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RAINBO

Comune di Bologna

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arpae emilia-romagna

NIER INGEGNERIA

MEEO
Meteorological Environmental
Earth Observation

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Document Summary

he present document includes essential elements for the correct development of the RainBO platform. In particular the document comprises:

- Collection of user's needs;
- Review of state of the art (SotA).

In particular, the aim of the first task is the identification of potential stakeholders (rule, skills and competences) in order to investigate and analyze user needs.
Meetings, interviews, workshop and questionnaires have been conducted to collect stakeholders' needs.
The involvement of stakeholders has been focused on specific use scenarios that have the main scope of:

- Defining the RainBO system function;
- Recognizing the risk scenarios focused on flash floods in urban area and in small basin;
- Identifying potential extension of use cases in order to increasing the efficiency of actual model and methods for early warning and regional planning.

Use scenarios are the description of specific situation of the system, which requires interaction with users and the identification of the main inputs and outputs.
This activity was useful also for the state of the art analysis concerning the data, models and methods already used for alert activation, planning process mapping, existing software, etc.
The review of SotA has been conducted by the evaluation of the literature, of the existing projects potentially related to RainBO in order to identify performances and strengths, restrictions and weakness/threats.

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Annex List

1. Collection of users and stakeholders needs

1.1. End user and stakeholders identification

The end users of RainBO platform are:

- Local decision makers: Head of Municipalities that are the local Authorities for emergency planning and disaster management;
- Local Agency responsible for management of water, building property, critical infrastructures;
- Association/organizations committed in climate changes, environments and natural protection;
- Local technical offices, responsible for regional planning and urban development.

As reported in the internal project document "Methodology for RainBo stakeholders network" (milestone of action E1), in order to identify and engage the potential end users, one of the key activity of RainBO is the stakeholders' identification and involvement.

This activity lasts all the project duration and it concerns organization of events and activities for both internal and external stakeholders (persons or a group with an interest in this project).

The internal stakeholders are Bologna Municipality and ARPA Emilia Romagna Region (hydro- meteorological service):

- ARPA provides relevant contribution in terms of the analysis of the current monitoring infrastructures and instruments and also knowledge about hydro-meteorological models;
- Bologna Municipality represents the role of local decision makers, so its contribution regards functional requirements and data to be collected.

Internal meetings with ARPA and Bologna Municipality (as internal main stakeholders) have been organized since 05 August 2016, to define the user cases and the main functionality of RainBO system.

The external stakeholder belong to the following categories:

- National, regional, local administrations;
- Territorial Agencies or associations;
- Universities/research institutes;
- European institutions;
- Citizens and business;
- Active EU projects and networks in the field of climate adaption.

The first step of the activity has been the creation of an updatable database of potential stakeholders. Some of them were chosen depending on skills, roles and competences, in other words depending on the characteristics that are more likely to produce a significant impact on RainBO strategic objectives.

In fact, the user needs analysis aimed at responding to the following questions:

- who the users are,
- what their tasks and goals are,
- how their experience levels is,
- what functions they want and need from a system,
- what information they want and need and understanding;
- how the users think the system should work.

The main external stakeholders – potential end users – that have been already engaged into the project are:

- Parma Municipality Civil Protection;
- Novellara Municipality;
- Cento Municipality;
- Civil Protection Agency of Emilia Romagna Region;
- Bologna Municipality Civil Protection.

RainBO team has organized specific meeting with these stakeholders to explain the aims of the project and to understand their needs.

The following table shows details about the meetings and the main issues resulted from discussions.

End users / main external stakeholders	**Meeting date**	**Location**	**Main user needs emerged**
Bologna Municipality Civil Protection	27/09/2016	Bologna Municipality office (Bologna)	• The main topic of Civil Protection activities is the intervention velocity, in particular concerning heavy rain in small basin: the projects should support the decision-makers to identify the potentially involved area (early warning) and to alert population. • The project should support Civil Protection operators with availability of detailed risk maps. • The project should be correlated with the Emilia Romagna Regional Warning System, in particular with the new regional project "Web-Allerte".

Parma Municipality Civil Protection	03/11/2016	Parma Civil Protection office (Parma)	• Parma has a strong experience in study and management of extreme rainfall phenomena on urban areas: Civil Protection has a client software as decision support system based on GIS (3D RTE) and specific hydrologic models to define hydraulic risk scenarios (FEWS system).Pangea srl, the company that developed the 3D RTE, was contacted for collaborating to the two softwares integration. • RainBO project could be integrated with Parma system in particular allowing the access to monitoring and forecasting data – early warning module.
	17/11/2016		• In order to connect RainBO platform to Parma ones, it's necessary to evaluate the exposure modality of data between the two software; • RainBO project could be the main instrument to promote knowledge in civil protection and to standardize data, information and mapping process. • Parma Civil Protection asks to RainBO team to evaluate the possibility of create a tool (for example a mobile App) for communication to population.
Civil Protection Agency of Emilia Romagna Region	14/11/2016	Regional Civil Protection office (Bologna)	• Emilia Romagna warning system has been just updated by Web-Allerte project so RainBO could represent a detailed study for small - medium basin that will be integrated into the regional system. • Regional Civil protection emphasized the importance of the off-line use of RainBO platform for emergency planning also in compliance with the Life-Primes projects.
Cento Municipality	22/11/2016	NIER Ingegneria SPA office (Castel Maggiore, BO)	• Opportunity of evaluating the possibility of integration private monitoring network (for example Emilia Romagna meteo); • Opportunity of integrating into RainBO platform crowdsourcing and the concept of human sensor (for informed system). • Opportunity of evaluating the interaction with drainage system (urban flooding phenomena). • Opportunity of connection with land reclamation Authority for collecting data concerning small river and minor drain net.

Novellara Municipality	29/11/2016	Novellara Municipality office (Novellara)	• Only paper maps of risk scenarios are available in Novellara Municipality. RainBO is a very important project because of the territorial database, vulnerability database which guarantees the updating and speedy consultation of data. • There is the need to have monitoring data of sensor network. • Opportunity to of evaluating the possibility of integration private sensors.

For each meeting a report, an agenda and a sign-sheet were produced and stored into project documentation (Annex 1).

1.1.1. Stakeholders involvement

The **RainBO** Project aims at reaching **improvement** of knowledge, methods and tools to respond to **extreme weather** events. One of its key activity will be the development of a **long term impact sustainability**, of the project results beyond its duration and involvement of important stakeholders of territory.

This will be reached through a comprehensive sustainable strategy and a series of liaising, consensus building and policy co-ordination tasks, events and activities with the active involvement of both internal and external stakeholders. The goal is to progressively transform stakeholders into factive partners that support and implement the project and participate in its decisions, by using their capacities to make a contribution as effective as possible. The mutual trust between the project and its stakeholders, and the mutual learning that it involves, will thus lead to a systematic change towards sustainable development.

Please see RainBO_Gdrive: (https://drive.google.com/drive/u/1/folders/0B9-q_Lj8LEqjT0tCMDRvWC1Ucms) **where has been stored both "Stakeholders engagement methodology" and "Stakeholders list"**

The **RainBO** Partnership is composed by regional authorities, local authorities and private agencies, **covering different policy implementation levels and institutional frameworks** and potentially involving a transnational collaboration network of key players and stakeholders. The direct and continuous involvement of concerned stakeholders in all project activities is therefore a core element which is necessary for the achievement of the set objectives and for the development of a broad consensus on planned initiatives.

This document focuses on how to involve different stakeholders in **RainBO** activities by suggesting possible ways/methods/actions to set up a long term cooperation. It thus provides guidelines on how to network with national, regional and local actors of the Italian and european territories and how to motivate them to step into **RainBO's** network and to keep them on board and willing to co-operate, by utilising the vast amount of information and knowledge that stakeholders hold to find workable, efficient and sustainable solutions. The objective of this document is, therefore, to develop a **long term approach to involve stakeholders** who are on board and willing to co-operate, by utilising the vast amount of information and knowledge that stakeholders hold to find workable, efficient and sustainable solutions. The objective of this document is, therefore, to develop a **long term approach to involve stakeholders to share knowledge and to work in synergy**, thus enhancing understanding and risks management skills and the capacity to find out more efficient solutions to potential problems.

In particular, **Activity of RainBO** project envisages the establishment of a **stakeholders co-operation network** by the implementation of two tasks:

- Establishment of a collaboration network of stakeholders, consortia and EU projects to promote project results and benefit from common interest events and initiatives;
- Consultations with stakeholders on setting up specific tools, methods and actions to integrate, promote and valorise the project results in the Italian area and beyond.

The stakeholders co-operation network will facilitate the capitalisation of project results through new co-operation schemes, joint initiatives and follow-up projects. In order to reach this collaboration level, we need to understand how to interact, communicate and involve with the identified stakeholders during different phases of the project, thus building and maintaining positive relationships with them. The action of stakeholder engagement was carried out in both directions and has had its climax in the day-long workshop of December 15, 2016 where many of the actors involved in the previous months were gathered.

To avoid the generation of many data from stakeholders involvement (for example, from focus groups, in-depth interviews, and surveys) with significant effort to synthesize into actionable results, it is important to focus on **key questions** for each stage of the users needs analysis—from formative assessments to feedback on concepts and design validation.

For this reason, a simple questionnaire has been administered to to the stakeholders. The main topic of the questionnaire concerned the two main functionality of the RainBO platform (as identified in the proposal):

- "Off line" use, for territorial planning and preparation to emergency response
- "On line" use, for early warning and detection of hazardous condition.

In the following table the key questions for both off-line and on-line use are collected.

