# PROLINE-CE

# WORKPACKAGE T3

## DEVELOPMENT OF A TRANSNATIONAL ADAPTATION PLAN FOR INTEGRATED LAND-USE MANAGEMENT

## O.T3.1 GOWARE - CE TRANSNATIONAL GUIDE TOWARDS AN OPTIMAL WATER REGIME

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## Sommario

# 1. Introduction

Several activities carried out during the first stages of the Project (desk reviews, deep stakeholder involvement, SWOT/DPSIR) emphasized the utility of developing GOWARE - CE "Transnational Guide towards an Optimal Water Regime" in terms of a more interactive and ready-to-use tool to support the different types of stakeholders potentially interested in water-related issues: preserving water quantity and quality and improving flood risk protection.

Specifically, the most effective way to address such goal is assumed to be that of developing a Decision Support Tool (DST) in which the Consortium's expertise, the different insights and lessons learned during the Project could be properly capitalized. In general terms, a DST is a computerized system that supports Users in the decision-making processes by means of analytical systems for the examination of multiple alternatives and for the identification of the most suitable management strategies in the different contexts it is used. In recent years, DSTs have been extensively applied in different research and practical contexts and several applications have been proposed in the field of environmental protection, water resources management and water-related risks mitigation. In the specific, GOWARE-DST has been designed for selecting, prioritizing and promoting the most suitable Best Management Practices (BMPs), accounting for the specific User's requirements, to protect water resources and to reduce the impacts of flood events in Central Europe area.

As reported, GOWARE relies on experiences gained in the previous activities carried out within the Project: in detail, the catalogue of BMPs were primarily identified during Activity T1.2 and consolidated in the Deliverable D.T1.2.2 "*Transnational best management practice report*". The practices were selected at national and regional level by Project Partners by means of desk review, expert judgment and stakeholders' feedbacks. Afterwards, in the framework of Activity T3.2, BMPs were revised according the issue at hand (e.g. fixed land use or general water management, geomorphological setting) and ranked according specific requirements and constraints (their relevance in respect to water protection functionality, cost and time of the implementation, multi-functionality and their robustness in terms of time of sustainability).

To ensure the widest attainable serviceability, GOWARE DST has been developed as web-tool (http://proline-ce.fgg.uni-lj.si/goware/) or Excel-based offline tool. The preliminary design of the proposed DST is provided in D.T3.2.1 "*Roadmap to transnational adaptation for integrated land use*", D.T3.2.2 serves as Engineering's and User's Guides supporting the use. Finally, D.T.3.3.1 provides an exhaustive review of feedbacks, remarks and suggestions collected during the testing carried out at National scale

Selection and ranking process, in GOWARE, is performed in two consequent stages: in the first one, a scoping analysis is operated by selecting four filters (Fig.1 – left side). In this way, the tool is enable to pre-select a set of BMPs from the initial catalogue, which will be ranked in the second stage of analysis (Fig. 1 – right side). For the BMPs prioritizing, GOWARE adopts the Analytic Hierarchy Process (AHP), an analytic method of analysis that permits putting together quantitative scores provided by expert judgments about a number of characterizing criteria with User-defined priorities to finally obtain the ranking of the suitable sub-set of BMPs.

This document is organized as following: first, a general introduction to the Decision Support Systems (DSSs) is provided. Then, the GOWARE design is briefly described and the two stages procedure of analysis are illustrated. In order to explain the specific methods of analysis implemented into the tool, Paragraph 3.3 is devoted at providing a detailed description of the AHP model. Finally, the results of the first operative off-line test of the tool, carried out during the second project Round Table held in Budapest in February 2019, are illustrated.

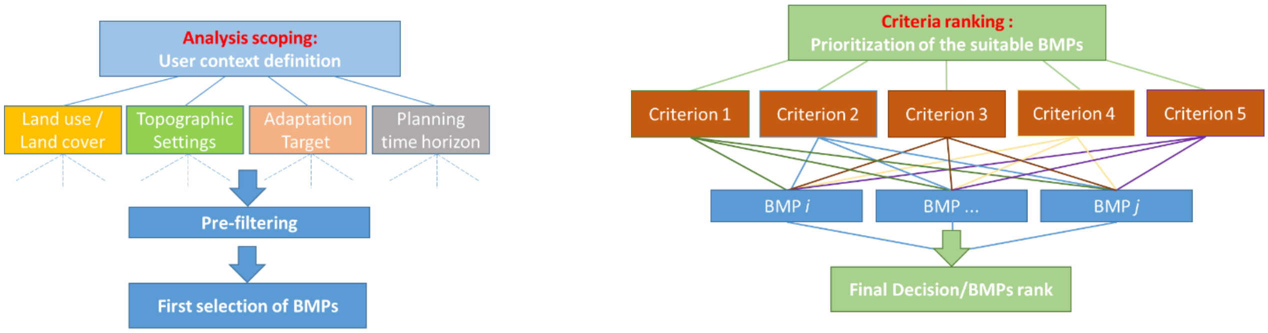


**Figure 1:** Schematic representation of the GOWARE structure. The pre-selection of BMPs is shown on the left side while the BMPs prioritization is shown on the right side.

# 2. Decision Support System (DSS)

## 2.1 Design and classification

A Decision Support System (DSS) is an interactive computer-based system or subsystem intended to help decision-makers in using communication technologies, data, documents, knowledge and/or models to identify and solve problems, complete decision process tasks, and make decisions (Power, 2014). The general design of a DSS is based on the integration of data, models and methods from multi-disciplinary sectors and its implementation is generally supported by the use of sophisticated analytical algorithms. The development of a DSS engages experts from a wide range of sectors and benefits from the participatory inclusion of stakeholders and decision makers (Jakeman et al., 2016). Furthermore, an effective DSS results adaptable, flexible, and easy to be developed and suitable at different level of management.

Although at present DSSs are widely recognized as a simplified representation of issues related to the development and evaluation of alternatives, they still miss a specific and common definition. The first definition of a DSS as part of the concept of decision calculus was given by Little (1970). Power (2008) defined a DSS as a computer application that improves capability, both individual and collective, in decision-making processes. According to Raheja and Mahajan (2013), DSS is a decision making supporting system made up by the combination of data, tools and User-friendly software. DSS was also defined as an application of various data and models to Human-Machine Interface (HMI) in order to assist decision makers at each level to achieve a scientific decision (Fang and Bing, 2009).

Nevertheless, scientific committee agrees on the general DSS architecture, which is composed by three key components (Fig. 2):

- The **Data Base Management Systems (DBMS)**, which keeps in a database storage data required for the decision making process. It allows Users to insert, delete, modify and query data;
- The M**odel Based Management Systems (MBMS)**, which provides quantitative/qualitative models required for the decision-making analysis. The models allow converting data stored in the DBMS into useful information for decision-making process;
- The **User interface system** (also known as Dialog Generation and Management Systems – DGMS), which enables Users to communicate with the DSS. It includes hardware (physical) and software (logical) components.

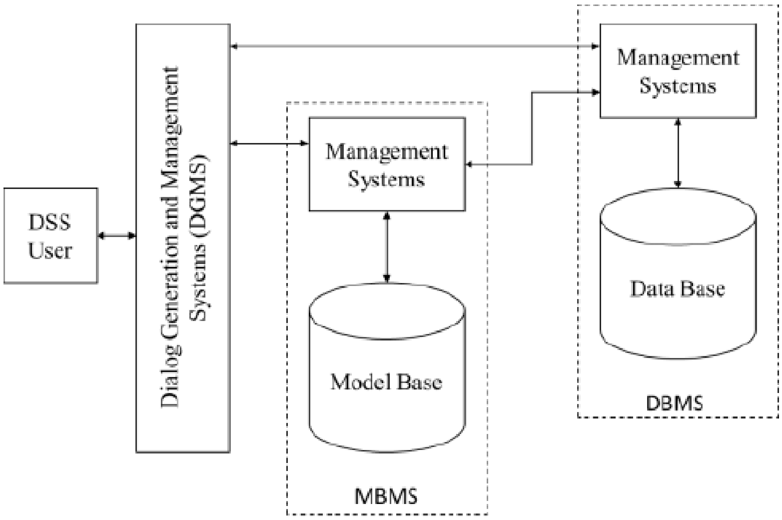


**Figure 2:** The main components of a Decision Support System (from: Sage, 2001)

Several criteria have been proposed for providing a standard DSS classification and, as consequence, numerous classifications have been developed during the time. It results that, as for their definition, DSSs do not have a standard and globally accepted classification (Hasan et al., 2017). One of the most used classification was proposed by Alter in 1980, who classified the types of DSSs according to the degree to which the system's output can directly determine the decision. In this case, two main DSS categories were identified (Fig. 3):

1) **Data-oriented DSSs, which include two types of DSSs:**

   1.1 *File Drawer Systems,* which are aimed to automate manual processes and provide access to data items;

   1.2 *Data Analysis Systems,* which are aimed to facilitate the analysis of current and historical data.

2) **Model-oriented DSSs, which include three types of DSSs:**

   2.1 *System oriented on Accounting Models, which are used for prediction in term of accounting basic on future output through standard calculations;*

   2.2 *System oriented on Representational Models, which are aimed to provide prediction and estimation on consequences of particular conducts, such as in the case of risk analysis;*

2.3 *Systems oriented on Optimization Models, which are oriented to produce optimal solution computation for a combination problem;*

2.4 *System oriented on Suggestion Models, which provide the logical process that leads to develop suggestions on a decision.*

Furthermore, the ***Analysis Information Systems*** encompass the two broad categories above illustrated. These systems provide access to a multitude of supporting databases for the decisional process, as well as a series of simple models providing information useful for solving decisional situations.

