BEtter Water-management for Advancing Resilient-communities in Europe

Action D4 – Assessment of socio-economic impact accounting for the hydrologic effectiveness of the interventions

Final report on socio-economic evaluation

Covering the project activities from 03/09/2018 to 30/06/2022

Project Data

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Beneficiary Data

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Glossary, Abbreviations, Acronyms

ARPAV	Agenzia Regionale per la Prevenzione e Protezione Ambientale del Veneto (Regional Agency for Environmental Protection and Prevention of the Veneto Region)
BEWARE	BEtter Water-management for Advancing Resilient-communities in Europe
COMSAN	Municipality of Santorso
COMMAR	Municipality of Marano Vicentino
CB APV	Consorzio di bonifica Alta Pianura Veneta
Floods	All events in which water inundates lands not normally covered by water (directive 2007/60/EC, 2007) (Salvati et al., 2014)
NWRMs	Natural Water Retention Measures as classified by the Office International de l'Eau (www.nwrm.eu)
RP	Return period
SCM	Stormwater Control Measure
SUDS	Sustainable Urban Drainage System
TESAF	Dipartimento Territorio e Sistemi Agro-Forestali, Università degli Studi di Padova (Department of Land, Environment, Agriculture and Forestry, University of Padova)

1 Executive summary

Action D4 of the BEWARE project focuses on the estimation of the economic impacts of the Project's main activities. In the two partner municipalities (Santorso and Marano Vicentino), seven pilot Natural Water Retention Measures (NWRMs) have been implemented (Actions C3 and C4). They contribute to the runoff water management, in case of heavy rainfall events, but they also provide additional co-benefits in terms of ecosystem services and act as demonstrative interventions for the local communities. In addition to the implementation of the NWRMs, the BEWARE project has also promoted direct activities of information, communication and education for the citizens living in the local communities, to promote participative approach to implement NWRMs and to demonstrate the importance of small NWRMs widespread across the municipalities. To achieve this goal, the project has actively favoured the replicability of the NWRMs at the private level (Actions C2 and C5).

This final report has a twofold purpose. Firstly, it performs a financial benefit-cost analysis, carried out to evaluate the effects (in terms of net present value) of the seven pilot NWRMs implemented by the project, together with a set of additional NWRMs expected to be implemented by private and public actors.

As a preliminary step for the benefit-cost analysis, a hydrological-hydraulic simulation model is performed to assess the flooded areas in the two municipalities of the project, considering both the baseline situation (without NWRMs) and the situation for which the NWRMs are implemented. Three different return periods (RPs) are considered for the analysis: 2-, 5-, and 30-years. In particular, the model allows to assess the number, location and costs of the additional NWRMs that have to be included. Grounded on this hydrological-hydraulic simulation model, benefits and costs of the interventions are assessed. With regard to the benefits, this analysis evaluates a set of private benefits originating from NWRMs, namely: i) pluvial flood-related avoided costs (as proxied by the avoided damage); ii) benefits to agricultural production in case of severe droughts; and iii) drinkable water saving, to be used for private uses (e.g., garden irrigation).

Pluvial flood related avoided costs are assessed by analyzing the runoff water raster maps and comparing the two situations. In particular, the buildings that experience a reduction in the flow depth level are firstly identified; then, to assess the benefits expressed as avoided damage, we consider building surface areas and their specific characteristics. Different flood damage functions are adopted in case of different buildings. This analysis is performed under two different scenarios: the current pluvial flood scenario and the one that takes into consideration the impact of climate change.

The benefits to agricultural productions, in the case of severe drought, come from the implementation of a Water Retention Basin (WRB). To assess its positive impact, an ad-hoc survey was administered to the agricultural holdings directly benefitting from the WRB.

Lastly, drinkable water saving benefits are assessed by taking a percentage of the total managed water, and considering the average cost of drinkable water for private uses.

In the benefit-cost analysis, the net present value is computed comparing all the aforementioned benefits (considering the annual benefits, on a 30-year timeframe) and the costs of the NWRMs, which include both implementation costs and maintenance and operational (M&O) costs, incurred annually for the entire economic lifetime of the interventions. In addition to the net present value, also the benefit-cost ratio, and the internal rate of return are proposed in the financial benefit-cost analysis. A net present value is estimated as being equal to € 3,628,178, assuming a discount rate of 4%. The benefit-cost ratio is 2.30, showing that the overall discounted benefits are more than two times higher than the overall discounted costs and the internal rate of return of the considered interventions is 14,1%. These figures are significantly higher in the climate change scenario (net present value equal to € 7,148,107, with a benefit-cost ratio of 3.52, and the internal rate of return of 23.4%).

The second purpose of the report is to assess the impact of the information and demonstration activities (such as, seminars and festivals) promoted by the BEWARE Project to increase citizens' awareness and willingness to implement NWRMs on their private properties, as a tool to mitigate the risk of pluvial floods. To achieve this goal, a questionnaire has been administered to the local citizens, with the main aim of assessing the overall knowledge of the NWRMs promoted by the BEWARE Project as well as the citizens' willingness to implement NWRMs. In particular, those citizens who took part in the project's activities have been compared with those who did not. Overall, 219 questionnaires were collected and analysed. The results suggest that the willingness to implement NWRMs is higher among the respondents who are aware of the BEWARE Project for all the NWRMs demonstrated by the project.

The rest of the report is structured as it follows. Section 2 sets out the objectives of this report. Section 3 discusses the hydrological-hydraulic simulation model and the financial benefit-cost analysis, which is grounded on it. Both the adopted methods and main results are shown and commented. A focus on the climate-change issue is considered as well. Section 4 discusses the role played by the BEWARE Project in enhancing people's willingness to implement NWRMs. Section 5 concludes.