ID	Off-Line use – Key questions
A_{off}	How do you consider the availability of information related to area potentially subject to flash floods, as a function of the information about adverse weather events (rainfall)?
B_{off}	How do you consider getting the simulation of the risk scenarios: correlation between areas potentially subjected to floods (evaluated by specific simulation model) and territorial elements (evaluated by specific vulnerability model?
C_{off}	How do you consider the opportunity of defining specific alert thresholds for your the local system?
D_{off}	Do you consider that the RainBO operating system could be an appropriate support for emergency planning, (as function of reference thresholds), and for the first emergency response (i.e. territorial recovery)?
E_{off}	How do you consider the detailed definition of the risk areas?
F_{off}	How do you consider the possibility of identify the need to mitigation interventions in the risk areas (priority analysis)?

G_{off}	How do you consider the urbanization restrictions definition (city plan)?
H_{off}	How do you consider the vulnerability analysis of the critical infrastructures connecting flash floods phenomena?
I_{off}	How do you consider the opportunity of define coordination actions with critical infrastructures Manager / Authorities (i.e. HERA SpA for Emilia Romagna Territory)?
J_{off}	Do you consider the availability of simulated scenarios an useful support for planning of civil protection training/drill?
K_{off}	How do you consider the possibility to consult / modify the cartographic data related to the scenarios (the operating system will have a GIS cartographic system)?
L_{off}	How do you consider the possibility to consult the monitoring network and the weather forecast data?

ID	**On-Line use – Key questions**
A_{on}	Do you consider useful the opportunity to get real-time data (from actual monitoring network) for weather forecast (pre-event phase)?
B_{on}	Do you consider useful the opportunity to get real-time data of attenuation signal cellular communication (pre-event phase)?
C_{on}	Do you consider useful to get comparison of the results derived from the innovative and traditional network (pre-event phase)?
D_{on}	Do you consider useful to get real-time hydrometric data (ongoing event)?
E_{on}	Do you consider useful, for emergency management support, the availability of reference scenarios, chosen between the simulated scenarios and/or historical events that are closer to the ongoing event?
F_{on}	Do you consider useful a civil protection system activation as function of threshold limits?
G_{on}	Do you consider useful to get a communication way / function to the population, for example by a specific mobile – App?
H_{on}	Do you consider useful to get information visualization on interactive map (territorial data, monitoring data, vulnerability data, risk maps, etc.)?

For each key question, the interviewed people (n. 27) could answer in the following ways (multiple-choice questionnaire):

- Very useful
- Useful
- Not useful for my work.

These questions were presented and completed during the Workshop of December 15, 2016, at MAMbo Museum in Bologna; the synthesis of results is shown below.

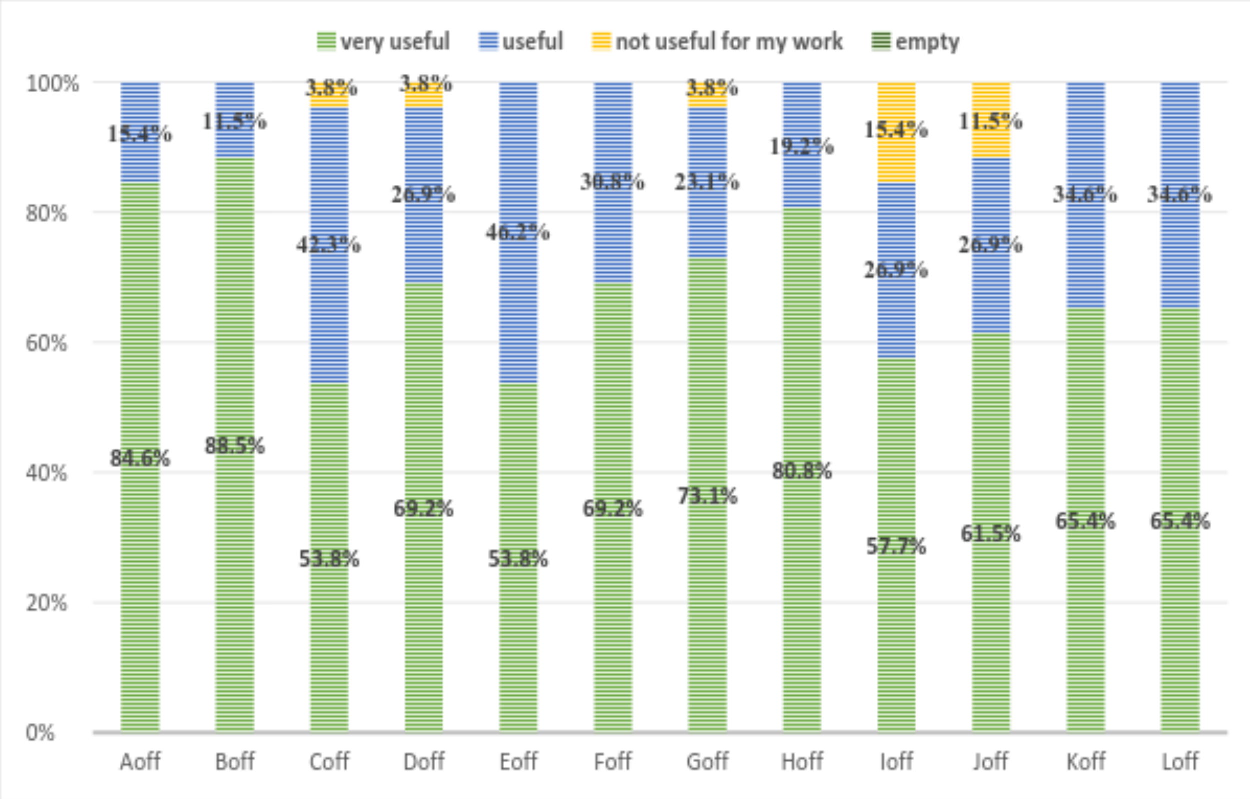


Figure 1 – Off line use: tendency of answers

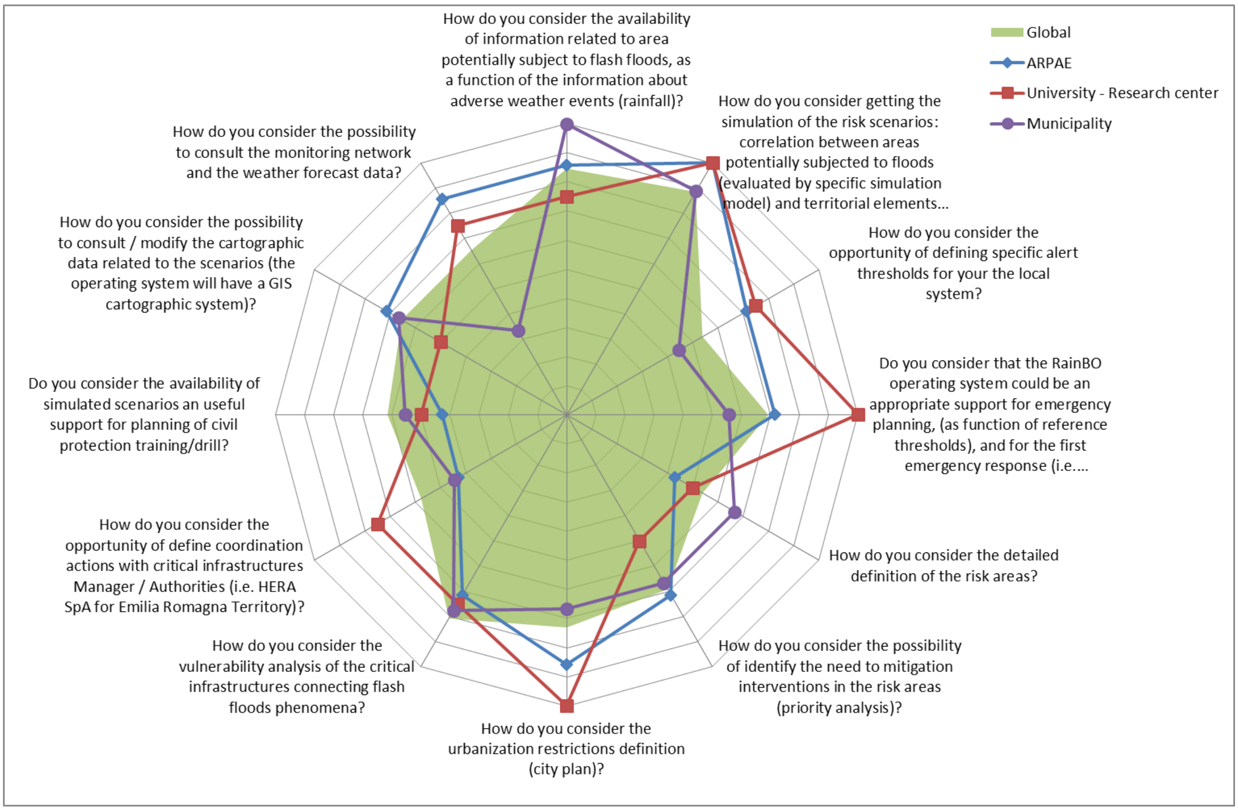


Figure 2 – Off line use: stakeholders ‘answers depending on rules or Organization (University, ARPAE, Municipalities).