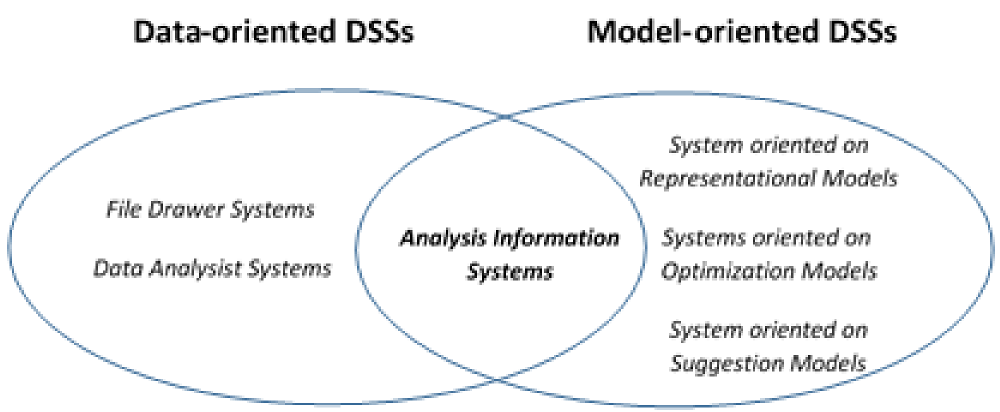


**Figure 3:** DSSs classification proposed by Alter (1980)

According to Donovan and Madnick (1977), DSSs can be classified based on the nature of decisional problem. They identified two DSS categories: i) ***institutional DSSs***, which allow solving structured problems within an organization; ii) ***ad-hoc DSSs***, which allow solving semi-structured problems. Institutional DSSs deal with decisions of a recurring nature while ad-hoc DSSs concerned with decision-making problems that are not usually anticipated or recurring. On the other hand, accounting for the final end-User, Hackathorn and Keen (1981) proposed three types of DSSs: i) ***single-user DSS*** *focuses on single User or class of Users*; ii) ***group DSS*** *focuses on a group of individuals;* iii) ***organizational DSS*** focuses on an organizational task or activity involving a sequence of operations and actors. Depending on the different relative level of efforts required for the DSS development and based on the level of interaction with the Users, DSSs were classified in three broad categories by Kersten and Lai (2008):

- **Passive DSSs,** are represented by tools that aid communication, calculation and data visualization in response to the input of a User. These tools augment data collection and analysis but interactivity is limited to the direct selection provided by Users;
- **Active DSSs,** are represented by tools that support construction and processing of solutions for Users based on the available data;
- **Proactive DSSs,** are represented by tools that combine the human element (feedback) and computer components to work together in order to get the best possible solution.

DSSs were also classified and described based on the way of support they provide (Power, 2004). **Model-driven DSSs** are complex systems that focuses on model access and manipulation. Analytical models are the major component of this kind of DSS. These kind of DSS do not need a big database, as it requires data and parameters given by Users. **Communication-driven DSSs** enhance the decision-making process by supporting communication between people working on the same task. **Data-driven DSSs** emphasize on data collection and their manipulation for a particular decision-maker need satisfying. They focus on large database designed to store data in such a way as to allow for its querying and analysis by Users. **Document-driven DSSs** support decision-makers by providing documents and web-pages management for information processing and strategies defining. Finally, **Knowledge-driven DSSs** use specific rules coded in computerized expert systems to support the decision maker.

Although DSSs have a number of advantages mainly related to the improvement of the individual's decisional capacity and to the ensuring of high objective and impartial character of the decision process, their effective implementation is still characterized by different limitations. First, the system design can result not effective due to the high computational effort and therefore the decision-making process can fail. Then, in order to be effective and efficient, they must be designed for a specific issue and for a specific type of decision problem and finally, these systems lack of "human capability" in terms of intuition, creativity, and instinct (Filip, 2007).

## 2.2 DSS for environmental resources management

DSSs are extensively applied in different research contexts including social sciences, applied sciences and managerial sciences. Several applications have been proposed for promoting the use of DSSs in the field of environmental resources protection such as pollution control, forestry conservation and agricultural production. Furthermore, DSSs have been developed to face problems of water-resource management and they play an important role in the water-related risk assessment and prevention, supporting the decision-making process for such complex issues.

The development of specific tools for the management of natural resources is a challenging issue because of the high interaction between factors acting in the environmental systems resulting in a high complexity of the environmental systems and therefore of the related decision processes. In fact, as highlighted by Giupponi and Sgobbi (2013), environmental issues are characterized by an intrinsic complexity due to the wide spatial and temporal distribution of the natural resources and related ecosystems. In addition, environmental resources are always the object of diversified, and often conflicting, interests and for this reason, groups and individual citizens are becoming important actors in planning and decision-making processes. Furthermore, during the last years, national and international policies for the protection of the environmental resources have become more articulated and complex. The high complexity of the natural resources management, and in particular of the water-related ecosystems, requires, therefore, the strong support from scientifically robust methods and tools to assist managers and policy makers, which promote the integration of scientific knowledge, economics and social aspects.

The identification of management and adaptation strategies represents also a relevant challenge for the sustainable use of the natural resources and for their conservation in a context of global climatic changes and local land use variations. In this case, DSSs are specifically designed for supporting the selection of the most suitable actions to be undertaken for the protection the natural resources in order to ensure their long time sustainability. This is the case of the DSS proposed in the framework of PROLINE Project, which is specifically devoted to the sustainable use of the drinking water resources and their effective management in different planning time horizons, also taking into account the potential flood impacts.

# 3. GOWARE - Transnational Guide towards an optimal water regime

## 3.1 Concept and methodology

GOWARE represents an operative Decision Support Tool (DST) specifically designed for facilitating potential Users in the decision-making process by implementing an analytical tool for the analysis of multiple alternatives and the consecutive identification of the most suitable ones.

GOWARE relies on operative tools enabling, in its final release, both the off-line (as Excel-based tool) and the on-line (as Web-tool) functionality of the systems. It is therefore considered as a concrete and consolidated realization of a Decision Support Tool (DST), suitable for supporting decision making process carried out by both single User and groups of Users. The off-line version is included in the GOWARE Toolkit, which is directly downloadable from a link available at the GOWARE dedicated Web-page (http://proline-ce.fgg.uni-lj.si/goware/).

Accounting for main gaps and leading problems identified in land use and floods management identified in the context of drinking water protection, GOWARE operatively advises interested end-Users and stakeholders about the most suitable and applicable practices, which should be integrated into operational management strategies and strategical policy guidelines.

The tool uses information collected in WP T1 and WP T2 of the PROLINE-CE project; in particular, it includes a catalogue of 92 BMPs identified by Project Partners at national and regional scale. The proposed measures have been characterized by experts who provided specific information regarding their suitability and their specific effectiveness. As shown in Fig. 4, GOWARE implements two stages of analysis that allow defining the user-based context and prioritizing the BMPs:

**Stage 1- Analysis scoping:** this phase consists in defining the context that appropriately represents the issues that the User is facing in the decision-making process. According to the defined context, the most suitable BMPs are pre-selected among the entire set of available practices (Box A in Fig. 4);

**Stage 2- Criteria ranking:** this phase consists in assigning a “relative importance” between defined characterizing criteria, by means of pairwise comparisons (i.e. considering the criteria two-by-two). The criteria ranking allows the prioritization of the pre-selected BMPs, which consists in giving to each BMP an order of suitability, according to the User judgments about the relative importance of the criteria (Box B in Fig. 4).

