall description**
Monitoring	The users can monitor the forerunner parameters of events.
Warning	The system will provide warning signals to user in case of exceeding of alert thresholds.
Support to warning system activation	An early warning system for heavy rain event in small basin can support civil protection operators to activate warning system. The interoperability with regional warning system or other DSS, already used, can increase the velocity of intervention, which is a basic requirement for this type of events.
Support to emergency management	The system can provide to the user the reference scenarios, with different level of reliability, which can be chosen in function of monitoring data and their correlation to historical events and simulation scenarios. Moreover, the user can consult and make queries on territorial data, on vulnerability maps and, more in general, on all information that will be available through RainBO DB. In addition to this, the user can follow event evolution by consultation of sensors data.

1.1.1. RainBO modules

As it is described above, RainBO software is a web-based platform with modular structure. In particular, the following

modules will be created:

1. Simulation Module for small catchments (Criteria3D)
2. Monitoring Module (composed by Rainlink 4MR Module and SensorNET Module)
3. Data Mining Module
4. Vulnerability Module
5. Planning's support Module (for territorial and emergency planning's support) – operative interface;
6. Forecast hydraulic level module for small catchments (from Simulation Database)
7. RandomForest Module for medium-large catchments (forecast of threshold crossing probability)
8. Early warning Module (for warning advising) – operative interface;
9. External communication Module (for interconnecting with external systems).

For the module 1), specific data sheets have been drawn up and reported in Annex 3.

For the modules 2) – 4), specific data sheets have been drawn up and reported in Annex 1.

In particular, the data sheets refer to the following topics:

- Short description of module functionality;
- Possible algorithm used by module;
- Input data;
- Output data;
- Possible GIS interface,
- Integration with other RainBO modules.

The requirements of RainBO modules and their main functionalities have been discussed between partners in specific meetings. The reports of the meetings, concerning RainBO modules and requirements specification, are included in Annex 2.

The Analysis of RainBO modules' requirements led to the review of the simplified framework of system architecture, towards what was presented in project documentations (see "Part C – detailed technical description of the proposed actions – Action 3, picture "RainBO platform architecture"").

This review would show better the relationships between modules and system database and the potential interoperability with external web-service.

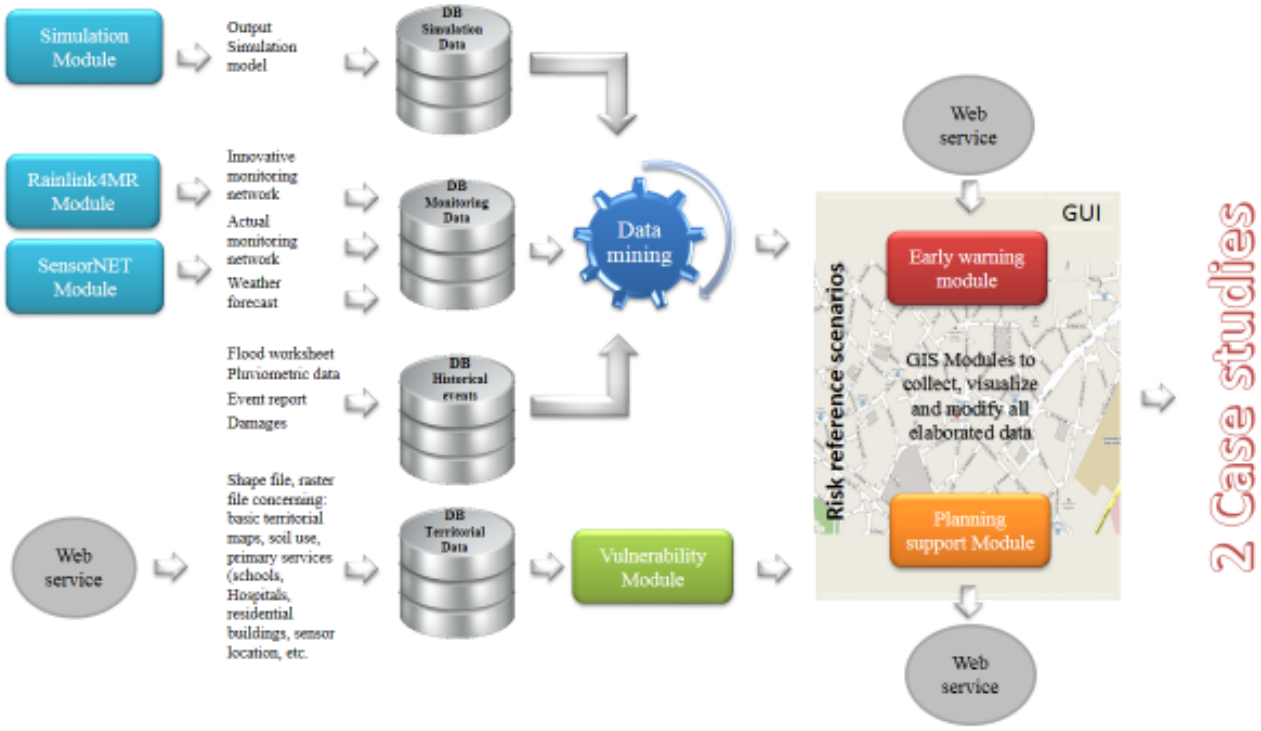


Figure 1 – Reviewed RainBO platform architecture

1.1.2. Use cases

For the two usage modalities of RainBO software, use-cases are design using "*use case diagrams*", consisting of simple schemes describing the services of the platform.