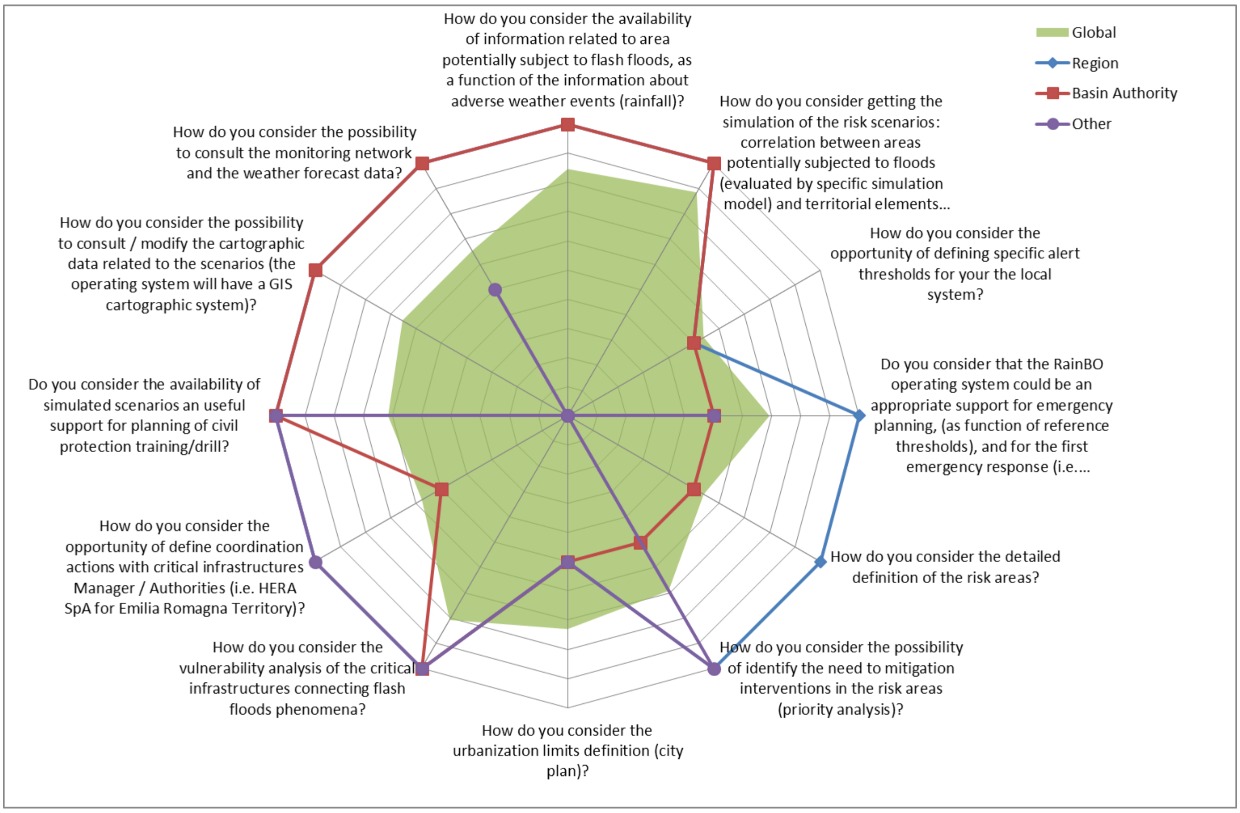


Figure 3 – Off line use: stakeholders ‘answers depending on rules or Organization (Region Administration, Basin Authorities, and other Organizations).

It’s clear that most important needs identified by the survey, concerning the planning activities (middle-long time), are:

- Knowledge of urban area potentially impacted by flash floods;
- The opportunity of getting simulation scenarios;
- The analysis of connection between drainage infrastructure and flash floods phenomena.

By the way, the possibility of using RainBO platform as a support to organize drills or training of Civil Protection or to promote cooperation with critical infrastructure managers are considered the least important functions.

In particular, as it is easy to imagine, the Municipalities aim for a better knowledge in risk scenarios and for an available georeferenced database of territorial information; on the other hand the technical /scientific organizations work towards monitoring and simulation models for a deeper knowledge of extreme rainfall phenomena.

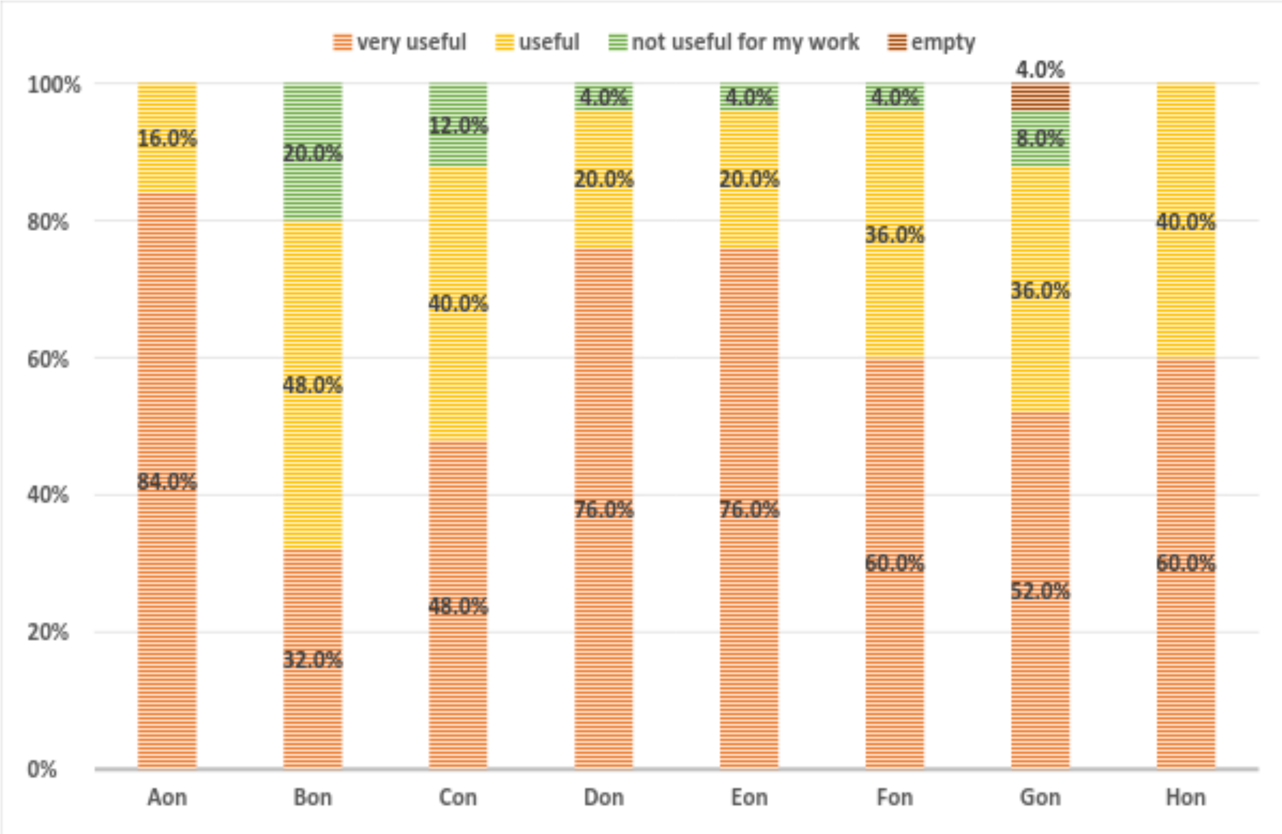


Figure 4 – Off line use: tendency of answers

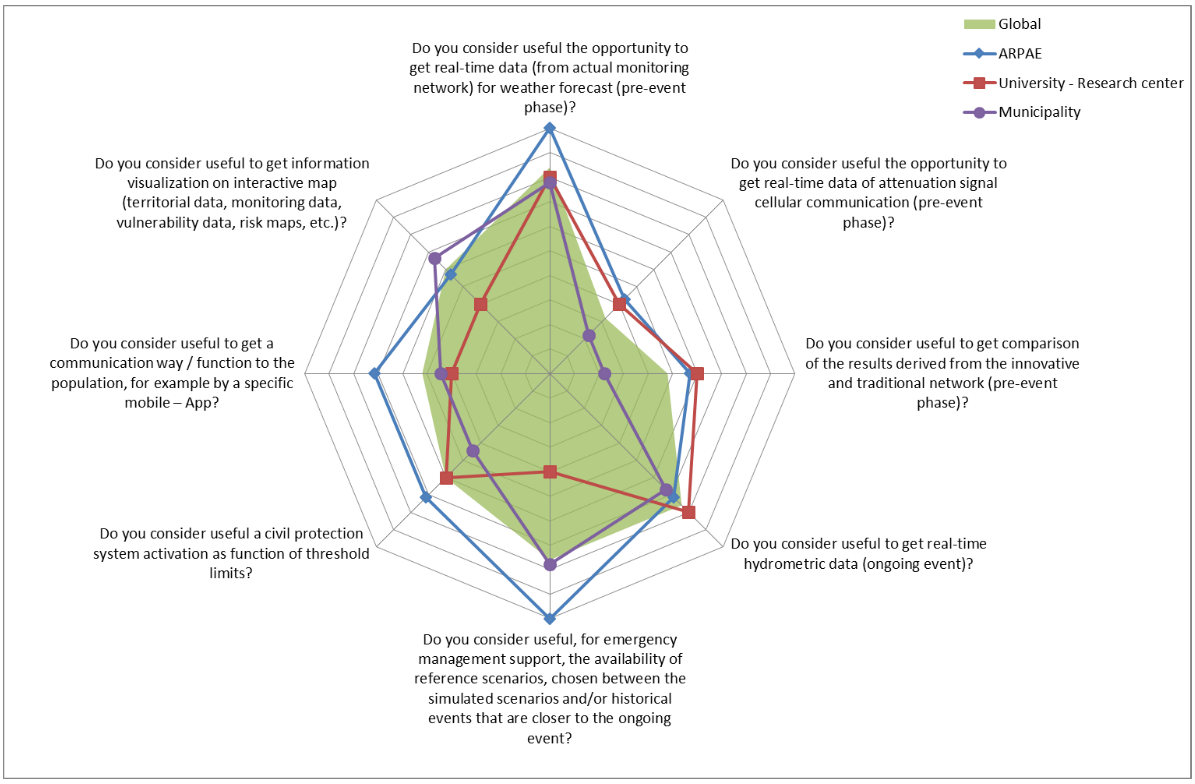


Figure 5 – On line use: stakeholders ‘answers depending on rules or Organization (University, ARPAE, and Municipalities).