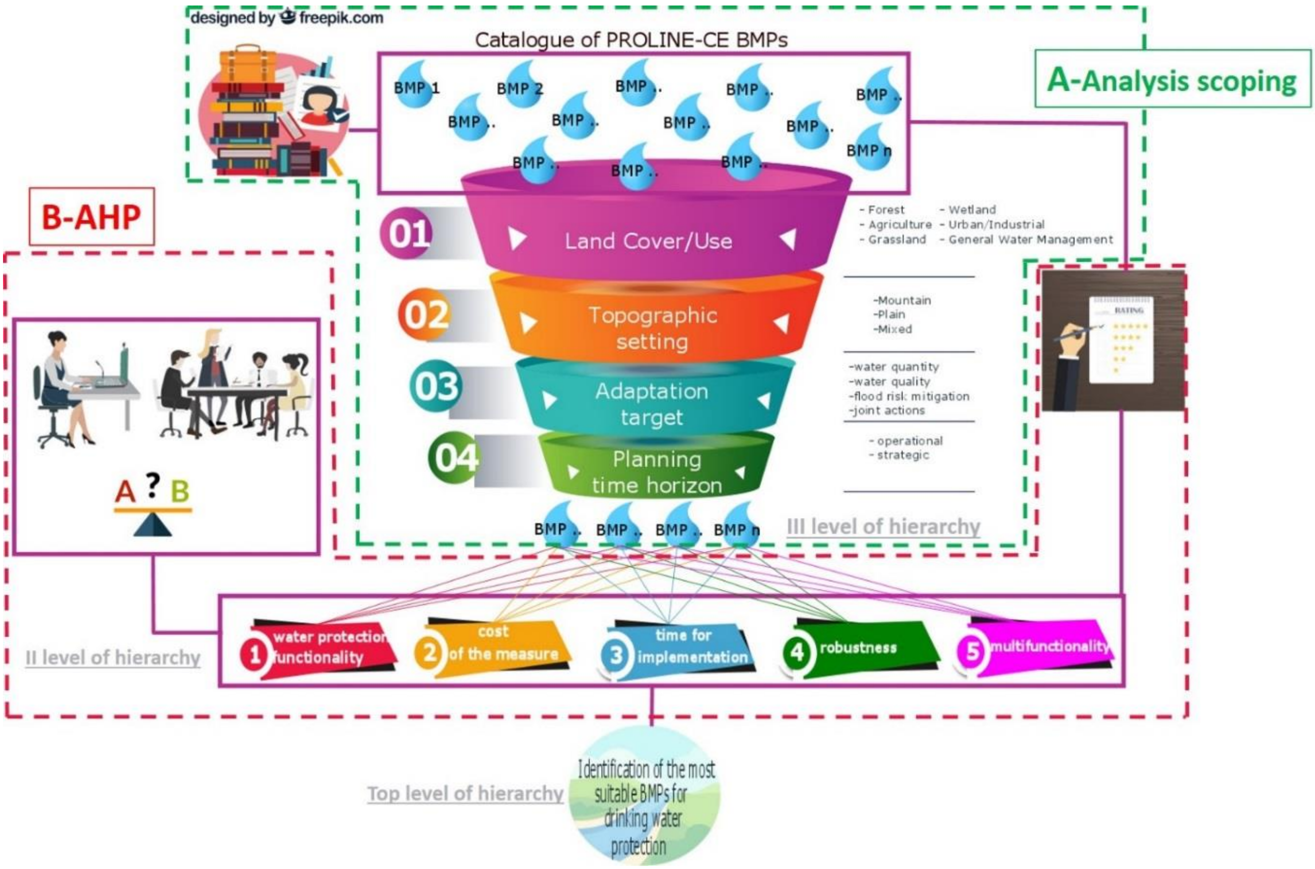


**Figure 4:** GOWARE design. The green dashed box includes the context scoping and pre-selection of BMPs (first stage of the analysis) while the red dashed box encompasses the criteria ranking and BMPs prioritization based on the Analytical Hierarchy Process (second stage of the analysis).

In the first stage, the specific context of analysis in which the User is operating is defined accounting for four filters: **i)** Land Cover/Use (forest, agriculture, wetland, grassland; urban/industrial/transport settlements and general water management measures for heterogeneous landscapes); **ii)** Topographic Settings (plain, mountain or both); **iii)** Adaptation Target (single or combined among water quantity, water quality, and flood risk mitigation); **iv)** Planning Time Horizon (Operational – day-by-day, Strategic – up to five years). The definition of these options allows filtering the BMPs and extracting the most suitable ones among those included in the catalogue.

In the second stage of analysis, User is enable to assign a relative importance between the following characterization criteria:

**Criterion 1) Water Protection functionality,** intended as the effectiveness for the main adaptation target in terms of protection of water resources (quantity or quality) and flood risk mitigation;

**Criterion 2) Cost,** defined in terms of relevance of "Economic issues" in driving the selection of BMPs;

**Criterion 3) Time necessary for the implementation** of the BMP;

**Criterion 4) Robustness of BMP,** intended as resilience also to external further forcing not planned in design phase or perfectly recognizable (e.g. climate change or land use change);

**Criterion 5) Multi-functionality,** intended as the capability to address also further functions (e.g. better provisioning, climate regulation, recreational) for which the BMP has not specifically designed.

Once the User has defined the relative importance among the criteria, GOWARE prioritizes the BMPs among those passing the pre-selection. In this way, the DST provides the User with the most suitable practices ordered according to his specific requirements. For this purpose, GOWARE adopts the Analytic Hierarchy Process (AHP), which permits putting together scores on the BMPs characteristics provided by expert judgment with User-defined priorities to finally obtain the ranking of the suitable sub-set of BMPs.

The values of the relative importance that each of characterization criterion assumes in the User's specific field of analysis are operated by means of qualitative classes ranging from 1 (to indicate the worst performances) to 5 (to indicate the best ones). The tool is, therefore, enable to evaluate the relative weight associated to each practice accounting for the quantitative values assigned to each criterion and to rank BMPs in order to achieve tailored solutions for the management of the User's issues. Furthermore, GOWARE incorporates an analytical technique for checking the consistency of the User's evaluations, thus signalling the bias in the decision-making process, and it is enabled for coping with the case in which the User does not provide a score to one or more comparisons.

## 3.2 Catalogue of Best Management Practices

During the PROLINE-CE activities, Project Partners have collected at national and regional scale the most suitable BMPs identified for coping with the water-related issues accounted in the project, concerning the management of drinking water availability, the protection of water quality and the mitigation of flood-related impacts. The catalogue of the BMPs is composed by 92 measures. Those practices have been characterized by experts who provided: i) specific information about their suitability in terms of land use, topographic setting, adaptation target, planning time horizon; ii) quantitative judgements ($J_i$ with i=1..5) for the five criteria in rates on 1-5, where "1" stands for worst performances (low functionality, high cost/benefit ratio, long implementation times, low robustness, reduced multi-functionality) while "5" stands for best-performing conditions. Details about the availability of BMP for each land use category are reported in Fig. 5, from which it is clear that most of BMPs are designed to address water-related issues in urban areas (20) and to address general management practices (26) while, on the other hand, less are devoted to the water management in wetland and grassland areas (less than 20).

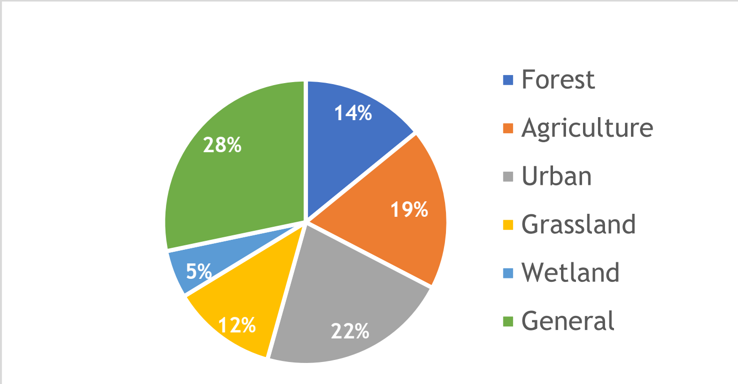


**Figure 5:** Percentage of BMPs identified for each land use category accounted in the project.

Furthermore, the analysis of the BMPs highlights that most of the investigated measures (almost 87%) are aimed at protecting water resources in terms of water quality: about 40% of the practices address specifically the water quality aspect, approximately 32% are able to cope with all the water-related issues considered in the project while some can address at the same time also water quantity (8%) or flood mitigation (11%) issues. These results are summarized in Fig. 6. In addition, the analysis shows that very few practices are exclusively devoted at ensuring the protection of the water availability and the management of floods (7% and 5%, respectively).

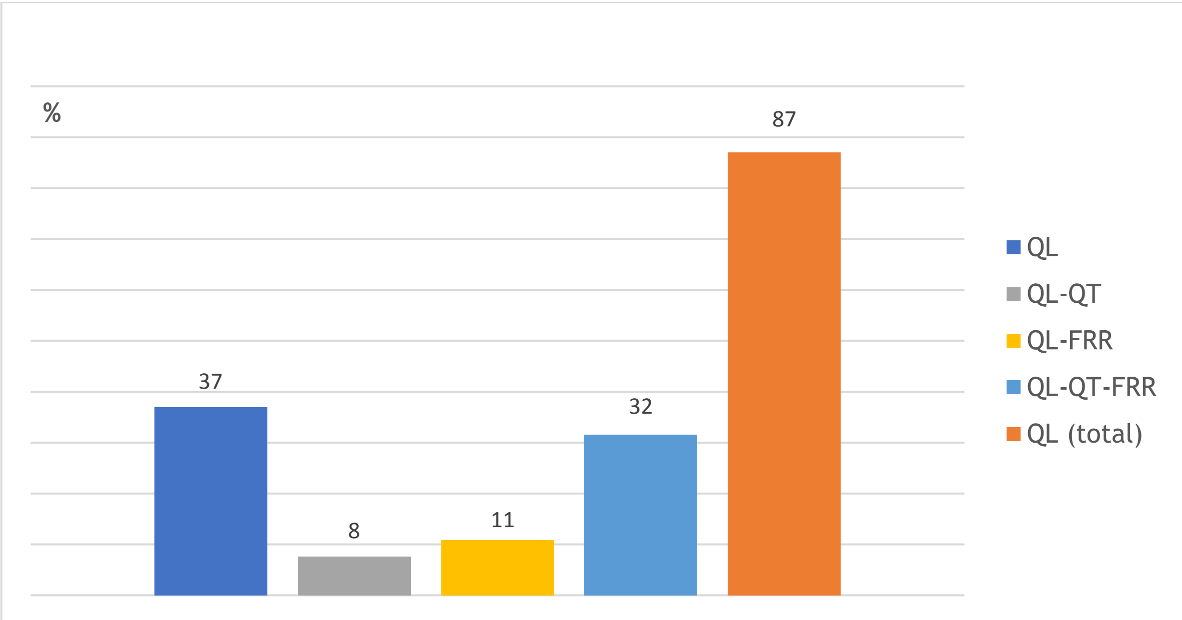


**Figure 6:** Percentage of BMPs suitable for addressing water quality issues (QL=Quality; QT=Quantity; FRR=Flood Risk Reduction).