1.1.2.1. OFF-LINE use case

RAINBO will provide to the users a considerable amount of data and related information that get a high level of knowledge on local municipal area. In particular, it can allow by a single system the following types of information:

- Territorial data (Territorial DB)
- Vulnerability maps (Territorial DB + Vulnerability Module)
- Hazard maps (Simulation DB + Territorial DB)
- Sensors Information (Monitoring DB + Monitoring Module)
- Weather forecast (Monitoring DB + Monitoring Module)
- Past emergency events information (Historical DB)
- Modelled scenarios / Risk maps (Simulation DB + Simulation Module + Vulnerability module)

The following scheme shows the main functionalities of RainBO for planning activities.

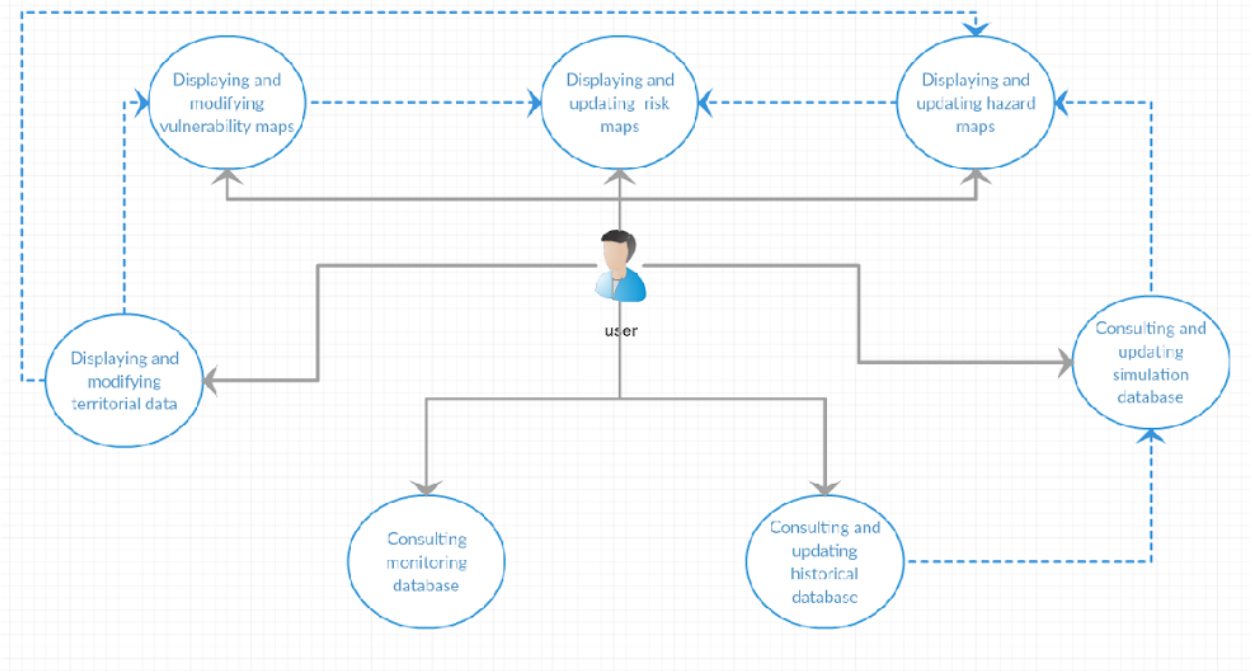


Figure 2 - OFF-LINE Use case

The most of information, above described, can be provided by GIS interface and they will be elaborated by "planning support module".

Figure 3 – GIS interface functionality in OFF-LINE use

1.1.2.1. ON-LINE use case

The main objective of early warning module (ON-LINE use) is the activation of warning system in order to support the users for the emergency activities by providing:

- detailed territorial information (more accurate than the regional level) about the expected phenomenon on a local scale;
- detailed monitoring information about event evolution.

RAINBO will provide to the users a considerable amount of data and related information. In particular:

- Maps of the reference scenarios: through data analyses, the simulated scenarios more similar to the real situation monitored can be selected (each scenario selection will be characterized by a different level of reliability);
- Reference Historical events: by means of data analysis, the past events more similar to the situations monitored in real time can be identified;
- Real-time monitoring data of the traditional monitoring sensor network[3];
- Real-time monitoring data of innovative monitoring sensor network and displaying of precipitation maps (signal attenuation system)[4];
- Vulnerability, Hazard and Risk maps of reference scenario;
- Early warning based on Forecast and Alert thresholds;
- Real-time monitoring data for weather - forecast.

The following scheme shows the main functionalities of RainBO for early warning activities.