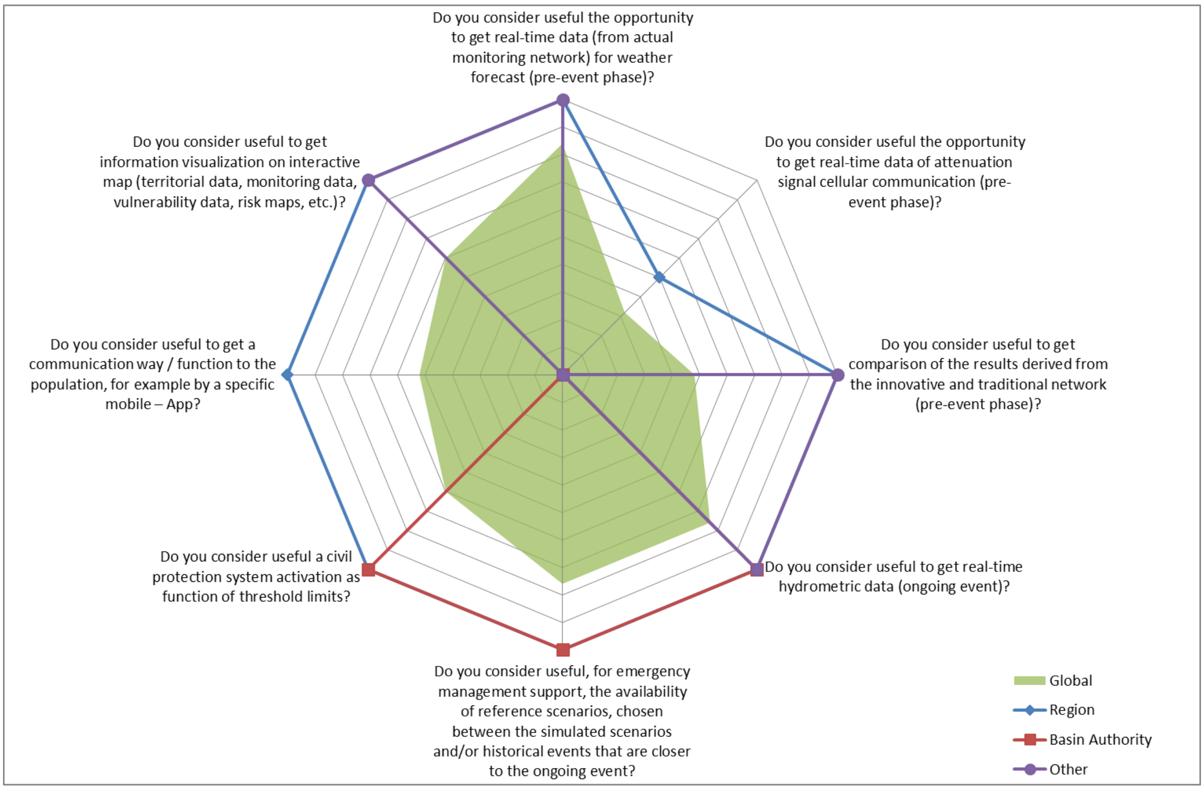


Figure 6 – On line use: stakeholders 'answers depending on rules or Organization (Region Administration, Basin Authorities, and other Organizations).

It is clear that most important needs identified by the survey, concerning the early warning (short time activities), are:

- The opportunity to get real time data for weather forecasting;
- The opportunity of getting real time data from sensors during the event;
- The support for the following phase of emergency management by the identification of referring scenarios.

The 52% of stakeholders (in particular the members of ARPAE and Regions) considers the opportunity of using RainBO also for communicating to population in emergency (alert phase) very interesting.

During the workshop, a SWOT Analysis was carried out, dividing audience in four groups.

SWOT is an acronym for *Strengths*, *Weaknesses*, *Opportunities*, and *Threats* and is a structured planning method that evaluates those four elements of a project. The stakeholders were dived in four groups and each group had to answer to the following questions, for three specific issues:

Specific Issue

	STRENGTHS	WEAKNESSES
Actual situation without RainBO	What are the strenghts of actual system used or of actual operative procedures?	• What are the weaknesses of actual system used or of actual operative procedures? • What are the main lacks in the actual system?
	OPPORTUNITIES	**THREATS**
Future situation with RainBO	• How could RainBO improve the weaknesses above identified? • How could RainBO improve the actual strenghts? • What support do you image by using RainBO platform?	Whar are the potential threats connected to the use of RainBO platform?

The three issues analyzed by the SWOT analysis were:

1. RainBO and support in emergency activation (early warning);
2. RainBo and Civil Protection planning (Civil protection plan, operative procedures, warning system, training, etc.)
3. RainBO and territorial planning.

The reports of the four groups brainstorming are collected in Annex 2.

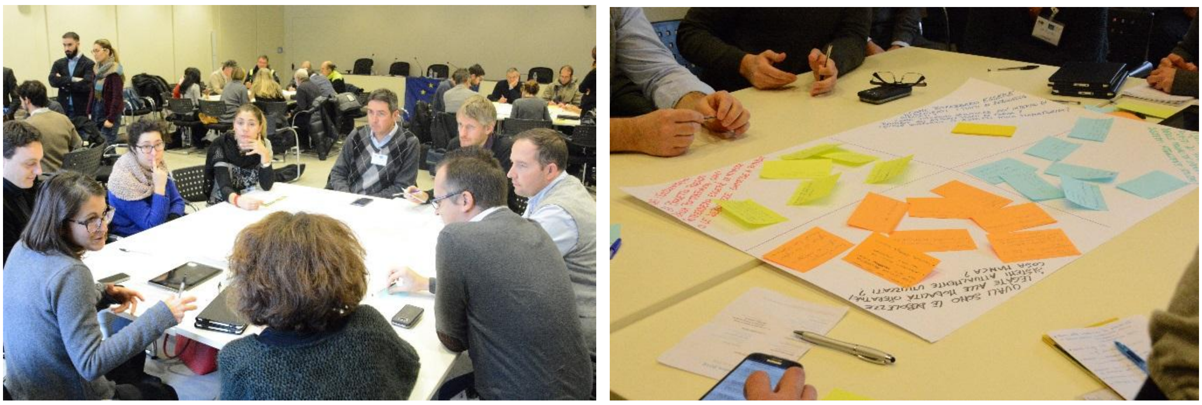


Figure 7 – SWOT Analysis session during workshop of December 15, 2016

1.2. List of User needs

Needs analysis is defined as a formal process focusing on how a product addresses the “needs” of people that would use the platform, and it is often used in tandem with requirements analysis - a study of the elements represented within a system.

In particular, the following table shows a list of user needs. An ID characterizes each user need, which is also correlated to functional and/or nonfunctional requirements that will be analyzed in the second deliverable of Action C1.

User needs ID	**Users needs description**	**Category of Functional requirements**	**Category of “non fucntional” requirements**
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.	Authorization level	Access security
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.	Modules Interfaces	Usability
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.	Legal compliance	Legal compliance
UN-04	The projects should support the decision maker to identify the area potentially involved (early warning) and to alert population.	Response time	Response time
UN-05	The project is not a DSS (decision support system) for emergency management, but it could be integrated with a DSS.	External interfaces	Interoperability
UN-06	Because of the rapidity of heavy rains phenomena, an efficient forecasting is needed in order to have warning time to active civil protection system.	Response time	Response time
UN-06bis	Because of the rapidity of heavy rains phenomena, an efficient monitoring system is needed in order to have warning time to active civil protection system.	Response time	Response time
UN-07	RainBO should guarantee the possibility of consult monitoring data in a easy way: The tradictional network sensors will shown by GIS module and detailed information will be associated to each sensor.	Interfaces /GIS	
UN-08	The platform and the modules will be provided with GNU GPL license and they will run on LINUX operating environment (open software)	External interfaces	Interoperability
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.	Interfaces	
UN-10	Easy process mapping: easy search and consultation criteria, easy modifying criteria, intuitive methods for advanced query of vectorial maps and raster data.	Interfaces /GIS	
UN-11	Opportunity to get real time data for weather forecasting	External interfaces	
UN-12	Integration between traditional monitoring and new monitoring infrastructure.	Interfaces	Efficency / Response time
UN-13	Opportunity of getting simulation scenario with different level of affability	Modules functionalities	Reliability

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	GIS	
UN-15	Opportunity of integrating into RainBO platform crowd sourcing and the concept of human sensor (for informed system).	External interfaces	
UN-16	Opportunities of promote the project as best practices at national and international level	Dissemination / Comunication	Flexibility
UN-17	The project should support civil protection operators with availability of detailed risk maps.	GIS / Modules functionalities	
UN-18	Engagement of Citizen	External interfaces	External interfaces
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.	Legal compliance / External interface	Interoperability
UN-20	Opportunity of evaluating the possibility of integration private monitoring network (for example Emilia Romagna meteo);	External interfaces	Interoperability
UN-21	Opportunity of connection with land reclamation Authority for collecting data concerning small river and minor drain net.	External interfaces	Interoperability
UN-22	Opportunity of evaluating the interaction with drainage system (urban flooding phenomena).	External interfaces	Interoperability

1.3. Advisory board

The establishment of an international Advisory Board (AB) is a strength of the project because the knowledge, understanding and overview of the AB members foster the project development, tackling the obstacles and providing a comprehensive vision of the expected results.

1.3.1. Advisory board commitment

One of the main task of the RainBO AB is to assure the transferability of the RainBo results. The AB will facilitate replicability, as it provides "best practice" and "guidelines" aimed at the implementation of a system that will effectively address the actual user-needs. The AB member will give concrete advices and contacts, and will support the consortium in the interpretation of requirements of further potential end-users.

The AB members are:

- Alessandro Battaglia, Department of Physics and Astronomy, University of Leicester, UK
- Sergio Castellari, European Environmental Agency, DK
- Maria Jontén, Civil Contingencies Agency (MSB), SE
- Cristina Garzillo, ICLEI, DE
- Alberto Viglione, Centre for Water Resource Systems, Vienna University of Technology, AU

This committee of scientists, consultants and potential end-users already active in the European Climate Adaptation field and with relevant network of European contacts is an asset for the project life.