Accounting for the topographic setting most of the selected BMPs can be implemented in both mountain and plain areas and very few are appropriate for a specific zone. Furthermore, considering the planning time horizon it results that half of the proposed measures are suitable for operative purposes (following a day-by-day implementation) and the other half is designed for strategical actions (with an acting time horizon up to five years).

Taking into account the judgments Ji associated to each criterion of characterization, it emerges that most of the practices (44%) are characterized by high functionality in terms of both protection of water resources and flood risk mitigation. Considering the "Economic issue", most of the practices (41%) exhibit a medium cost/benefits ratio ($J_3$=3). Accounting for the time necessary for the implementation, it emerges that, even if some practices have long implementation timeframe, most of the measures could be implemented quite rapidly ($J_5$=5 in 47% of BMPs). In both cases (cost and time for implementation), less than 6% of the practices present the lowest rank value ($J_i$=1). Furthermore, a very high number of practices presents high resilience to external factors not planned in the design phase and very few of them (<5% with $J_4$=1) present a low robustness. Finally, almost half of the BMPs are also suitable to address issues not directly related to the water protection, being characterized by a high multi-functionality ($J_5$=4-5) while very few of them are characterized by a low level of multi-functionality ($J_5$=1 in <5% of BMPs).

## 3.3 Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP) is a Multi-Criteria Decision Analysis (MCDA) tool introduced and developed by Thomas Saaty (1980) for the analysis of complex decision-making processes and for supporting decision makers in the selection of the most suitable decisions among a number of alternative solutions. It, therefore, considers a set of options among which the best decision is to be made based on a number of evaluation criteria. In recent years, such approach has been widely adopted for water management issues and for the implementation of operative actions, proving to be an effective tool for dealing with complex decision-making processes.

The AHP allows structuring a decision-making problem by dividing it in a finite number of stages and of elements and evaluating and ranking the alternative solutions. It allows assigning a priority to a series of decision-making alternatives and identifying the one(s) that achieves the most suitable trade-off among all the available solutions, accounting for the specific context of the decision-making problem. It is based on the pair comparison between alternatives (or between the criteria that characterize the alternatives) in order to give to each of them a score of relative importance and to finally rank the available alternatives.

The process starts with dividing the decision-making problem into elements in order to form a hierarchical order that simplifies the decision analysis. Once the hierarchy is built, the Users systematically evaluate the various elements by comparing them to each other (considering the criteria two-by-two) and giving them a score with respect to their relative impact on an element above in the hierarchy. In making the comparisons, the Users typically use judgments about the elements' relative meaning and importance. The judgement values are then transferred to a pairwise comparison matrix (Siddayao et al., 2014). The process ends with the attribution of a weight to each of the available alternatives that allows, after, identifying the most suitable solutions.

The AHP method can be summarized by the following operative steps:

1- Formulate the hierarchic tree;
2- Create a pairwise comparison matrix;
3- Check the consistency of the assigned values;

4- Calculate the weights;

5- Evaluate the final ranking of the alternative and take the final decision.

The available alternatives (**$A_i$**; i = 1, …. j) represent the criteria that can be selected in the decision-making process. In general terms, **$A_i$** is defined as the i-alternative and **$a_{ij}$** is the numerical value resulting from the comparison between **$A_i$** and **$A_j$**. If the number of alternatives is **n**, the number of total comparisons is **n(n-1)/2**. These comparisons will generate the comparison matrix **$A_{nxn}$** that will be used to calculate the weight values of each single alternative (Fig. 7). In creating the comparison matrix, an evaluation process is required in order to indicate how much one alternative is more important than another one.

The diagonal elements of the matrix are always equal to 1 because of the comparison is made between the same alternatives, while the non-diagonal elements show the relative importance of the alternatives taken into account in the comparison. If the elements of the pairwise comparison matrix are shown with **$a_{ij}$**, which indicates the importance of alternative "**$i^{th}$**" over "**$j^{th}$**", then **$a_{ji}$** could be calculated as **$1/a_{ij}$** (Boroushaki and Malczewski 2008). In Fig. 7, an example of a pairwise comparison matrix is shown.

| | **A1** | **A2** | **A3** | **Aj** |
|---|---|---|---|---|
| **A1** | **1** | $a_{12}$ | $a_{13}$ | $a_{1j}$ |
| **A2** | $1 / a_{12}$ | **1** | $a_{23}$ | $a_{2j}$ |
| **A3** | $1 / a_{13}$ | $1 / a_{23}$ | **1** | $a_{3j}$ |
| **Aj** | $1 / a_{1j}$ | $1 / a_{2j}$ | $1 / a_{3j}$ | **1** |

**Figure 7 -** A generic comparison matrix.

From Fig. 7, it is clear that the comparisons are made between the elements of the upper region of the matrix (blue cells) and that the score values in the lower part (yellow cells) are equal to the reciprocal values assigned in the blue cells. In this specific case, the number of comparisons is equal to 6, being the number of alternatives (n) equal to 4.

In Table 1 are shown the scores that are commonly assigned in the evaluation of the relative importance of each alternative (adapted from Saaty, 1980) and the related verbal interpretations (judgements).

**Table 1 -** Scores and judgements generally used in the comparison between the alternatives available in a decision-making process.

| **Score ($a_{ij}$ values)** | **Judgement** |
|---|---|
| **1** | Ai is equal important to Aj |
| **3** | Ai is moderately more important than Aj |
| **5** | Ai is more important than Aj |
| **7** | Ai is strongly more important than Aj |
| **9** | Ai is absolutely more important than Aj |
| **2, 4, 6, 8** | Intermediate values between adjacent values |

| | |
|---|---|
| **1/3** | Ai is moderately less important than Aj |
| **1/5** | Ai is less important than Aj |
| **1/7** | Ai is strongly less important than Aj |
| **1/9** | Ai is absolutely less important than Aj |
| **1/2, 1/4, 1/6, 1/8** | Intermediate values between adjacent values |

Once the weight comparison matrix is obtained, the AHP method employs different techniques to determine the final weights of each alternative: one of the most used technique is the "**eigenvector approach**" (lambda max technique - $\lambda_{max}$), in which a vector of weights is defined as the normalized eigenvector corresponding to the largest eigenvalue $\lambda_{max}$. Nevertheless, this method requires hard efforts and for this reason, simplified methods, which provides a good approximation of the lambda max method and easily enforceable in programming codes, have been proposed (Malczewski, 1999; Kordi, 2008).

Among the others, **mean of normalized values** is a method that allows calculating an approximation of the eigenvector associated with the maximum eigenvalue through a simple arithmetic procedure. In this case, first the sum of the scores in each column of the pairwise comparison matrix is calculated (see row in orange in Fig. 8). Then, each element in the column is divided by the calculated sum in order to obtain normalized values and the corresponding normalized pairwise comparison matrix $\mathbf{A}_{norm}$ (see Fig. 9).

| | A | B | C | D | E |
|---|---|---|---|---|---|
| A | 1.00 | 7.00 | 7.00 | 5.00 | 3.00 |
| B | 0.14 | 1.00 | 1.00 | 0.33 | 0.20 |
| C | 0.14 | 1.00 | 1.00 | 1.00 | 1.00 |
| D | 0.20 | 3.00 | 1.00 | 1.00 | 1.00 |
| E | 0.33 | 5.00 | 1.00 | 1.00 | 1.00 |
| SUM | 1.82 | 17.00 | 11.00 | 8.33 | 6.20 |

**Figure 8 -** An example of a pairwise comparison matrix. A, B, C, D, E refer to the available alternatives proposed in the decision-making process. Note that white cells are reciprocal of the blue cells with respect to the green diagonal.

Last, the arithmetic average of the entries on each row of $\mathbf{A}_{norm}$ is calculated to build the Priority Weight Vector "**w**" that is an m-dimensional column vector (see column "Weights" in Fig. 9). Based on the results of this analysis, it is possible to state how important each alternative is in the decision-making process (accounting for the percentage of weight values).

| | A | B | C | D | E | Weights |
|---|---|---|---|---|---|---|
| A | 0.55 | 0.41 | 0.64 | 0.60 | 0.48 | 0.54 |
| B | 0.08 | 0.06 | 0.09 | 0.04 | 0.03 | 0.06 |
| C | 0.08 | 0.06 | 0.09 | 0.12 | 0.16 | 0.10 |
| D | 0.11 | 0.18 | 0.09 | 0.12 | 0.16 | 0.13 |
| E | 0.18 | 0.29 | 0.09 | 0.12 | 0.16 | 0.17 |

**Figure 9 -** A typical normalized pairwise comparison matrix (**A**$_{norm}$). The weight values, calculated as arithmetic mean, are shown in the orange column. These values are used for the final ranking of the criteria.

Then, the values provided by AHP according to specific User's requirements are used to return the weighted sum related to each BMP:

$$R = \sum_{i=1}^{5} w_i J_i$$

They can be ranked according the values R so obtained returning the most suitable options tailored according to User's preferences.

### 3.3.1 Consistency evaluation

It is good practice that AHP analysis incorporate an analytical technique for checking the consistency of the decision maker's evaluations, thus reducing the bias in the decision-making process and therefore avoid rank reversal issue (see for example Fig. 10).