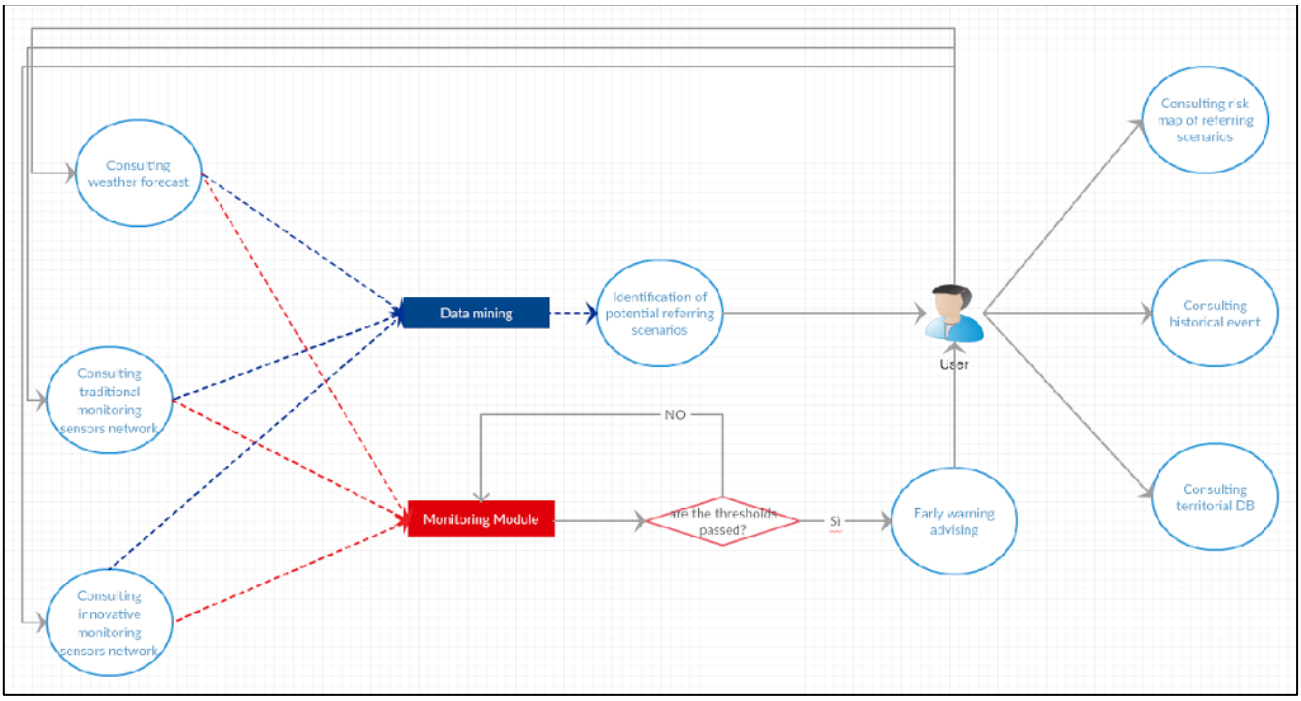


Figure 4 – ON-LINE use case

[3] See next paragraph 1.2.
[4] See next paragraph 1.3.

The most of the information previously described can be provided to the users by a GIS interface.

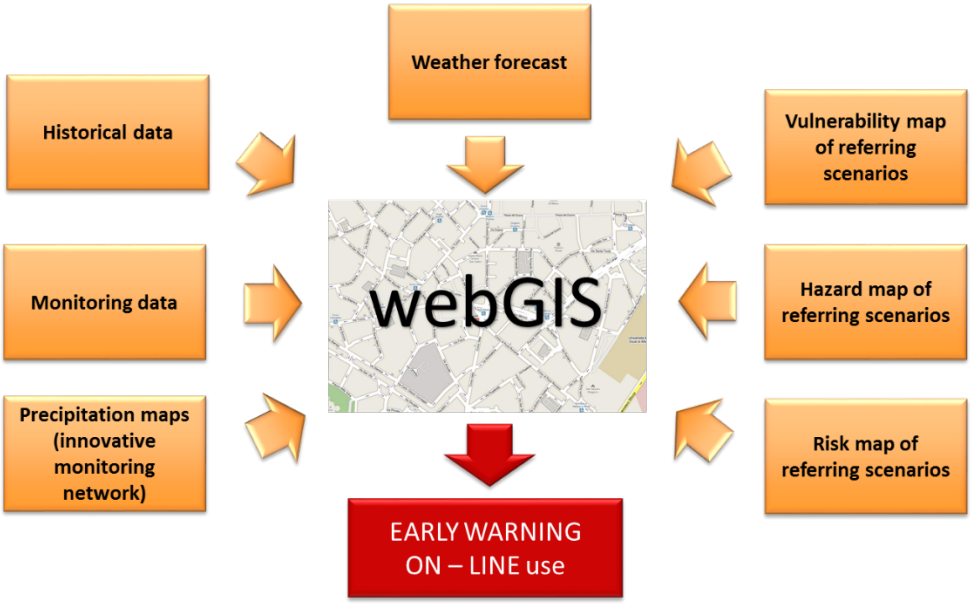


Figure 5 – GIS interface functionality in ON-LINE use

1.2. Interface with available monitoring system

The available monitoring system is managed by Arpae and is mainly made up by meteorological modeling, radar, sensors of soil moisture and idro-meteo regional units. Meteorological modeling and radar data are distributed on open data platform, while data of sensors of soil moisture and idrometeo regional units, as well as of those of new sensors installed in Ravone basin, are distributed on R-MAP platform. The interface with available monitoring system will be constituted by webservices with standard XML that will read data from Monitoring DataBase and making them available to all the module of the RainBo platform.