The AB commitment is organized by means of scheduled milestones, that will provide important advices according to the AB experience and expertise, in order to improve project management and its activities. In more details, during the first AB meeting held in Bologna on the December 15th, 2016, a schedule of activities have been proposed to the AB. The project foresees 4 meetings, where the AB members are asked to review the project draft deliverables to be discussed during the meetings.

I meeting: plenary session. Bologna December 15, 2016. AB establishment and activities planning.

Working document: project draft Deliverable on action C1 (Analysis of RainBo system requirements).

II meeting: Skype call, October 2017. Focus on Action C3

Working document: project draft Deliverable on action C3 (Software architecture and GUIs)

III meeting: Skype call, October 2018. Focus on Action C4

Working document: project draft Deliverable on action C4 (platform, prototype).

IV meeting: plenary session, May 2019. Focus on Action C5

Working document: project draft paper on action C5 (replicability and transferability)

In addition to these duties, the lead partner could request AB evaluations on project priority topics at agreed dates.

2. Review of State of the Art (SotA)

2.1. Performance and limits of available of Hydrological models to applied in local scale for assessment of flash flood

CRITERIA 3D

The hydrological model Criteria 3D developed by Arpae (Bittelli et al., 2010) is a numerical, catchment-scale model that solves flow equations of surface and subsurface flow in a three-dimensional domain. The hydrological component is a dynamic link library implemented within a comprehensive model which simulates all the physical processes occurring in a catchment: surface energy, radiation budget, snowmelt, potential evapotranspiration, plant development and plant water uptake. The model has been tested by comparing distributed and integrated three-dimensional simulated and observed perched water depth, stream flow data, and soil water contents for a small catchment. The model successfully described the water balance and its components as evidenced by good agreement between measured and modelled data.

As mentioned above, Criteria 3D simulates all the hydrological processes at basin scale, thus it needs as input several environmental data, above all: a high resolution DTM describing the topography of the catchment, pedological soil map, land use map and data series for 5 meteorological variables at hourly step (i.e.: temperature at 2 m, relative humidity, precipitation, global solar radiation, wind intensity). These specific input represent a constraint because the high resolution DTM and the high number of simulated processes bring to a long computational time, thus only small catchments can be simulated.

Flood Early Warning System (FEWS)

The Flood Early Warning System of Emilia Romagna is based on a Delft FEWS system developed by Deltares (https://www.deltares.nl/en/, WL-Delft Hydraulics, 2005) and provides an open shell system for managing forecasting processes and/or handling time series data. Delft-FEWS incorporates a wide range of general data handling utilities, while providing an open interface to any external model.

FEWS - Emilia Romagna was developed since 2005 (Casicci et al., 2006) and nowadays is composed by several modules capable to import a wide set of data, including real time observation, meteorological forecast, radar data, etc. All this data feeds several models managed by the system that are used for flood forecasting, drought management, oil spill and salt intrusion evaluation and also for statistical analysis and evaluation of hydrologic variables.
Inside FEWS-ER a wide class of mathematical models are used (statistical, hydrologic, hydraulic, water management etc.) for different purposes, with different temporal and spatial scale and with different lead time.
Within this system and beside these models a Random Forest (RF) model (Breiman, 2001) was recently developed and implemented in order to provide a fast and preliminary response during flash flood events. RF is a classifier model and could be described as a tree-structured classifiers, it is defined by a training procedure capable to find out, for a set of input and output data, several conditional trees.
The original code is written in Fortran by Leo Breiman and Adele Cutler, whereas Andy Liaw and Matthew Wiener implemented the R port "Breiman and Cutler's Random Forests for Classification and Regression - Package 'randomForest' (2015-10-06).
The RF model could be classified as a data driven model, this means that the model does not solve conceptual or physical equations of hydrological processes, but it tries to find a relation between input data and observed results without any knowledge of processes. Within these hypothesis, it is trivial that the model constraints are a good amount of data available and its limits are the same imposed by data themselves. This kind of model can be very useful when not all processes can be explained or mathematically solved and usually provide a fast and reliable response when all forcing variables are considered. For this application the RF model creates a classification algorithm based on discharges and mean areal rainfall observed in the antecedent time window.
In FEWS-ER, using real time observation, RF can easily classify the event, providing the threshold crossing probability. During flash flood events this kind of information could be crucial for civil protection and local administration in order to face emergency situations. The RF algorithm implemented into the FEWS system is based on the RandomForest R package.

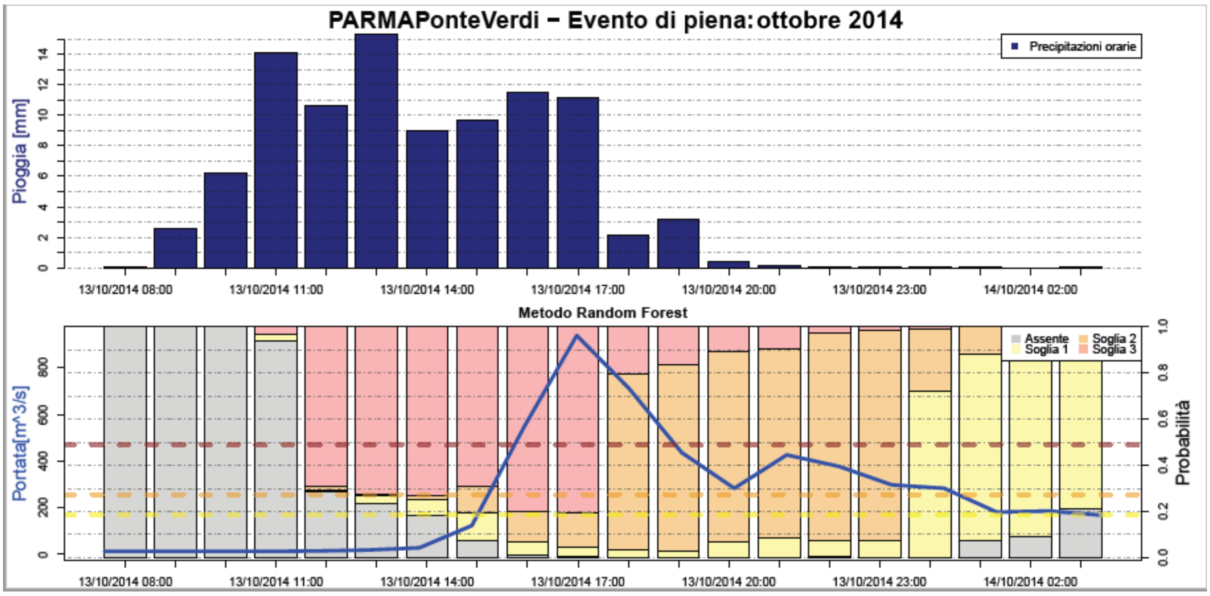


Figure 8 – Observed precipitation and discharge (input) and threshold crossing probability (output) of RF model during flood event in October 2014.

2.2. Performance and limits of available meteorological forecast model

The meteorological forecast model COSMO

The weather forecast modelling of Arpae is based on the numerical model COSMO, developed in the framework of the COSMO (Consortium for Small-Scale Modelling) European consortium, whose members are the national meteorological offices of Italy, Germany, Poland, Romania and Switzerland. Italy belongs to the consortium in collaboration with USAM of Italian Military Air Force.

The meteorological activities follow two main topics: deterministic modelling (COSMO LAMI) and probabilistic modelling of Ensemble, where COSMO LEPS is, so far, the main operational application.

The numerical models of weather forecast are mathematical models that uses initial conditions (meteorological conditions at a given time) and compute the forecast for the following times. The initial condition is defined using observed data as satellite, radar, weather stations on ground and ocean. The quality of these data is checked before their assimilation aimed at defining the initial condition.

In order to obtain a good skill and reliability, the operational use of the COSMO model in the member states of the consortium, is based on several modelling chains that simulate the atmosphere on limited spatial domain, starting from essential boundary conditions provided by a global model. As a consequence, Cosmo is therefore a regional model or limited area model (LAM), because the 3D grid on which the meteorological parameters are defined covers a limited area of the Earth.

At national level, an agreement called LAMI (Limited Area Model Italia) was signed between Meteorological Office of Italian Air Force, Arpae Emilia-Romagna and Arpa Piemonte, to develop and operationally manage national numerical forecast chains in Italy. In the framework of LAMI agreement, Arpae manages the Cosmo I7 and Cosmo I2 chains, that provide numerical weather forecasts with a 7 km and 2.8 km of spatial resolution (distance between two points of the grid) respectively. Cosmo I7 covers a time step of 3 days, whereas Cosmo I2 computes forecasts on 2 days extent.

The forecasts based on these two modelling chains are performed two times per day (00 and 12 UTC).

The need to assess the bias in the deterministic numeric forecast, where the future state of the atmosphere is set from the given initial conditions, has brought to the development of probabilistic forecast systems in the COSMO consortium, including the uncertainty of the models.

Cosmo Leps (Limited Area Ensemble Prediction System) is the system of probabilistic forecast, *ensemble forecasting*, that computes multiple forecasts, based on COSMO model, starting from different initial conditions and with different setup of the model. These ensemble of forecast scenarios allow to estimate the probability of occurrence of an event and to estimate the uncertainty (error) of the forecast.

1. **Features of COSMO LAMI – Deterministic Forecast System**:

COSMO area: Mediterranean area with 5 km resolution;

Boundary conditions: from ECMWF/ IFS;

Initial conditions: LETKF (CNMCA) and nudging (Arpae-ER);

Forecast range: 72 hours;

COSMO national area: Italy with 2.2 km resolution;

Boundary conditions: from COSMO Mediterranean area;

Initial conditions: nudging;

Forecast range: 48 hours;

COSMO RUC: fast assimilation cycle with 2.2 km resolution;

Boundary conditions: from COSMO Mediterranean area;

Initial conditions: nudging;

Forecast range: 18 hours;

Data assimilation system: an ensemble based data assimilation system of 2.2 km resolution on national area, based on LETKF method. The analysis at 5 km, needed to initialize COSMO on Mediterranean area, are provided by Italian Military Air Force and acquired from a LETKF on Mediterranean area.