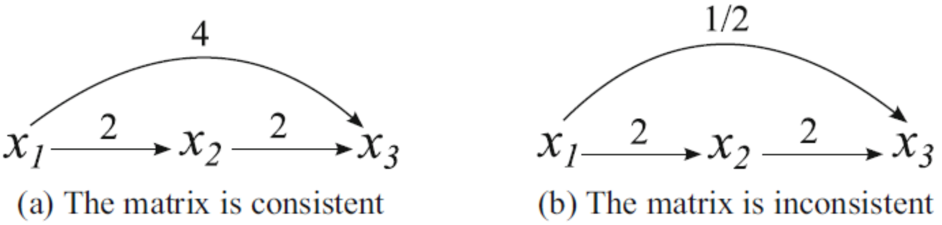


**Figure 10** – Examples of consistent and inconsistent transitivities (Brunelli, 2015).

In order to fulfil this purpose, the accuracy of the matrix, which is referred to the consistency of the pairwise preferences, is evaluated by means of the **Consistency Ratio** using the following formula (Malczewski, 1999):

**CR = CI / RI**

where **CI** represents the Consistency Index and **RI** is the so-called Random Index.

The Consistency Index CI is expressed as:

$$CI = (\lambda_{max} - n) / (n - 1)$$

where $\lambda_{max}$ is the principal eigenvalue of the matrix (it is a scalar) and **n** is the order of the matrix.

Operatively, CI can be calculated by the matrix product of the pairwise comparison matrix and the weight vector (*multiplying each score in each column of pairwise comparison matrix by its weight*) and then calculating the weighted mean of each row of the new matrix.

RI depends on the number of elements that are compared (n). RI values, referred to different values of **n,** are shown in Table 2 while in Table 3 illustrative examples of Principal Eigenvalues, CI, RI and CR values are shown.

**Table 2 -** Random Index values (adapted from Saaty, 1980).

| n | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| **R.I.** | 0.00 | 0.00 | 0.58 | 0.90 | 1.12 | 1.24 | 1.32 | 1.41 |

According to Saaty (1980), in a 5 by 5 matrix, a threshold equal to 10% (5% and 8% for the 3 by 3 and 4 by 4 matrices, respectively) has to be adopted for considering the matrix as consistent and therefore for accepting the estimation of the Priority Vector **w**. Nevertheless, first testing carried out also for GOWARE-DST highlighted how such limit could be strict.

Specifically, the value of CR = 0.1 indicates that the judgments are 10% inconsistent (Brunelli, 2015). In the example shown in Table 3, the comparisons can be considered consistent since the CR value is equal to 0.06 against a limit of 0.1.

**Table 3 -** Example of Principal Eigenvalues, CI, RI and CR values.

| Weights | Principal Eigenvalue | Consistency Index (CI) | Random Index (RI) | Consistency Ratio (CR) | Threshold |
|---|---|---|---|---|---|
| 0.54 | 5.29 | 0.07 | 1.12 | 0.06 | 0.1 |
| 0.06 | 5.27 | | | | |
| 0.10 | 5.30 | | | | |
| 0.13 | 5.25 | | | | |
| 0.17 | 5.20 | | | | |

Within the activities carried out for development of the PROLINE-CE DST, desk review concerning several approaches proposed in the scientific literature for the evaluation of weights provided by pairwise comparison analysis and their consistency has been performing (Brunelli, 2015). The final choice of the implemented methods is therefore in line with the State-of-the-art, aiming at minimizing some drawbacks recognized in the AHP approach (e.g. rank reversal issue).

### 3.3.2 Missing comparisons

In complex decision-making processes, it can happen that end-User may not (does not want to) provide a score for the evaluation of the relative importance between two criteria. This could lead to an incomplete pairwise comparison matrix in which some entries are missing. In this case, the AHP model requires setting its parameters to avoid overestimating weights to be assigned to the accounted criteria. Several methods have been proposed for solving this issue, mainly based on the following two approaches: 1) the comparison matrix is completed by means of an expert based judgment and then the priority vector is calculated; 2) the priority vector is directly calculated by means of modified algorithms.

When the “the eigenvector approach” or “the mean of normalized values” procedure are applied, the missing comparisons issue is generally faced by applying the method proposed by Harker (1987), in which the priority vector is estimated without completing the comparison matrix but considering only the available comparison values for creating a supporting matrix. In details, the supporting matrix is constructed by setting “zero value” to the cells referring to the missing comparisons and increasing the score value in the diagonal by adding the number of missing comparisons present in the accounted row ($1+m_i$, where “m” refers to the number of missing values in the “$i^{th}$” row). By applying the proposed algorithm, the estimation of the priority vector is not affected by the presence of missing values.

### 3.3.3 Group decisions

Generally, in real context of analysis, decisions are made by groups of decision makers such as stakeholders, boards or teams of experts. In this case, it is opportune accounting for all the provided opinions and aggregating them in order to provide a synthetic weight priority vector. According to Forman and Peniwati (1998), there are two methods to derive a priority vector from a set of pairwise comparison matrices:

1) **Aggregation of individual judgments (AIJ)**, in which the comparison matrices are aggregated into a single comparison matrix from which the priority vector is calculated. In this case, the priority vector estimation takes place after the aggregation of all the single judgments from a single pairwise comparison matrix.
2) **Aggregation of individual priorities (AIP),** in which a set of priority vectors is calculated from all the available pairwise matrices and then they are aggregated to obtain the representative priority vector. In this case, the priority vector estimation takes place after the derivation of all the priority vectors derivation.

In this second case, the aggregation of all the priority vectors derived from each single comparison matrix can be performed by calculating the weighted geometric mean or the weighted arithmetic mean. These two formulas clearly lead to different priority vectors, but they are both accepted in the literature (Brunelli, 2015). In GOWARE DST (attached Excel file in Toolkit), the first approach is implemented.

# 4. AHP testing phase

## 4.1 Data collection

The first test of the AHP approach has been carried out during the second Project Round Table held in Budapest in February 2019. The test was aimed at evaluating the functionality of the methods implemented into the tool and to assess the grade of stakeholders’ awareness about the proposed characterization criteria. It permitted improving the products included in Toolkit.

Participants from the different countries involved in the project joined the testing and they had different background in the field of water management. During the meeting, first, the GOWARE design and targets were illustrated. Afterwards, participants were asked for filling out a questionnaire and providing their own opinion about the relative importance for each criterion, assigning a score by considering the proposed criteria two-by-two. In Fig. 10, the table proposed for filling the questionnaire is shown. In this testing phase, participants were allowed indicating only odd scoring values (from 1-9) [the same approach is implemented in final version of GOWARE DST].

| | *Please indicate what criteria do you consider more relevant:* | | | | How much more? | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | *A* | *B* | | | | | | | |
| *1* | Water protection functionality | Cost of the measure | A | B | 1 | 3 | 5 | 7 | 9 |
| *2* | Water protection functionality | Time necessary for implementation | A | B | 1 | 3 | 5 | 7 | 9 |
| *3* | Water protection functionality | Robustness of BMP | A | B | 1 | 3 | 5 | 7 | 9 |
| *4* | Water protection functionality | Multi-functionality | A | B | 1 | 3 | 5 | 7 | 9 |
| *5* | Cost of the measure | Time necessary for implementation | A | B | 1 | 3 | 5 | 7 | 9 |
| *6* | Cost of the measure | Robustness of BMP | A | B | 1 | 3 | 5 | 7 | 9 |
| *7* | Cost of the measure | Multi-functionality | A | B | 1 | 3 | 5 | 7 | 9 |
| *8* | Time necessary for implementation | Robustness of BMP | A | B | 1 | 3 | 5 | 7 | 9 |
| *9* | Time necessary for implementation | Multi-functionality | A | B | 1 | 3 | 5 | 7 | 9 |
| *10* | Robustness of BMP | Multi-functionality | A | B | 1 | 3 | 5 | 7 | 9 |

**Figure 10 -** Pairwise comparison between the five criteria identified in the PROLINE-CE project for the characterization of the BMPs. This table was provided to the participants for carrying out the first testing phase of the AHP tool.

## 4.2 Data analysis and consistency evaluation

At the end of Project meeting, 42 questionnaires were collected. Among them, 40 were correctly filled (95%). Furthermore, only 14 people indicated their field of research: five of them were directly related to water management agencies, two were related to environmental protection agencies, three were hydrologist, one was a geologist, one was a physical geographer, one was an academic researcher and one was a landscape architect.