SensorNet platform will implement atomic modules to collect data from the different sources and to save them in the Monitoring DataBase in a standard format. Each module contains the access mode and the commands necessary to retrieve data from a specific source. SensorNet platform constitues also the graphic interface for all the measures monitored belongin to available monitoring system as well as to innovative one.

The frequency of data delivery and the transmission delay from the Arpae monitoring system depends on the type of data: in the RainBo project the “traditional” data will be collected from weather stations, radar and meteorological models.

Weather stations: the delivery frequency of weather station report is 30 minutes, whereas the transmission delay ranges between 20 and 30 minutes.

The new stations that will be installed in the framework of the RainBo project (see Deliverable New water Level Data, Action C2) have a delivery frequency of 5 minutes, with data recorded each 1 minute, the transmission delay is about 2 minutes. Available by means of open data of Arpae.

Radar data: the data acquisition occurs every 5 minutes, including the sampling time with a transmission delay of 3 minutes. Available by means of open data of Arpae.

Meteorological model: for Cosmo I2 the model produces two runs per day (00 - 12 GMT) and the transmission delay is 4 hours. Available by means of open data of Arpae.

1.3. Interface with the innovative monitoring system

The innovative monitoring system is based on microwave link signal processing algorithm RAINLINK customized for RAINBO purposes. The main scope of the monitoring system is the data acquisition from the telecommunication microwave links data management system, the data processing applying the RAINLINK algorithm, the generation of precipitation maps both historical and in near real time, the storage of the output into the Monitoring Database.

The system is currently configured to generate precipitation maps every 15 minutes but it can be set up for higher frequency of data acquisition. The precipitation maps can be delivered with a short delay depending on the target area and the computational resources available.

The innovative monitoring system is conceived for expert users only and do not include a graphic user interface since the products (precipitation maps) are supposed to be provided to the RainBO database.

The hardware (virtual/ physical hardware) requirements estimated for running the monitoring system over the target areas are: 1 core , 20GB RAM , up to 1 TB of storage (depending on the data archiving approach) , OS linux with R package installed.

The input data are structured in two specific formats. The first one deals with the antenna and link description, it can be in excel, csv, ascii and shall describe the characteristics of the infrastructure in terms of length of the link, frequency expressed in GHz and geographic coordinates.

The second data format is related to the transmitted power measurements and can be in excel, csv , ascii and shall report the position and or label of the link, the measured power and the related timestamp.

The output data shall be a GIS ready data format that can be GeoTIFF, JPEG but also netCDF and HDF5 in case of the output shall be used in weather forecasting models.

The RAINLINK4EMR algorithm works with 15-min maximum and minimum or instantaneous received powers and it performs the following processing steps:

- it calculates signal attenuation estimations and the instantaneous path-averaged rainfall depths.
- It distinguishes real rain signals from noise by space correlation assessments and applying variable thresholds to remove outliers.
- real rain signals are interpolated over a grid to obtain a rainfall map, applying an ordinary Kriging process which employs a spherical variogram model.
- Rainfall maps are delivered every 15 min with a delay of a pair of minutes of processing time (still to be tested in real-time); a daily accumulation map is produced every day. The 15 min maps are comparable with real time radar reflectivity maps, the daily accumulated ones are comparable with rain-gauge datasets.

1.4. RainBO Database

RainBO platform is made by four databases addressing four different functions:

1. Monitoring DataBase
2. Territorial Data
3. Simulation Database
4. Historical Database

The monitoring database is conceived for the hosting of all data collected from weather monitoring systems which are the network of weather ground stations and meteorological radar managed by Arpae, microwave link precipitation monitoring system, external weather datasources such as private monitoring networks (emilia romagna meteo) and crowd sources. This database will be continuously populated with real time data like precipitation, soil moisture, water levels in point series data or gridded data form such as geoTIFF, hdf5, netcdf, grib, gif, jpeg. These data have the scope of rapid querying and alert/warning maps generation. Independently by the kind of the data source (institutional, private, crowd) the data collected must be in standard GIS ready formats according to the type of data, raster for images, shape for punctual measurements. In both cases, since the collected data are environmental parameters, the content can be real, integer or float.

The territorial database is conceived for the hosting of static geographical information such as soil use, streets, infrastructures of service networks (gas, telecommunication, etc.), primary services (hospital, school), residential buildings. Also in this case the data collected must be in standard GIS ready formats according to the type of data (raster for images, shape for punctual, linear and aerial information) to be combined with monitoring data for alert and warning services. Territorial database is conceived also for the hosting of vulnerability, hazard and risk maps of referring scenarios.

The simulation database has the aim to define the type and the degree of event criticalities.