2. **Features of COSMO LEPS – Ensemble Prediction System**

COSMO-IT-EPS area: LAM EPS - convection-permitting system over Italy and surrounding sea with 2.2 km of resolution;

Boundary conditions: from COSMO-ME-EPS, ECMWF-ENS or COSMO-LEPS;

Initial conditions: LETKF-KENDA;

Stochastic perturbation of model physics;

Soil perturbations;

Domain: COSMO-IT.

In general terms, the skill of meteorological models depends on the different meteorological patterns and on the season. Arpae evaluates the performance of the forecast model by means of 3-months reports available on the following links:

https://www.Arpae.it/sim/?previsioni/verifica_previsioni#precipitazioni

https://www.Arpae.it/sim/?previsioni/verifica_previsioni#temperature

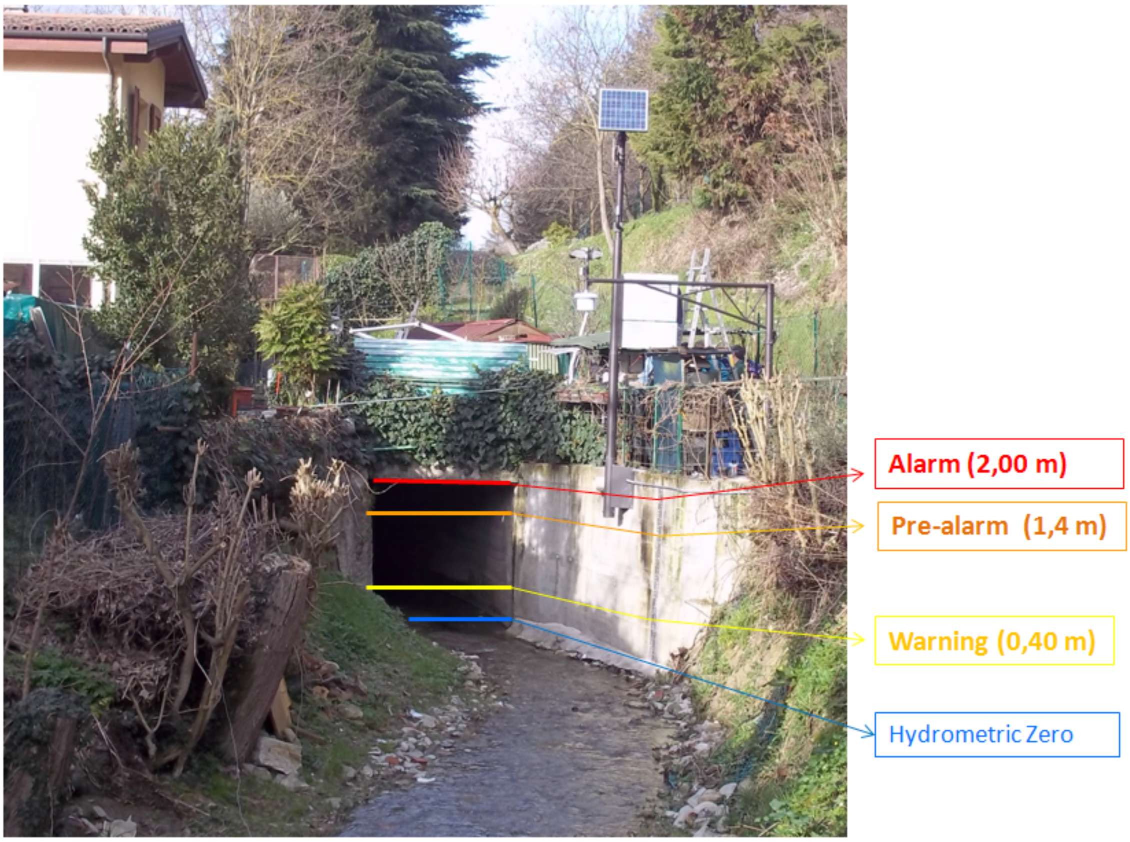
In general weather forecasting needs accurate rainfall observations with high spatial and temporal in order to improve the accuracy and reliability of numerical models. However, there is a lack of accurate rainfall information for the majority of the land surface of the earth, notably from ground-based weather radars; moreover, the number of reporting rain gauges is dramatically declining in Europe, South America, and Africa, so satellites are often the only source of rainfall information. Despite their increasing coverage and spatio-temporal resolution, measurement errors and sampling uncertainties limit the stand-alone applicability of satellite rainfall products. The microwave rainfall monitoring system proposed in the RainBO project exploits the microwave links used worldwide in commercial cellular communication networks. Along such links, radio signals propagate from a transmitting antenna at one base station to a receiving antenna at another base station. Rain-induced attenuation and, subsequently, path-averaged rainfall intensity can be retrieved from the signal’s attenuation between transmitter and receiver by applying, almost in real-time, a rainfall retrieval algorithm.

Rainfall monitoring based on commercial terrestrial microwave links is tested for the first time in Burkina Faso, in Sahelian West Africa. In collaboration with one national cellular phone operator, Telecel Faso, the attenuation was monitored at 1 s time rate for the monsoon season 2012. The time series of attenuation (on a 29 km long microwave link operating at 7 GHz) is transformed into rain rates and compared with rain gauge data. The method is successful in quantifying rainfall: 95% of the rainy days are detected. The correlation with the daily rain gauge series is 0.8, and the season bias is 6%.(http://onlinelibrary.wiley.com/doi/10.1002/2014GL060724/abstract).

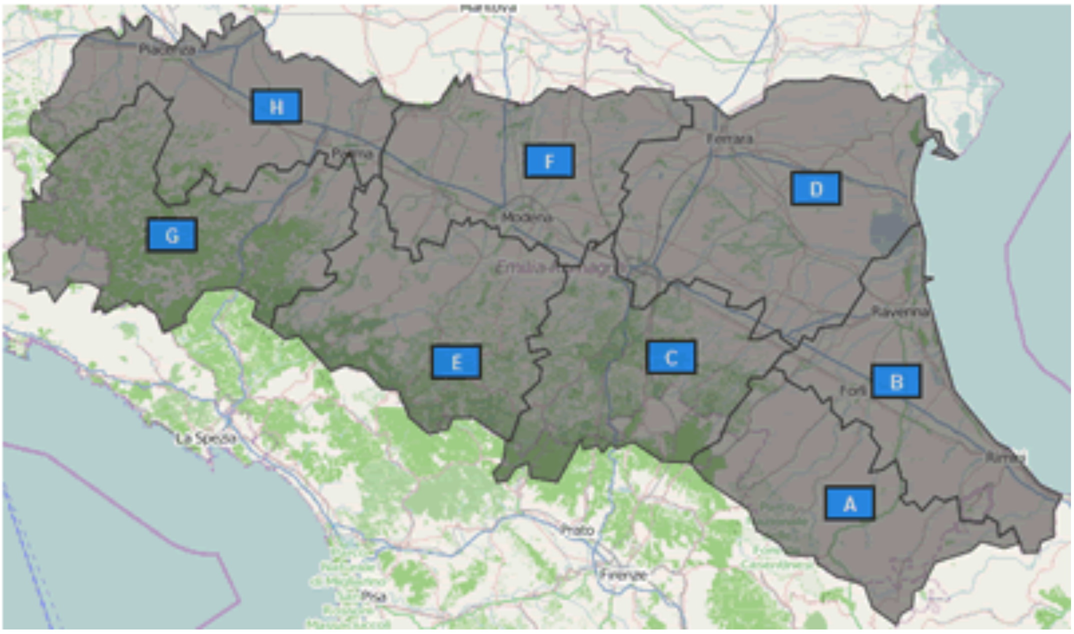
Such a network was already used also to retrieve the space–time dynamics of rainfall for an entire country, like in the case of The Netherlands (35,500 km2), a densely populated country in Western Europe with almost 17 million inhabitants. The available data were minimum and maximum received powers over 15-min intervals with a precision of 1 dB, based on 10-Hz sampling. In general, power losses along links are measured and stored by cellular communication companies to monitor the stability of their link networks. In that case, 15 minutes rainfall maps were provided.

2.3. Criteria of warning of potential critical heavy event

Arpae has a network of 242 hydrometer in order to monitor the water level of streams in Emilia-Romagna, to evaluate the criticalities of Civil Protection and the safety of the region. Each hydraulic section has 3 specific threshold/levels of alarm. In the picture below, the 3 thresholds of Ravone are shown.



The region has been subdivided in 8 macroareas with homogeneity of climate and hydrology for Civil Protection purposes. Cumulated precipitation of 50 mm in 24 hours per macroarea is considered the threshold for potential hydrological risk and alert of Civil Protection. In the picture below, the map of the macroareas in Emilia-Romagna.



1. The list of macroareas from East to West of Emilia-Romagna region is:
   a. mountain catchments, from Savio to Lamone;
   b. plain catchments, from Conca to Lamone and Adriatic cost up to Reno delta;
   c. mountain catchments, from Senio to Samoggia (Reno catchment);
   d. plain catchments, from Senio to Reno and Po (right bank);
   e. mountain catchments, from Panaro to Enza;
   f. plain catchments, from Reno (left bank) to Enza (right bank);
   g. mountain catchments, from Parma to Trebbia;
   h. plain catchments, from Enza (left bank) to Tidone.

The heavy rainfall rate events are getting more frequent due to the well known climate change effects on meteorological dynamics. For that reason the traditional networks of ground measurement stations made by rain gauges that are still suffering of a general number reduction as mentioned in the previous section, are not adequate to provide the right characterization of intense phenomena. Usually, in case of extreme events, traditional rain gauges underestimates the rainfall rate of more than 10%. Of course this error causes an issue in case of the measured data are used as input for weather forecast models.