The analysis of the results is shown in Fig. 11: according to 90% of the answers, **water protection functionality** is more relevant than the cost of the measure as well as 85% of the people assume that this criterion is more relevant than the time necessary for the implementation of the measure. Furthermore, almost 60% of the participants indicated that water protection functionality is more relevant than BMPs robustness and multi-functionality (respectively 25 and 24 participants). Accounting for **the cost of the measure**, it resulted that it is considered more relevant only when it is compared with the time necessary for the implementation of the BMPs. On the other hand, the **implementation time** has not high relevance compared to the other criteria, in fact only when compared with the BMPs robustness, 15 stakeholders (37%) gave a positive feedback to this characteristic. Nevertheless, also in this case, the pairwise comparison proved that the relevance of the implementation time is lower (42% of the interviews). In the case of the **robustness**, stakeholders gave a higher relevance when compared to the cost of the measure and the time of implementation (55% and 42.5%, respectively). Finally, the **multi-functionality** has a higher relevance almost in all the pairwise comparisons (57.5%, 62.5% and 40% accounting for BMP cost, implementation time and robustness, respectively) and only in the case of the comparison with water protection functionality it has a lower relevance (according to 20% of the interviews).

| | *Who is considered more relevant?* | | | | |
|---|---|---|---|---|---|
| | *A* | *B* | A | B | Equal |
| *1* | Water protection functionality | Cost of the measure | 36 | 3 | 1 |
| *2* | Water protection functionality | Time necessary for implementation | 34 | 1 | 5 |
| *3* | Water protection functionality | Robustness of BMP | 25 | 9 | 5 |
| *4* | Water protection functionality | Multi-functionality | 24 | 8 | 8 |
| | | | | | |
| *5* | Cost of the measure | Time necessary for implementation | 21 | 14 | 5 |
| *6* | Cost of the measure | Robustness of BMP | 13 | 22 | 5 |
| *7* | Cost of the measure | Multi-functionality | 13 | 23 | 4 |
| | | | | | |
| *8* | Time necessary for implementation | Robustness of BMP | 15 | 17 | 8 |
| *9* | Time necessary for implementation | Multi-functionality | 9 | 25 | 6 |
| | | | | | |
| *10* | Robustness of BMP | Multi-functionality | 8 | 16 | 16 |

**Figure 11 –** Results AHP analysis based on the questionnaires provided to stakeholders during the meeting.

Collected data were used for evaluating the grade of consistency of the scores following the consistency analysis procedure described in the previous paragraph. The processing of the results has revealed how due attention should be reserved to providing "consistent" pairwise comparisons; indeed, several matrix largely exceed the minimum threshold fixed, according the literature indications, to identify "consistent judgments" potentially mining the reliability of findings. The consistency analysis has been carried out for all the pairwise matrices provided by each participant: results show that the consistency index values range between a minimum of 0.06 and a maximum value of 1.76 and that only 12.5% of the matrices (11 judgments) are consistent according to the strict threshold proposed by Saaty (1980) for five alternatives (0.1).

The application of the AHP method has allowed calculating the priority vector and therefore defining the relative importance of each proposed criterion. As stated in the previous paragraph, in the case of groups of Users, the evaluation of final priority vector has to account for all the provided judgments. In this specific case, both methods proposed to derive a priority vector from a set of pairwise comparison matrices have been applied: first, a single pairwise matrix has been obtained by applying the AIJ method and a corresponding priority vector has been estimated. Then, the AIP approach has been applied and the priority vector has been calculated by using both the geometric and the arithmetic weighted mean of the individual priority vectors (calculated by applying the mean of normalized values procedure).

The aggregation of all the matrices into a single comparison matrix (AIJ approach) has allowed estimating the priority vector "w" that shows the relative weights that each criterion (water protection functionality, cost and time of the implementation, robustness and multi-functionality) has gained, accounting for all the provided judgments (40):

$$W = (0.38; 0.12; 0.12; 0.17; 0.21)^T$$

The aggregated comparison matrix is shown in Fig.12, where yellow cells identify the judgements expressed as numerical values assigned to each comparison between two criteria and calculated as weighted mean of all the Participants' judgements while in the white cells are indicated the reciprocal values.

| AHP Multi-criteria analysis | | | | | |
|---|---|---|---|---|---|
| **Pairwise comparison** | Water protection functionality | Cost of the measure | Duration of implementation | Robustness | Multi-functionality |
| Water protection functionality | 1.00 | 3.50 | 3.60 | 1.70 | 1.90 |
| Cost of the measure | 0.29 | 1.00 | 1.20 | 0.70 | 0.60 |
| Duration of implementation | 0.28 | 0.83 | 1.00 | 0.90 | 0.50 |
| Robustness | 0.59 | 1.43 | 1.11 | 1.00 | 0.80 |
| Multi-functionality | 0.53 | 1.67 | 2.00 | 1.25 | 1.00 |

**Figure 12 -** Pairwise matrix obtained from the aggregation of all the single matrices defined by the Participants' judgements.

The analysis based on the AIP approach has been carried out first accounting for the whole dataset (40 judgements) and then extracting only the judgments for which consistency analysis has shown a value of CR lower than the set threshold (11 judgements). Fig. 13 shows an Illustrative example of symmetric matrix used by the AHP algorithm implemented in GOWARE for the analysis of the Participants' judgments. In this specific example, the matrix resulted consistent.

| AHP Multi-criteria analysis | | | | | |
|---|---|---|---|---|---|
| **Pairwise comparison** | Water protection functionality | Cost of the measure | Duration of implementation | Robustness | Multi-functionality |
| Water protection functionality | 1.00 | 5.00 | 7.00 | 5.00 | 3.00 |
| Cost of the measure | 0.20 | 1.00 | 1.00 | 0.33 | 0.20 |
| Duration of implementation | 0.14 | 1.00 | 1.00 | 1.00 | 1.00 |
| Robustness | 0.20 | 3.00 | 1.00 | 1.00 | 1.00 |
| Multi-functionality | 0.33 | 5.00 | 1.00 | 1.00 | 1.00 |

**Figure 13 -** Illustrative example of a consistent pairwise matrix. Individual relative weights assigned by each Participant to the comparison between two criteria are in the yellow cells while in the white cells are indicated the reciprocal values.

The following priority vectors (w1_t and w2_t) show the relative weights that each criterion has gained by aggregating all the judgments provided by Participants (40 samples) and calculated as arithmetic (w1) and geometric (w2) weighted mean:

$$w1\_t = (0.34, 0.15, 0.12, 0.18, 0.21)^T$$

$$w2\_t = (0.31, 0.12, 0.10, 0.15, 0.19)^T$$

On the other hand, the following priority vectors (w1_p and w2_p) are obtained by considering only the consistent judgements (11 samples):

$$w1\_p = (0.41, 0.18, 0.08, 0.14, 0.19)^T$$

$$w2\_p = (0.77, 0.60, 0.48, 0.56, 0.61)^T$$

The obtained results highlight that:

1) the the priority order of the criteria do not change when the two approaches are used (AIJ and AIP methods)
2) in the case of AIP approach, the differences between the vectors estimated by means of the geometric mean and weighted mean are negligible when all the samples of the dataset are included in the calculation (see w1_t and w2_t);
3) In both cases (total and partial dataset), the priority order of the criteria does not change when two averaging methods are used (AIP approach)

After the AHP processing analysis was performed, the minimum, the maximum and the mean values of the priority weights estimated for each criterion have been calculated accounting for both the entire dataset (Table 4) and the sub-set of consistent data (Table 5).

In both the investigated cases, it emerged that water protection functionality results to be the most relevant criterion taken into account by stakeholders in their decisions, as well as the time necessary for the implementation of the BMPs is considered as the less relevant aspect in the selection of suitable water management strategies.

As expected, an important role in the identification of suitable practices is played by the capability of the measure to address more than one function and service (multi-functionality). Finally, the cost for the implementation of the measures and their robustness have a variable level of relevance: the cost has a higher relevance if only consistent judgements are taken into account otherwise, the robustness is considered more relevant.

**Table 4 -** Minimum, maximum and mean (arithmetic and geometric) values of the weights calculated for each criterion accounting for all the 40 individual vectors.

| | Minimum values | Maximum values | Mean values (w1) | Mean values (w2) |
|---|---|---|---|---|
| Functionality | 0.12 | 0.59 | 0.34 | 0.31 |
| Cost | 0.03 | 0.45 | 0.15 | 0.12 |
| Implementation | 0.03 | 0.28 | 0.12 | 0.10 |
| Robustness | 0.04 | 0.35 | 0.18 | 0.15 |
| Multi-functionality | 0.04 | 0.44 | 0.21 | 0.19 |

**Table 5 -** Minimum, maximum and mean (arithmetic and geometric) values of the weights calculated for each criterion accounting for the 11 consistent individual vectors.

| | Minimum values | Maximum values | Mean values (w1) | Mean values (w2) |
|---|---|---|---|---|
| Functionality | 0.17 | 0.59 | 0.41 | 0.77 |
| Cost | 0.06 | 0.45 | 0.18 | 0.60 |
| Implementation | 0.04 | 0.17 | 0.08 | 0.48 |
| Robustness | 0.04 | 0.29 | 0.14 | 0.56 |
| Multi-functionality | 0.06 | 0.35 | 0.19 | 0.61 |

# 5. Additional information

For each selected BMP, additional information are provided (according to insights provided by Project Partners). They are aimed at supporting stakeholders in different tasks: (i) classifying the type of measure (governance, structural, land use management) and then also which could be the most effective "actuators" (e.g. land use planners, water operators, regional/local policy makers); (ii) returning a clearer view about the regulatory framework supporting the implementation and management of the practice and which are the main legislative reference to take into account; (iii) identifying the main investigations carried out in scientific literature or past/current European and National projects. Specifically, the following additional aspects are considered:

- A specific label regarding to the nature of the practice (governance, structural, land use management);Key Type of Measures (KTM) provided in the Water Framework Directive (2000/60/EC), indicated by a number from 1 to 25 (see Annex 1);
- Key EU legislation (mainly Directives) related to the practices (see Annex 2);
- Measures included in the European Agricultural Fund for Rural Development (2007-2013) referred to the Axis of reference (see Annex 3);
- Relevant resources for the implementation of the practices, including grey literature, peer-reviewed papers and EU Projects;
- Additional Project Measures (APM), corresponding to five typologies of measures proposed in PROLINE-CE Project (see Annex 4).