It will be a table that refers to a single creek/river and contains the following variables:

- Reference period (months)
- Initial condition of soil moisture (%)
- Initial water level at the reference hydrometer (cm)
- Forecast of the precipitation event duration (hours)
- Forecast of precipitation sum (mm)
- Forecast of the maximum intensity of precipitation (mm/h)

The data will be grouped into ranges (e.g.: 30-40 mm, 8-12 hours, etc.) and they refer to forecast data or observed data at the beginning of the forecast rainfall event (initial condition).

Each combination of these variables will be linked to a forecast range of peak water level (e.g.: 50-100 cm) at the reference point, corresponding to a different value of risk forecast.

The historical database would collect several information up to now available from different sources and different formats.

Flood data sheet: detailed description of the flood event on its river course. Format: .xls file

Pluviometric data: sum of hourly precipitation [mm]. Format: .csv file

Event report: report of extreme precipitation events describing the weather phenomena and analysis of the observed data. The description of the impacts on the territory can be included (for the most significant events). Format: .pdf file

1.5. General constraints

RainBo platform shall be composed at least by the following modules:

1. Simulation Module for small catchments (Criteria3D)
2. Monitoring Module (composed by Rainlink 4MR Module and SensorNET Module)
3. Data Mining Module
4. Vulnerability Module
5. Planning's support Module (for territorial and emergency planning's support) – operative interface;
6. Forecast hydraulic level module for small catchments (from Simulation Database)
7. RandomForest Module for medium-large catchments (forecast of threshold crossing probability)
8. Early warning Module (for warning advising) – operative interface;
9. External communication Module (for interconnecting with external systems).

Normally each module will expose standard interfaces (web services) in order to ensure system generality and replicability as well as their interoperability and integration with other platforms (open architecture).

Each module must be able to be implemented on different physical machines (scalability).

Each module must be configurable, ie the operating parameters must be read from the table and not written in code (configurability).

The platform's modularity also ensures maintainability over time, as well as its evolution, because each module can evolve or be replaced independently from each other.

Each DB will consist of tables and relationships that will allow management of data as general as possible. For each type of data, the data model will be specified with all the attributes associated to this information.

Each DB will be centralized and will enable that the data will be shared, managed and update from different users.

The Monitoring database provides data from different sources into a single standard format regardless of the type of measure and the type of interface with which they are made available. For the meteo, measure units and samples time data wiil be standardized.

For Territorial database, the definition of a data model for mapping of territorial will allow their systematization and standardization, useful to the management of all types of critical events, not only of that focus of the project (flash flood). The standardization of territorial data will guarantee, also, the interoperability also with other systems.

2. RainBO system requirements

The following table contains the list of the system requirements.

Requirement ID	Overall requirements description

REQ. 1	The Simulation Module (Criteria3D) must acquire as input data: ● DTM sizing from to 2m to 10m depending on catchment dimension, ESRI .flt raster format, max 500.000 cell number. ● Soil map and soil db: raster file (ESRI .flt) and SQLite database ● Land use maps: same extent and format of DTM ● Historical meteo data set, saved in a SQLite database, for the following parameters: - temperature (°C) - precipitation (mm) - radiation (W/m2) - Relative humidity (%) - wind intensity (m/s) See annex 3 for more detail
REQ. 2	The RainLink4EMR Module must acquire the following input data: ● Instantaneous received power measured on the antenna of the Microwave telecommunication network (dB) every 1 or 15 minutes ● Minimum and maximum received power measured on the antenna of the Microwave telecommunication network (dB) every 1 or 15 minutes ● Date and time (UTC) ● Frequency of the Microwave signal (GHz) ● Path length (km) ● latitude of link (°km) ● longitude of link (°km) Input data can be acquired as csv or excel file.
REQ. 3	The Vulnerability Module must acquire as input data: ● georeferential territorial data(shape, raster, associated metadata) ● Hazard maps concerning the hydraulic level at the entrance of drainage urban network (polygonal shapefile linked to 3 probability classes: frequent, less frequent, rare)
REQ. 4	The planning's support Module must acquire as input data: ● georeferential territorial data(shape, raster, associated metadata) ● Vulnerability maps (shape file and associated metadata) ● Risk maps (shape file and associated metadata)
REQ. 5	The Early warning Module must acquire, as input data: ● Georeferential territorial data (shape, raster, associated metadata) ● Vulnerability maps (shape file and associated metadata) ● Risk maps (shape file and associated metadata) ● Hydraulic level at the entrance of drainage urban network (cm) ● Level of event severity (depending on alert threshold) ● Georeferential image in jpeg, hdf5 format, provided by The RainLink4EMR module
REQ. 7	The module for acquisition from RainLink4EMR data must acquire the following input: ● Georeferred image in jpeg, hdf5 format related to precipitation estimation ● Table reporting the precipitation level for each monitoring point.
REQ. 9	The module for acquisition of data from the Simulation Module must acquire table in CSV format (field separation symbol ";"), with the following variables, grouped in ranges.: ● Reference time (seasons/months) ● Initial soil humidity (%) ● Initial Hydraulic level (cm) ● Foreseen duration of precipitation (hours) ● Foreseen precipitation accumulation (mm) ● Maximum foreseen precipitation intensity (mm/h) ● Forecast Hydraulic level (cm) at the reference hydrometer
REQ. 10	The module for acquisition of historical data must acquire, as input, a CSV file , (field separation symbol ";").