Tipping-bucket rain gauges are the most popular recording rain gauges used by many weather and hydrological agencies. They are known for providing high accurate measurements of low to intermediate intensity rainfalls. This type of gauge produces rainfall data in digital form, which can be readily processed by computers. However, tipping-bucket rain gauges are known to underestimate the rainfall at higher intensities because of the loss of rainwater during the movement of the bucket. Then, at high rain rates, this kind of instrument may suffer from underestimation problems due to the fact that it cannot keep up with heavy rain during a severe extreme event.

The approach based on telecommunication microwave links proposed in RAINBO aims at going beyond the limits of traditional instruments in order to increase the accuracy of the statistics on precipitation that are used for risk maps and emergency planning as well as input for weather forecasting models.

Moreover the use of telecommunication links represents an increase of the number of ground measurements that can be taken in almost real time.

2.4. Criteria and best practices on the flash floods planning and adaptation strategies to reduce damages and increase territorial resilience

Flash floods phenomena connected to climate changes in urban-local-scale area are a very crucial problem these days, so a lot of studies, best practices and articles are available on this topic.

Flood events in recent years (with consequent ì life loss and huge damages) require urgent reaction. The increasing of occurring of this kind of phenomena is due to climate change.

Therefore, prevention and mitigation of flooding has been recently debated widely all over Europe and all over the world because of the events occurred in the last 15 years; in fact, many studies and documents on best practices related to this topic are available on internet.

In the following pages a summary of the most interesting investigations is presented. Many of the methods and and measures to face the problem are shared among the available literature studies.

Strategies can be divided in two main categories:

- Structural
- Non- structural

As shown in the figure below.

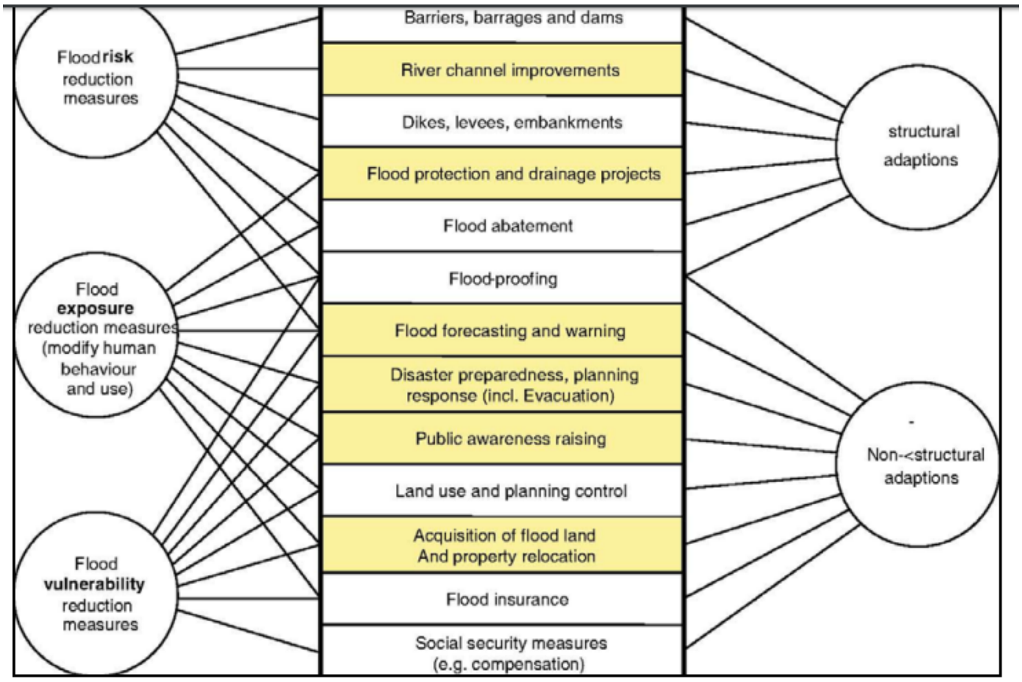


Figure 8 – Flash Flood Management Measures (Parker, 2000)

All the measures indicated in the figure are meant to mitigate flood risk and build resilience, in terms of hazard, exposure and vulnerability.

An effective system to protect a territory should be based on a combination of all strategies and on an integrated approach.

STRUCTURAL MEASURES

Structural measures focus on the development of infrastructure that will protect and reduce the risk of flood damages (Oliveri and Santoro, 2000).

In particular the structural measures that can be crucial in areas where flash floods occur can be, for example:

Measures in the whole catchment area: Delaying the speed of surface run-off and limiting the erosion, with a consequent reduction of flood impacts (e.g. terraced farm crops, construction of stone walls on the baulk, promotion of correct farming practices, development of forested lands and pastures, stabilization of the beds of small streams via wooden or stone thresholds, reinforcing steep slopes, and stabilizing the bottoms and sides of drainage ditches).

Regulating rivers and streams: to control the water regime limiting the slope of river and streambeds, while reinforcing the banks to limit erosion (e.g., barriers made of wood, stone or gabions, wooden or stone thresholds, various types of anti-debris dams), as well as dikes and embankments to protect buildings. Many of these engineering projects are presently made with natural materials, to minimize impacts on the environment and the landscape. In urban areas, well-organized drainage systems made up of channels, culverts, sewers etc., can prevent floods by conveying storm water away.

Shaping retention: to reduce immediate flooding, for example small reservoirs that collect water permanently or temporarily: retention reservoirs, dry reservoirs and polders; small dikes and dams raised from local materials, and such structural measures as culverts under roads.

River conservation: For a river valley to be prepared to redirect flood water, a river corridor should be shaped in the correct way so to control of its depth and slope, and care for the capacity of the valley (cutting down trees). These measures deal with the environment as a whole (including not just the lay of the land, but also its flora and fauna), protect all the natural elements and use some of them that can abet activities to limit damage caused by floods.

Sediment management: to reduce damages caused by flash floods.

NON- STRUCTURAL MEASURES

Non-structural measures are the non-physical tools and strategies used to reduce and prevent further hazards, including policy, legislation, land-use management, emergency response planning and community participation (Kundezewicz, 2009). RainBO platform can be considered as included in this category.

First, an effective **forecasting** system plays a fundamental role, but due to the rapidity of the phenomenon, the forecasting can be very difficult: a Real Time prediction system should be necessary.

In fact, the forecast system should provide sufficient lead-time for individual communities in the floodplain to respond. The greater the lead-time, the more reduction in life loss..

End-to-end forecast and response/decision support system can consist, for example, of the following elements or steps, which must be combined and linked to optimize the results:

1) data collection and communication;
2) meteorological and hydrologic forecasting and forecast product generation;
3) disseminating forecasts to users;
4) decision making and support;
5) actions taken by users.

The interaction of the technological components of the integrated End-to-End forecast system can be represented as a chain composed of many links. Each link must be fully functional to benefit the community or population at risk. As with links in a chain, should one link not be functioning properly, the entire system breaks down. In other words, if a perfect flash flood forecast is generated but does not reach the population at risk (dissemination), then the forecast system may not be useful.

An important consideration for flash flood detection, forecast, and warning, is that, because of the short lead times and much localized impacts, flash flood management must focus on the mitigation and warning requirements to save lives. Generally speaking, there is little time to save property during a flash flood event.

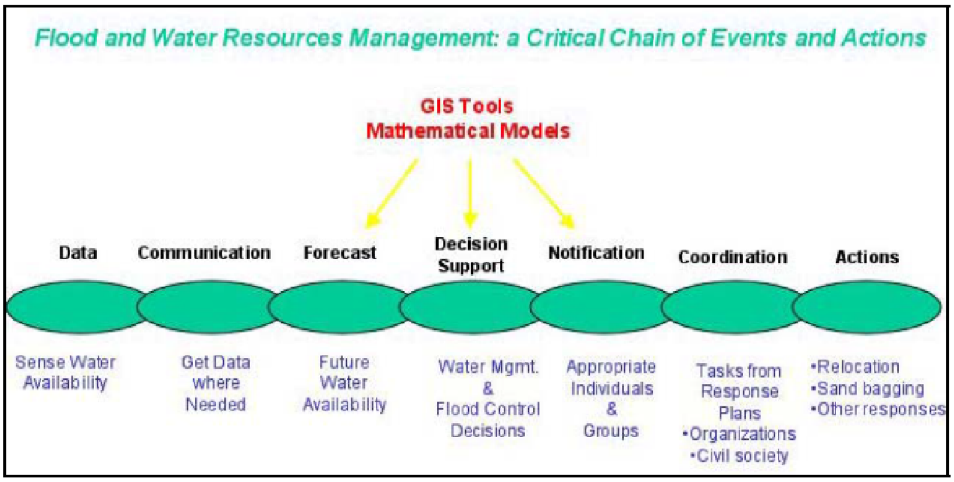


Figure 9 – Integrated Flash Flood Forecasting, Warning and response System – [Management of flood – World meteorological organization – a tool for integrated flood management – May 2012]

A timely and reliable flood **warning** and forecasting system, depending upon consistent hydro-meteorological basins rather than on sectors, is one of the basic conditions for an improvement of the protection against floods.

An effective early-warning and forecasting system. Because of the short reaction time in the event of flash floods the warning of flash floods should be based on real-time information from an automatic precipitation gauges network combined with quantitative radar precipitation data and supported by quantitative rainfall forecasts. The system of the flood warning services should be decentralized, and capable of providing local warnings with a time advance, which would be impossible to be ensured by using central systems.

An automatic information system, providing and exchanging data about should be set up and operated together with the flood warning services and other participants involved in the flood protection.

An effective and reliable system of flood forecasting and warning dissemination should be set up to inform flood authorities and citizens in threatened areas. Classical and new media such as official warnings, state and private broadcasting services, satellite-based communication system, alarm calls on the radio (switching on radios by re-mote control), mobile telephones, the Internet and teletext etc should be used, tested and performed according to technological progress.

Another important aspect, shown in the figure above is, in fact, the use of a GIS (Geographic information System), and, in general, **spatial planning** which consists in the creation of maps.