The additional information have been analyzed in order to identify which kind of measure resulted more influent and which European legislation had more relevance for BMPs included in GOWARE catalogue.

In details, accounting for the KTMs, it results that most of the practices included in the GOWARE catalogue are referred to KTM 2, 14, 17, 21, 23, 24 while no practices are assumed referring to KTM 5, 10, 18, 19.

With regard to the EU legislations, the Groundwater Directive (2006/118/EC), the Nitrates Directive (91/676/EEC) and the Environmental Quality Standards Directive (2013/39/EU) have resulted to be the reference directives for most of the BMPs. The histogram in Fig. 14 shows how many times each EU water-related Directive has been used as reference for the GOWARE BMPs.

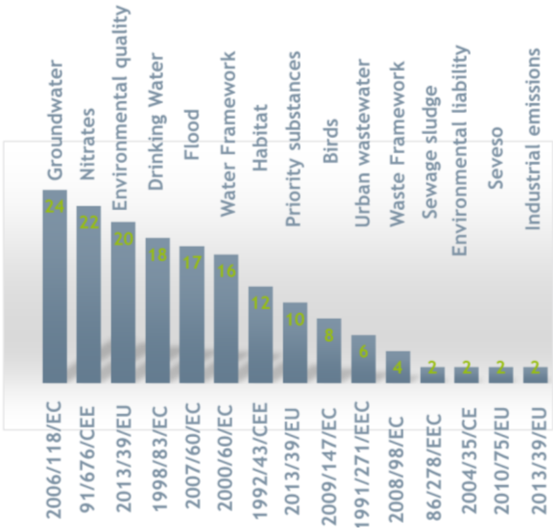


**Figure 14 -** EU water-related Directive and their occurrence as reference for the implementation of the BMPs proposed in PROLINE-CE Project.

In addition to the EU directive, the following EU Regulations are also used as reference for the BMPs refereed to the water protection in the agricultural areas: Fertilisers Regulation (EC Regulation N. 2003/2003), Regulation on the Registration, Evaluation, Authorisation and Restriction of Chemicals (EC Regulation N. 1907/2006), Plant Protection Products Regulation (EC Regulation N. 1107/2009), Biocidal Products Regulation (EU Regulation N. 528/2012), Regulation on Invasive Alien Species (EU Regulation N. 1143/2014).

Measures related to land and water management are also included in the European Agricultural Fund for Rural Development (EAFRD, 2007-2013) and, in particular, Axis 2 identifies 13 practices specifically devoted to environment and land management. The most relevant measures concern the promotion of payments linked to Directive 2000/60/EC (213) Agri-environmental programs (214) and Natura 2000 found (224). With regard to the management of forest, measure 225 promotes the environment payments for ensuring the protection of forest ecosystems and related services.

The analysis of the additional information has highlighted that the most cited documents are scientific paper in the category of grey literature (25 documents) and peer reviewed papers (21 documents), which also include 4 review-papers. Furthermore, 17 EU Projects deal with the management of water related processes and are aimed to ensure drinking water protection, also accounting for CC scenarios. In details, 5 H2020 projects have been identified for adding operative references to practices mostly related to the management/protection of water quality in urban area. Accounting for the practices that promote the Nature-based Solutions, the following relevant documents have been suggested:

- UN World Water Development Report: "Nature-based Solutions for Water" (2018)

- Report of the Horizon 2020 Expert Group on "Nature-based Solutions and Re-Naturing Cities" (2015)

- IUCN Publication "Nature-based Solutions to address global societal challenges" (2016)

As reference for the adaptation to Climate Change, the EU strategy has resulted the most recent available document at European level while the European Climate Adaptation Platform (Climate-ADAPT) and the Act platform (developed under a Life Project) are the webpages/tools that provide the widest range of information about the financial instruments available at European level for supporting CC adaptation actions. The EEA report 23/2018 has resulted very useful for providing indications about industrial waste-water treatment and effective management.

Furthermore, in the framework of Project activities, 5 typologies of Additional Project Measures (APM) concerning supervision procedures, regulatory processes, financing mechanisms, landslide and erosion control and the impact of different man-made structures on flood have been proposed to improve the characterization of the different practices. APM1 "Improved permitting, control and supervision procedures including regulatory supervision process, approvals, technical standards and their implementation. Permitting procedures in the field of water management usually address the process related to granting of emissions, abstractions, and construction on potentially flood prone zones. The permitting procedures should follow the advances in technology that enable more efficient, long term status supervision, enabling also close interaction with the modelling process as "validation tool" has resulted to be the most used additional measure for BMPs characterization.

Finally, accounting for the definition of the type of strategy to which each BPM is devoted (in terms of governance, structural, land use management), it resulted that most of the identified practices (59) are in the governance category, 44 are aimed to structural actions and 39 provide operative land use management indications. Nevertheless, very few BMPs (9) are suitable to be used at the same for governance, structural, land use management strategies.

# 6. National test

During June, the web-tool version of GOWARE has been tested at national level by consulting a relevant number of key stakeholders that have provided their opinions and suggestions for improving the entire framework and visualization/provision of the results. Different suggestions have already permitted to fix bugs or solve criticalities in web-tool while, in part, they have driven a more aware drafting of Engineering and Users' guides and the release of an offline (Excel-based) version where some issues arisen during the testing have been addressed.

In order to facilitate the stakeholders' engagement, dedicated (physical or remote) meetings have been organized in the different Project's countries. To permit a consistent and homogeneous collection of feedbacks, a web-survey has been developed. It is already active at the foot of the web-tool page. It is composed by five questions that are aimed at evaluating the effectiveness of the filters in defining the context of analysis, the understandability of the pair-wise comparisons, the comprehensiveness of the BMPs catalogue, and the usefulness of the additional details provided for each BMP. During the testing phase, 32 web-questionnaires have been filled in by stakeholders.

The results of the web-survey allow to state that Users have shown a high acceptance for the models implemented in GOWARE, which therefore resulted to be an easily applicable tool; nevertheless, a number of suggestions and criticalities have been highlighted. In detail, the main criticality concerns the filter related to the "Adaptation target". For this specific case, it has been suggested to provide only a specific selectable option for each issue (e.g. Water quality/Water quantity/Flood mitigation) in order to avoid misunderstandings, as already fixed in the Excel-based versions of the tool. Accounting for the pairwise comparison methodology proposed for the evaluation of the weights to be assigned to each criterion, stakeholders have considered this approach as an interesting concept, worth to be extended to other decision/assessment processes not strictly related to water management issues. As improvement, they pointed out that providing more detailed information about how to choose the numerical value between 1 and 9 as score value of their judgements could facilitate the usability of the tool.

Several stakeholders required to be provided with a larger catalogue of BMPs addressing also secondary water related issues or most affecting also specific regions of Central Europe domain. In some cases, they provided suggestions for including specific BMPs that could be easily included in the catalogue.

Furthermore, the availability of "Additional information" has been well accepted and considered very useful for better contextualizing BMPs in the EU governance context and for facilitating their operative implementation. Nevertheless, most of the participants to the web-survey (60%) believed that also other kind of key information could complement the tool in order to support the choice of the most suitable BMPs.

Once GOWARE web-tool is used, the User can download the results of her/his analysis. In this case, the relative weights that each criterion has gained from the Users' judgments are exported as Excel file and saved in the system. The analysis of the results obtained from the web-applications carried out during the test phase has allowed calculating the following priority vectors "w", which express the relative weight values of each criterion as arithmetic mean (w_mean1) and geometric mean – w_mean2:

$$w\_mean1 = (0.25, 0.17, 0.19, 0.21, 0.17)^T$$

$$w\_mean2 = (0.23, 0.15, 0.18, 0.20, 0.16)^T$$

From these results it is evident that "Water protection functionality" resulted be the most relevant aspect taken in consideration by Users. Furthermore, "Robustness", intended as the capacity of the measures to cope with different external factors not planned in design phase or perfectly recognizable as also resulted to be of strong interest, gained high relative weights (0.21 and 0.20). Finally, both priority vectors show that Users judgements gave low importance to the "Economic issue" required for the measure implementation.

The engagement of different categories of stakeholders (e.g. national and regional authorities, public water suppliers, and municipalities) during the GOWARE web-tool test phase and, in general, during the Project lifetime has allowed defining a network of potential end-Users that could be strongly interested in adopting GOWARE as operative tool for the management of water related issues.

# 7. Conclusions

The main objective of PROLINE-CE is represented by the improvement of drinking water resources protection as well as the enhancement of the mitigation of the potential impacts of flood/drought events by promoting an integrated land use management approach. The main project's outputs are therefore aimed at facilitating the implementation of existing strategies and management plans towards increasing effectiveness of land-use management actions and improving organisational structures.

To this purpose, the CE Transnational Guide towards an Optimal WAter REgime (GOWARE), which represents the operative web-tool developed in the framework of the PROLINE-CE project, has been designed to assist end-Users at different level of management providing effective information and ease implementable tools of analysis. Specifically, GOWARE is built upon all the outcomes of the previous project Work Packages (WPs) and therefore it represents an effective summary result of all the activities carried out during the project lifetime. It is designed as a Decision Support Tool (DST) and in its final release it operates both off-line and on-line; furthermore, the tool is suitable for single users or within workshop and meeting activities.