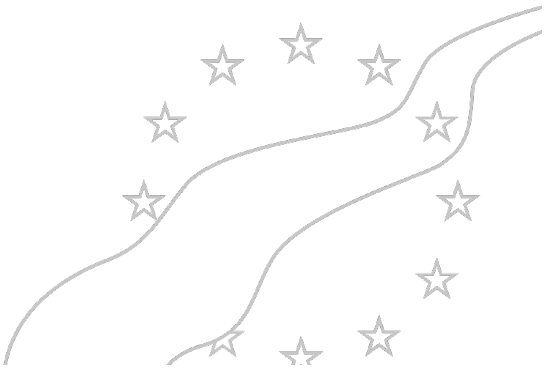
REQ. 11	The input file of the module for acquisition of historical data must have the following fields: • Data • Latitude • Longitude • Event overall description • Hydraulic level at the reference hydrometer
REQ. 12	The input file of the module for acquisition of historical data must include data referring a single historical event.
REQ. 13	The file of input data of the module for historical data acquisition must have the following format: • Data in ISO 8601 format • latitude in decimal degrees • longitude in decimal degrees • Overall text description of event • Hydraulic level at the at the reference hydrometer in cm
REQ. 14	The module for acquisition of territorial data must acquire the following input: • Shapefile and raster • Associated metadata
REQ. 15	The module to forecast hydraulic level from Simulation Database (small catchments) must acquire the following input: • Data in ISO 8601 format • Traditional sensors database (Monitoring Database) o Soil humidity measured (%) o Hydraulic level measured (cm) • Weather forecast o Foreseen duration of precipitation (hours) o Foreseen precipitation sum (mm) o Foreseen maximum intensity of precipitation (mm/h) • Simulation Database
REQ. 15bis	The module RandomForest is aimed at forecasting threshold crossing probability and it needs the following input: • Hourly time step series at each hydrometer for the following variables in csv format: o Calculated mean rainfall (mm/h) o Observed discharge (m^3/s)
REQ. 16	The data mining Module must acquire as input data: • Geo-referred territorial data • Historical data from Historical DB • Monitoring Data from Monitoring DB • Simulation Data from Simulation DB
REQ. 17	The external communication module must acquire as input data: • Requestes from external sources • List of external services to which address information
REQ. 18	The Simulation Module must provide as output the map of the hydraulic level (cm) on the whole simulated catchment according to the specific meteo, soil and plant conditions. In particular it provides the hydraulic level value at the reference point, e.g. at the entrance of drainage urban network for the culvert streams as the Ravone creek.
REQ. 19	The output of Simulation Module (hydraulic level in cm) is a value greater than zero.
REQ. 20	The RainLink4EMR module must provide as output: • Geo-referred images in jpeg, hdf5 format • Table reporting the precipitation level for each monitoring point.
REQ. 21	Vulnerability module must provide as output: • Vulnerability maps (shapefiles and metadata) • Risk Maps (shapefiles and metadata)

REQ. 22	Planning's Support module must provide as output: ● Georeferential territorial data (shapefiles, Rasters, Metadata) ● Vulnerability maps (shapefiles and metadata) ● Risk Maps (shapefiles and metadata)
REQ. 23	Early warning Module must provide as output: ● Territorial georeferenced data (shapefiles, rasters, metadata) ● Vulnerability maps (shapefiles and metadata) ● Risk Maps (shapefiles and metadata) ● Hazard maps ● Water level at the entrance of drainage network at peak time ● Video alert
REQ. 24	Sensor data acquisition module must provide sensor database
REQ. 25	RainLink4EMR data acquisition module must provide RainLink4EMR database.
REQ. 26	The data acquisition module from Arpae forecasting system must provide forecasts database
REQ. 27	The data acquisition module from simulation system must provide simulation database
REQ. 28	The historical data acquisition module must provide historical events database
REQ. 29	The territorial data acquisition module must provide territorial database
REQ. 30	The module to forecast hydraulic level from Simulation Database (small catchments) must provide the following output: ● a range of maximum water level at the reference hydrometer.
REQ. 30bis	The module RandomForest to forecast threshold crossing probability will provide the following output for each hydrometer: ● a set of time series with probability values related to each threshold (%)
REQ. 30ter	The default hydraulic level assessment shall be based on hydrometers observed data and related thresholds.
REQ. 31	Data mining Module must provide the following output: ● Statistics ● Pattern ● Time series
REQ. 32	External Communication module must provide the following output: ● Water level at the entrance of the drainage network (cm) at peak time ● Degree of severity of the event depending on the maximum height of the entrance of the drainage network ● Other
REQ. 33	The algorithms used in the Simulation Module (Criteria3D) are detailed in Annex 3
REQ. 34	RainLink4EMR module calculates every 15 minutes the map of precipitation accumulation
REQ. 35	RAINLINK package (https://github.com/overeem11/RAINLINK) to be debugged and improved by MEEO in order to make it working and fit with RainBO purposes, in order to produce precipitation maps by using microwave link data. The new version of the algorithm customized for the project is named Rainlink4EMR (Rainlink for Emilia-Romagna).
REQ. 36	Vulnerability module must be performed only if the alarm system level is "0" (degree of severity)
REQ. 37	The planning module must allow the interrogation of the input data
REQ. 38	Planning module must allow exportation of query results as: ● Vectorial data ● Text data ● Datasheet
REQ. 39	Early warning module must allow the interrogation of input data