Spatial planning can contribute to the hazard reduction throughout a flash flood prone catchment, appropriate planning can limit the impacts of increased runoff caused by urbanization.

Connecting analysis to the territory and to a spatial representation can be very effective and usefulfrom first steps of planning to dissemination of results.

In order to plan an effective flash flood management and mitigate loss of life and damages it is essential to identify risks caused by flash floods. Carrying out a **Risk Assessment** allows choosing proper methods to reduce losses caused by flash flood. In general, the main elements are hazard, exposure and vulnerability as defined below:

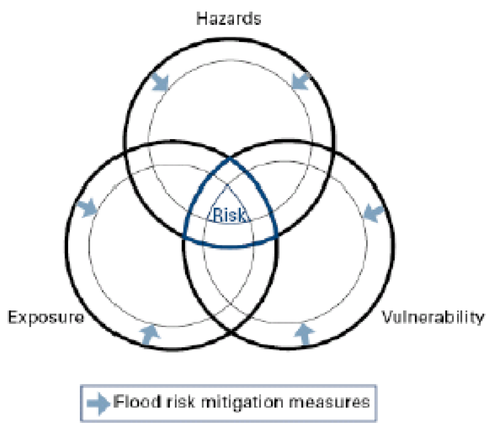


Figure 10 – Flood Risk Carachterization, [World Meteorological Organization 2006]

- Hazard: flash flood magnitude, which is defined by probability of occurrence: inundation maps of risk areas.
- Exposure: human activities and environment in the hazard zone
- Vulnerability: susceptibility of an area to flood losses defined by geophysical, economic and societal characteristics.

Participatory planning: Plans at the local level should be initiated by self-government, but the planning process itself should be conducted with the participation of all interested subjects: those at risk, those who are competent in developing risk reduction activities (e.g. crisis services, institutions overseeing the maintenance of rivers and streams, construction of dams, drainage, and forecasting services), as well as those who, to some degree, can help in limiting flash flood impacts (e.g., local NGO’s, mass media).

Planning should be an interdisciplinary process and should involves all interested stakeholder.

An effective approach should be based, in fact, on the expertise and capacity of various competent actors and their interaction with those directly affected. For flash floods in particular this calls for a close interaction between the hydrological and meteorological services, however, beyond that the information products and services provided through the National Hydrometeorological Services need to be based on user needs and that is where crisis services, local and district administrations and various other users need to be actively involved.

Besides, a **solid legal and institutional framework** is necessary to ensure the effectiveness of prevention and response planning at all levels: (from international setting, to national, to provincial/basin until local level and company/individual level). Flash flood management touches upon several sector-specific areas, so responsibilities and roles in each stage of management should be defined within solid legal and institutional framework. An appropriate legal and institutional framework is necessary to develop a successful flood management plan. Especially when dealing with flash floods, the role of local disaster management organizations is utterly important. This means local disaster management organizations should be given appropriate powers and responsibilities both legally and institutionally.

Damages of floods can concern mostly all aspects of an urban society: properties, infrastructures, production activities, and people. This is why a proper **insurance system** is to be organized and carried out in order to considerably mitigate the effects that extreme events have. Various countries have already established insurance schemes for this type of hazard.

Raising preparation and awareness in people are essential factors to make non-structural measures more efficient. A participatory approach can make local communities and residents understand their risks and responsibilities for flash flood management. Local communities should be aware of flash flood risks and this might likely increase the efficiency of flash flood management.

All the measures mentioned above intend to increase the level of **resilience** of a territory.

Resilience can be defined as the capacity to experience a disturbance with minimal or no impacts, maintain functionality of systems, and allow for rapid recovery (Liao, 2012 and Ahern, 2011).

In other words, cities need to adapt to the changing environment to become less vulnerable to risks and become resistant to disturbances.

The right attitude to resilience should consist in social economic and ecological aspects and evaluation. An integrated approach is necessary in order to make all the strategies as more effective as possible.

Ahern (2011) proposed five urban planning and design strategies for building urban resilience;

Strategy	**Description**
Multifunctionality	Multifunctionality can be achieved through integrating and combining functions, which allows increased diversity of system function (Ahern, 2011).
Redundancy and modularization	Redundancy and modularization refer to multiple components provided for a similar function so that the distribution of the same function makes the system more resilient to a disturbance (Ahern, 2011).
Bio and social diversity	Biodiversity alongside social, physical, and economic diversity are vital factors to increase urban resilience. Maintaining diversity helps to prevent system failure and allow rapid recovery to disturbances.

Multi-scale networks and connectivity	Multi-scale networks and connectivity involves functional support of a system through connective networks (Ahern, 2011). To maintain functionality it is important to ensure connectivity to prevent system network malfunction.
Adaptive planning and design	Adaptive planning and design corresponds with adaptation and design planning associated with lack of knowledge about future predictions and uncertainties associated with the degree of disturbances.

2.5. Existing projects

In Italy, in particular Emilia Romagna Region several projects have dealt with the climate changes adaptation in particular concerning to flooding risks.

The following table reports the synthesis of main Emilia Romagna projects about flash floods / hydraulic risk, focusing on potential connection with RainBO.

Project Name	**Lead Organization**	**Description and main objectvies**	**Potential connections with RainBO**
LIFE-Primes – (Preventing flooding risks by making resilient communities)	Civil Protection Agency of Emilia Romagna Region	The main objective of the project is increasing territorial resilience and reducing the damages caused by hydrogeological risk. The project deals with a participatory process with citizen in order to define operative procedures to manage emergency and to create resilient communities. Test cases: Imola, Mordano, S. Agata sul Santerno, Lido di Savio, Poggio Renatico (località gallo).	RainBO could be useful for emergency planning and for management of the participative plans. The organization of share workshop or dissemination events could be useful for integration of these two projects.
Progetto "Web Allerte"	Agenzia + ARPA SIMC (CFR)	The "Web-Allerte" project has the main aim to collect in only one platform all the data and information about meteo-hydrological-hydraulic risk. The web platform will be accessible from all the actors of regional civil protection system. This project is the main output of the process of updating the regional warning system: on the website will be available the information for weather forecast and the alerts. Moreover it will use as the formal way to spread warning for civil protection emergency. Throught web allerte the stakeholders will get risk maps (static version) and statistical data. Each Municipalities will have a personal web-space where publishing its emergency plan and by which would send message to registered citizens about alert and correct behavior in emergency.	RainBO could interact directly with Web-Allerte, through the Regional Civil Protection Operative Centre. In other words, RainBO early warnings could be transmitted to Regional Civil protection where they could be used for the creation of specific scenarios and published on web - Allerte site. In fact, actual regional warning system has not a deep level of detail and RainBO could be a zoom on small basin in urban area. From Regional Civil Protection, RainBO could get territorial data.

BLUE AP (Bologna Local Urban Environment Adaptation Plan for a Resilient City)	Bologna Municipality	The main aim of BlueAp project is to improve an Adaptation Plan to climate changes, in order to make the Bologna city less vulnerable and more capable of reacting to floods, drought, and other consequences of climate changes. The plani consists mainly in local Climatic profile, Local adaptation strategy and was a participatory process which involved actively population, public and private institutions.	RAINBO can be considered a follow-up for the project, because intends to develop solutions for improving the resilience of the city referring to vulnerabilities in Local climate profile and Adaptation plan.
iCity	Ayuntament de Barcelona (ES) / Bologna Municipality (partner)	Developing the concept of public virtual space strictly connected to the real public space and creating a sharing platform. Common Web gate creation for all services and definition of methodology and governance processes to ensure quality services. And their compliance to population needs.	Usage of heterogeneous sensors, by shared protocols and accessible by web, can be integrated also in RainBO system for both existing and innovative infrastructures.
T-Rain	Aria Technologies (lead), MEEO Srl	Feasibility study for the utilization of Microwave data links coming from cellular networks within a new system for monitoring intense urban rainfalls in high spatial and temporal resolution (more reliable). The objective of the study are looking for telecommunications operators data availability, analyzing existing complementary services on the market, amd defining business model.	The system based on Microwave link of the Project T-Rain can be used as a method to evaluate rainfalls in RainBO (both historical and real time)
Urban SIS	Swedish Met. Hydro. Institute (lead) ARPAE	The objective of Urban SIS (Sectoral Information System) is to develop, demonstrate and put into production a method to downscale climate and impact indicators to the urban scale, delivering the information in such format that it is directly useful for consultants and urban engineers/scientists as input to specific/local models or dimensional calculations concerning in particular the following urban hazards: Intense rainfall, Heat waves, Extreme air pollution levels.	Bologna is one of the pilot cities of the project; the proof of concept will provide data for: models for water treatment plant capacities and spill; health impact studies for overflow pollution from sewage water plants; river discharges / flash floods / flooding after intense rainfall; models for high resolution radiation temperature in cities; health impact studies for heat waves; local scale air pollution models; health impact studies for air pollution (also co-occurring with heat waves)"
KEP ALERT	Serbian environmental Agency /ARPAE	Strengthening Serbian multi-hazard early warning and alert system. Phase II: Improving dynamical real time data exchange at central and local level, to increase efficiency, directly involve populations and reduce costs for action.	Optimal transfer of information at local level; message system management to alert population

R-MAP Rete ambientale di monitoraggio partecipativo	ARPAE - SIMC	Defining methods and protocols to share environmental data and building a prototype of monitoring station. Collecting environmental data by citizens and disseminate them to meteorological services, Civil Protection etc. Feedback to providers to improve the quality of data. Sensibilization on environmental topics in schools and universities. Creating a virtuous circle: training institutes, public administrations, private companies and citizens.	Improving measurements of meteorological and environmental events through collaboration between public and private networks for acquisition of meteorological data . RainBo Platform will implement R-MAP protocol thorugh Sensornet platform, to collect data coming from new sensors on Ravone basin, provided by RainBO project, as well as from traditional moniotring systems of Arpae.

A specific worksheet for each project is collected in Annex 3.

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