GOWARE is aimed at promoting sustainable land use strategies and it allows identifying the management practices that better fit with the needs and the requirements of all the potential stakeholders with different backgrounds, such as ecologists, hydrogeologists, foresters, urban planners, university researchers, policy as well as local water suppliers and farmers, supporting them in the decision-making process. To this purpose, it implements the Analytic Hierarchy Process (AHP) as Multi-Criteria Decision Analysis (MCDA) method, which is recognized as one of the most suitable and consolidate analysis system for finding compromise solutions of management. The design of the tool has required the definition of a catalogue of Best Management Practices (BMPs), specifically selected to address in an effective way water-related issues and to enhance the implementation of water protection actions in different land-use contexts. Based on national experiences of the project Pilot Actions (PAs), a number of BMPs were selected by Project Partners (PPs), accounting for their contribution in the improvement of drinking water safety and their effectiveness in the management of water-related risks.

The first attempt for testing the AHP tool implemented in GOWARE-DST was carried out during the second project Round Table in Budapest (February, 2019) and it was aimed at highlighting the main criticalities in the proposed AHP model, evaluating its effective functionality and therefore facilitating the operative putting into practice of the system.

Preliminary considerations have highlighted that the main issue faced in the project PAs is represented by the protection of water quality. In fact, most of the identified BMPs resulted suitable for coping with the intense chemical and biological contamination of drinking water resources and for ensuring their protection through the implementation of sustainable management actions in all the investigated land use categories. In this perspective, the proposed tool should contribute to facilitate the operative implementation of several EU policies purposes (Water Framework Directive, Drinking Water Directive, Groundwater Directive), specifically defined for the achievement of a "good status" of the water resources. In accordance with the Water Framework Directive (WFD, 2000), water quality protection results, therefore, one of the main environmental priorities of the project participating countries, which are located mainly in the Central Region of Europe and for this reason are less vulnerable to the water scarcity issue.

From the analysis of BMPs included in the catalogue emerged that most of the selected practices represent categories of public services commonly related to general management practices for environmental protection and restoration and, if appropriately implemented, they can guarantee the preservation of the ecosystem and hydrological services provided by different land-use categories (forest, agricultural, grassland and wetland). Furthermore, the investigated ecosystems are able to provide a variety of other relevant public services, such as air quality, erosion control and beautiful landscapes. For this reason, the capability of the BMPs to address further environmental functions plays a crucial role in the selection of the most suitable strategies for the drinking water protection. This point is also in line with the main purposes of the 2030 Agenda for Sustainable Development, which highlights the important role played by Nature-Based Solutions (NBS) for addressing contemporary water management challenges across all sectors, and particularly regarding water availability for agriculture, sustainable cities, risk reduction and water quality.

The high number of BMPs characterized by different level of application (policy level and operational level) allows to state the GOWARE results actually suitable for stakeholders operating at different level of management: administrators and decision-makers could benefit from the high availability of strategical practices that meet their long time territorial planning requirements while, on the other hand, operational practices, such as those devoted to the implementation of sustainable agricultural practices, can be of greatest interest for local end-Users (e.g. farmers, individual). Nevertheless, the implementation of BMPs is limited by economic, administrative, social acceptance or governance issues, resulting in long-term procedures. Hence, further research activities have to be focused on the operative implementation of proposed BMPs at national (guidelines issued by state agencies) and local level (e.g. BMP implemented by public water suppliers, municipalities).

Since GOWARE results to be a flexible tool, it can be easily extended by adding BMPs with focus on other relevant environmental issues. In particular, special attention should be provided to the assessment of the direct and indirect impacts of climate change on drinking water sources and to the proposal of effective adaptation strategies. PROLINE-CE project has already stressed the role that climate changes could have in exacerbating the issues currently suffered by communities, proving that the protection of drinking water in a context of climate change represents an environmental issue common to all the countries involved in the project.

Climate change impacts, associated with the increase of anthropic pressures, could strongly affect water quality not only for drinking water purposes. Furthermore, climate change is expected increasing the severity and the frequency of water-related extreme events and modifying the rainfall and temperature patterns, with large differences in the CE area. For these reasons, further investigations should include a proper assessment of the local impacts of climate change for all the related aspects, promoting also in this case a proper mainstreaming of adaptation actions in local policies and regulations. In order to increase the effectiveness of the tool in accounting for the climate change issue, in its further developments, GOWARE should be implemented with characterization criteria specifically devoted for this purpose as well as a larger set of strategies properly devoted to climate change adaptation and mitigation should be identified and included in the BMPs catalogue. In this way, the tool could also represent an operative system for promoting and supporting the fulfilling of the Second Cycle of Flood Risk Assessment and Management Plans (due in 2021) required by the Flood Directive, in which specific requirements on climate change are prescribed.

In conclusion, GOWARE will summarize a common methodology and a vision for integrated water protection management and will support the partners in establishing adequate information transfer to stakeholders. Further activities, based on a deeper stakeholders' involvement, should promote the dissemination and the capitalisation of PROLINE-CE results, extending the existing GOWARE and building synergies with other EU projects. In this way, the project and its main outcomes will provide a significant contribution to the promotion of sustainable ecosystem management, water protection and flood risk mitigation.

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# Annex 1

<u>List of Key Type of Measures (KTM):</u>

KTM1. Construction or upgrades of wastewater treatment plants

KTM2. Reduce nutrient pollution from agriculture

KTM3. Reduce pesticides pollution from agriculture

KTM4. Remediation of contaminated sites (historical pollution including sediments, groundwater, soil)

KTM5. Improving longitudinal continuity (e.g. establishing fish passes, demolishing old dams)

KTM6. Improving hydromorphological conditions of water bodies other than longitudinal continuity

KTM7. Improvements in flow regime and/or establishment of ecological flows

KTM8. Water efficiency technical measures for irrigation, industry, energy and households

KTM9. Water pricing policy measures for the implementation of the recovery of cost of water services from households

KTM10. Water pricing policy measures for the implementation of the recovery of cost of water services from industry

KTM11. Water pricing policy measures for the implementation of the recovery of cost of water services from agriculture

KTM12. Advisory services for agriculture

KTM13. Drinking water protection measures (e.g. establishment of safeguard zones, buffer zones etc)

KTM14. Research, improvement of knowledge base reducing uncertainty

KTM15. Measures for the phasing-out of emissions, discharges and losses of priority hazardous substances or for the reduction of emissions, discharges and losses of priority substances

KTM16. Upgrades or improvements of industrial wastewater treatment plants (including farms)

KTM17. Measures to reduce sediment from soil erosion and surface run-off

KTM18. Measures to prevent or control the adverse impacts of invasive alien species and introduced diseases

KTM19. Measures to prevent or control the adverse impacts of recreation including angling

KTM20. Measures to prevent or control the adverse impacts of fishing and other exploitation/removal of animal and plants

KTM21. Measures to prevent or control the input of pollution from urban areas, transport and built infrastructure

KTM22. Measures to prevent or control the input of pollution from forestry

KTM23. Natural water retention measures

KTM24. Adaptation to climate change

KTM25. Measures to counteract acidification

# Annex 2

List of EU legislations:

- Groundwater Directive 2006/118/EC
- Priority Substances Directive 2013/39/EU
- Marine Strategy Framework Directive 2008/56/EC (MSFD)
- Nitrates Directive 91/676/EEC (ND)
- Floods Directive 2007/60/EC (FD)
- Urban Waste Water Treatment Directive 91/271/EEC (UWWTD)
- Drinking Water Directive 98/83/EC (DWD)
- Bathing Water Directive 2006/7/EC)
- Regulation (EC) N° 1907/2006 on the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)
- Industrial Emission Directive 2010/75/EU (IED)
- Sewage Sludge Directive 86/278/EEC (SSD)
- SEVESO Directive 82/501/EEC
- Environmental liability with regard to the prevention and remedying of environmental damage Directive 2004/35/EC
- Fertiliser Regulation N° 2003/2003
- The Biocide Products Regulation N°528/2012 (BPR)
- The Plant Protection Products Regulation N° 1107/2009 (PPPR)
- The Cosmetic Products Regulation N° 1223/2009 (CPR)
- Waste Directive 2008/98/EC
- Environmental Quality Standards Directive 2013/39/EU
- Habitat Directive 92/43/EEC
- Birds directive 2009/147/EC
- EU Regulation 1143/2014 on Invasive Alien Species
- Commission decision establishing a Community civil protection mechanism 2007/779/EC
- Common Agricultural Policy (CAP)

# Annex 3

List of Rural Development Measures proposed by the EAFRD (2007-2013) – Axis 2: Environment, land management:

211 - Natural handicap payments to farmers in mountain areas

212 - Payments to farmers in areas with handicaps other than mountain area

213 - Natura 2000 payments and payments linked to Directive 2000/60/EC

214 - Agri-environment payments

215 - Animal welfare payments

216 - Non-productive investments

221 - First afforestation of agricultural land

222 - First establishment of agroforestry systems on agricultural land

223 - First afforestation of non-agricultural land

224 - Natura 2000 payments

225 - Forest-environment payments

226 - Restoring forestry potential and introducing prevention actions

227 - Non-productive investments

# Annex 4

List of Additional Project Measures (APM):

APM1: Improved permitting, control and supervision procedures

APM2: Regulatory processes regarding flood risk management

APM3: Improved financing mechanisms for all water

APM4: Landslide and erosion control measures

APM5: Improved understanding of the impacts of different man-made structures and infrastructure potentially affecting flood flows