REQ. 40	Early warning module must display the current level of severity
REQ. 41	Early warning module must report the severity level to the communication module

REQ. 42	The SensorNet module shall acquire the following input:
	• Traditional sensors data
	  o hydraulic level measured (cm)
	  o rain gauge (mm)
	  o temperature (°C)
	  o soil humidity measured (%)
	  o radar (.geotiff)
	• Meteorological modeling data (weather forecast)
	  o Foreseen duration of precipitation (hours)
	  o Foreseen precipitation sum (mm)
	  o Foreseen maximum intensity of precipitation (mm/h)
	• New sensors installed in Ravone basin
	  o rain gauge (mm)
	  o hydraulic level measured (cm)
	• Precipitation map (RainLink4EMR Module)

REQ. 42.01	The acquisition module of monitoring data is provided by Sensornet that collects all available monitoring data, including those related to the forecast weather. All data are acquired and saved into the Monitoring DB, as soon as they are made available from the different sources. RainLink4EMR module can be external or internal at Sensornet platform but, in any case, it will stored the data into the Monitoring DB. Monitoring DB : • Traditional sensors data • Meteorological modeling data • New sensors installed in Ravone basin • Precipitation map (RainLink4EMR Module)
REQ. 43	The graphic interface of monitoring data is provided by Sensornet, that can show the graphic of the puntual measures and the images of that grid ones.
REQ. 43.01	The graphic interface of monitoring data can show more than one measure in the same graphic to monitor their correlation or to allow to monitor their evolution at the same time.
REQ. 43.02	The graphic interface of monitoring data can be preventively configured for each user to show all and only the measure of his interest.
REQ. 43.03	The graphic interface of moniotoring data can visualize the real-time monitoring data as welle as the historical ones.
REQ. 44	System status update must be performed cyclically.
REQ. 45	System status update must define depending on the received input, what are the scenario that match the current meteo data and forecasts.
REQ. 46	The degrees of severity must be compliant to regional requirements legislation
REQ. 47	The system shall associate the forecast of maximum water level at the reference point with a severity level.
REQ. 48	System status update must send an alarm to the Early warning module only if at least one severity level is different from the current severity level
REQ. 49	The processing procedure to obtain precipitation map from microwave data is included in the *service.sh* that represents *t*he core of the Rainlink4EMR: this script automatically downloads and formats the available data, sends them to the algorithm and prints the graphical outputs that can be visualized by the SensorNET GUI.
REQ. 50	The web platform must allow the use of 3 different access levels
REQ. 51	The web platform must allow each enabled user to use a single access level



2.1. Functional requirements

The following table contains the association between **user needs** and **functional** requirements.

ID user needs	User needs overall description	Req. ID
UN-01	The potential RainBO users are administrative subjects, which have restrictions in their work according to their role. For this reason, different level of access should be identified.	REQ. 50
		REQ. 51
UN-02	The potential users have not the same background and the same knowledge so the RainBO system should be guarantee ease use also for no expert users: easy and intuitive interfaces should be created for the operative modules of RainBO platform, depending on use (on-line and off- line) and depending on the different level of access.	REQ. 52
UN-03	Seeing as one of the main stakeholders of the project is the decision maker, in particular Municipalities Civil Protection Authority, so legal compliance is required and the integration with the warning system of Regional Civil Protection is a strong restriction. RainBO will be developed in according to Civil Protection Guide Lines and regulation.	REQ. 46
UN-04	The projects should support the decision maker to identify the area potentially involved (early warning) and to alert population.	REQ. 3
		REQ. 23
		REQ. 39
		REQ. 40
		REQ. 41
UN-05	The project is not a DSS (decision support system) for emergency management, but it could be integrated with a DSS.	REQ. 32
UN-06	Because of the rapidity of heavy rains phenomena, an efficient forecasting and monitoring system are needed in order to have warning time to active civil protection system.	REQ. 34
		REQ. 42
		REQ. 44
UN-07	RainBO should guarantee the possibility of consult monitoring data in a easy way: The traditional network sensors will shown by GIS module and detailed information will be associated to each sensor.	REQ. 23
UN-09	Standardized data: For each type of data, the standard file format will be specified and the attributes associated to this information. For the meteo, measure units and samples time data will be standardized.	REQ. 1
		REQ. 2
		REQ. 3
		REQ. 4
		REQ. 5
		REQ. 6
		REQ. 7
		REQ. 8
		REQ. 9
		REQ. 10
		REQ. 11
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		REQ. 13
		REQ. 14
		REQ. 15

		REQ. 17
		REQ. 18
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		REQ. 30
UN-10	Easy process mapping: easy search and consultation criteria, easy modifying criteria, intuitive methods for advanced query of vectorial maps and raster data.	
		REQ. 22
		REQ. 23
		REQ. 37
		REQ. 38
		REQ. 39
		REQ. 40
UN-11	Opportunity to get real time data for weather forecasting	REQ. 42
		REQ. 43
UN-12	Integration between traditional monitoring and new monitoring infrastructure.	REQ. 45
UN-13	Opportunity of getting simulation scenario with different level of affability	REQ. 45
UN-14	Opportunity of following the heavy rain phenomena evolution (getting real time data form sensors during the event) and of increase knowledge about urban area potentially impacted by flash floods	REQ. 42
		REQ. 43
		REQ. 44
UN-15	Opportunity of integrating into RainBO platform crowd sourcing and the concept of human sensor (for informed system).	
UN-16	Opportunities of promote the project as best practices at national and international level	
UN-17	The project should support civil protection operators with availability of detailed risk maps.	REQ. 21
		REQ. 22
		REQ. 23
UN-18	Engagement of Citizen	
UN-19	Emilia Romagna warning system has been just updated by Web-Allerte project so RainBO could represent a detailed study for small - medium basin, which will be integrated into the regional system.	REQ. 32
UN-20	Opportunity of evaluating the possibility of integration private monitoring network (for example Emilia Romagna meteo);	REQ. 32
UN-21	Opportunity of connection with land reclamation Authority for collecting data concerning small river and minor drain net.	REQ. 32
UN-22	Opportunity of evaluating the interaction with drainage system (urban flooding phenomena).	REQ. 32

2.2. Non functional requirements

The following table contains the association between **user needs** and **"non functional"** requirements.

ID user needs	User needs overall description	Req. ID
UN-08	The platform and the modules will be provided with open source license and they will run on LINUX operating system environment (open software)	REQ. 53
		REQ. 54

2.3. Main features of the graphical use interface

The graphical user interface shall have at least these features:

1. The graphical user interface shall be web based: it has to be reached by any computer at any time
2. The graphical user interface shall have a GIS interface: geographical data (geo-referenced)
3. The graphical user interface shall implement user profiling.
4. Users shall be profiled on functionality permits on and geographic area of interest.
5. Functionality permits shall be based on user's role and competences.

Annex 3 - CRITERIA3D

CRITERIA3D is a C library implementing a three-dimensional water balance for small catchments. It includes a coupled surface and subsurface flow and it needs hourly or sub-hourly meteo data as input.

At today there are two softwares that use the library: one is the European FP7 European Project VINTAGE, the second is the software PRAGA, developed by Arpae for agro-meteorological use, including algorithms for meteorological data spatialization, snow accumulation and melting, topography dependent solar radiation and crop growth.

For a detailed description of the CRITERIA3D model, see Bittelli et al., 2011.

For the RAINBO project a complete C++ open source version of the model will be implemented, using QT cross-platform library and SQLite databases. The CRITERIA3D code is available at the following address: https://github.com/ftomei/CRITERIA3D

Soil data

The soil data needed by CRITERIA 3D include a soil map and a pedological database: the soil map is a raster file (ESRI .flt format) of the same extent and resolution of the DTM, where each cell has a value corresponding to the univoque soil ID in the soil database (SQLite). The SQLite database is organized in two tables: **soils** and **horizons**.

The table **soils** is an identifier table where each soil is defined by a numerical code (id_soil) referred to the soil map.

Each soil is typically composed by several pedological horizons, described in the **horizons** table, where each record describes the horizon in terms of pedological features as texture, structure, and organic matter content, that determines the shape of the soil water retention curve in the CRITERIA3D model.

In more details, each record of the horizons table contains:

- soil_ID: univocal numerical code to identify the soil *
- horizon_nr: number of horizon *
- upper_depth: upper depth of the horizon, [cm] *
- lower_depth: lower depth of the horizon, [cm] *
- coarse_fragment: percentage of soil particles > 2 mm
- organic_matter: percentage of organic matter
- sand: fraction of sand, [-] *
- silt: fraction of silt, [-] *
- clay: fraction of clay, [-] *
- bulk_density. Bulk density, [g cm^{-3}]
- theta_sat: water content at saturation, [m^3 m^{-3}]
- ksat: water conductivity at saturation, [cm day^{-1}]

* The data marked with a star are mandatory.

Meteo data

The hourly meteo data needed by CRITERIA 3D are stored in a SQLite database, where each table contains the data of a single monitoring station. The model can work with at least a single station input, but it is better to use all the data of the weather stations included within the catchment or close to it.

In more detail, every table in the database contains the following variables:

- date (YYYY-MM-DD HH format)
- temperature (°C)
- precipitation (mm)
- radiation (W/m2)
- Relative humidity (%)
- wind intensity (m/s)

Land use data

Land use data are defined by a land use map (a raster file ESRI .flt format of the same extent and resolution of the DTM) where each cell has a value corresponding to a different land use (e.g urban area, street, fallow, wood, orchard, summer herbaceous crop, etc.) that will be defined in a parameters SQLite database.

Bibliography

Bittelli, M., Pistocchi, A., Tomei, F., Roggero, P., Orsini, R., Toderi, M., Flury, M., 2011, *CRITERIA-3D: A Mechanistic Model for Surface and Subsurface Hydrology for Small Catchments*. Soil Hydrology, Land Use and Agriculture, 253.