2 Introduction: the aim of the report

The action D4 of the BEWARE project focuses on the assessment of the economic impact of the project, through a financial benefit-cost analysis, while additional non-valued co-benefits are only mentioned. The benefit-cost analysis considers the impact (in terms of net present value) of both the seven Natural Water Retention Measures (NWRMs), already realised as pilot interventions by the BEWARE Project, and a set of additional NWRMs, expected to be implemented by private and public actors, considering the two partner municipalities of the project (Santorso and Marano Vicentino), located in the Altovicentino Area (Veneto Region). With regard to the pilot interventions, they are the results of the actions C3, and C4 of the Project. Conversely, the actions C2 and C5 favour their replicability among citizens. Within the BEWARE Project, both agricultural and urban NWRMs have been realised, and in particular:

- an underdrained bioretention and a rain garden, in Piazzale delle Libertà (Santorso);
- rain garden, infiltration trench, and pervious pavement, in the graveyard of Via Prati (Santorso);
- a rainwater harvesting and drywells, in Corte Acquasaliente (Santorso);
- a grass swale and a bioretention area, in Collina del Grumo (Santorso);
- a detention basin with an internal bioretention pond, in Via Volti (Santorso);
- sustainable urban drainage systems, in the area of the elementary school of Marano Vicentino;
- a water retention basin (WRB) implemented in an agricultural area (Giavenale), close to Marano Vicentino.

The aforementioned NWRMs not only play a key role in the runoff water management in case of heavy rainfall events, hence mitigating the consequences of pluvial floods (thanks to the smaller extent and lower depth of pluvial floods) (Alves et al., 2019), but they can also provide additional co-benefits in terms of provision of ecosystem services (Veerkamp et al., 2021; Evans et al., 2022). Moreover, the implemented NWRMs also act as demonstration interventions, which are particularly helpful in increasing local citizens' awareness in terms of NWRMs and the positive impact they can play. To increase local citizens' awareness, the BEWARE project has also promoted additional activities of information, communication and education, targeted to the local communities with the aim of: i) promoting a participative approach to the NWRMs implementation; ii) demonstrating that the implementation of small and widespread NWRMs can enhance hydraulic safety, effectively coping with the effects of the climate change; iii) favouring the replicability of these actions, also at the private level.

The lack of knowledge among citizens regarding the economic benefits of the NWRMs and their costs represents one of the most critical barriers to their implementation (Sharma et al., 2016; Johnson and Geisendorf, 2019). To overcome this obstacle, in the BEWARE context, two different analyses have been carried out. First, a financial benefit-cost analysis has been implemented to demonstrate the economic sustainability of the NWRMs. It considers the implementation of a larger set of NWRMs at the local community level, which are similar to the pilot NWRMs realised by the BEWARE Project, and assuming the involvement of both the public local government and private citizens in the NWRMs adoption (Section

3). Second, the impact of the activities of the BEWARE project on the citizens' willingness to adopt NWRMs on their private properties has been addressed (Section 4).

In the benefit-cost analysis, two different scenarios are considered: the current pluvial flood scenario and the one that takes into consideration the impact of climate change, namely, one of the main environmental problems in the 21st century (IPCC, 2018). As a consequence of it, also hydrogeological disasters (hence, pluvial floods) have become more frequent and more severe in many areas of the world (Weyrich et al., 2020), among which the Veneto Region as well (Sofia et al., 2017). In both scenarios under consideration, different pluvial flood Return Periods (RPs) are considered: namely, 2-, 5-, and 30-year RPs for the current scenario; and relatively shorter RPs for the climate-change scenario.

For both scenarios, a hydrological-hydraulic simulation model is performed to assess the flooded areas both in the baseline situation and in a situation in which NWRMs to manage runoff water are implemented in the two municipalities. According to the simulated results, the costs of the NWRMs are compared with their expected benefits. The costs include both the implementation costs and the maintenance and operational (M&O) costs, which are incurred annually for the entire economic lifetime of the interventions. Conversely, several benefits are associated to the NWRMs in terms of ecosystem services (Scholz et al., 2013): provision, regulating, supporting and cultural services (TEEB – The Economics of Ecosystems and Biodiversity, 2011). In this analysis, we only evaluate a set of private benefits, i.e., those direct monetary benefits accruing to either private agents (i.e., local citizens, business and firms, farmers) or the city itself (i.e., the local public government) (Johnson and Geisendorf, 2019), such as:

- pluvial flood-related avoided costs, as proxied by the avoided damage, considering both private and public buildings, as a consequence of the smaller extent and lower depth of floodings after the implementation of the NWRMs in comparison with the situation with no interventions;
- benefits to agricultural production, given the reduction of damage in case of water shortage, due to severe drought periods;
- drinkable water saving, given the chance to use the collected rainwater for private non-drinkable uses (i.e., watering private gardens, car washing).

For each benefit type, the baseline situation – which is used to derive and describe the benefits of the NWRMs – is defined as the case with no implemented NWRMs (Wilbers et al., 2022).

As a reference period for the estimation of costs and benefits, a 30-year time horizon is considered and a set of indicators, commonly adopted in financial benefit-cost analyses, is proposed (Sartori et al., 2014): Net Present Value (NPV), Internal Rate of Return (IRR), and Benefit-Cost Ratio (BCR).

Given the importance of involving private citizens in spreading the implementation of NWRMs at local level, a survey among 219 citizens has been carried out, to evaluate the impact of the BEWARE Project's dissemination and information activities on citizens' personal willingness to implement them on their properties. The analysis compares the willingness to implement NWRMs among those citizens who took part in the project's activities and among those who did not.

3 Benefit-cost analysis

3.1 Method

3.1.1 The hydrological-hydraulic simulation model

Firstly, hydrological-hydraulic simulations have been implemented in order to estimate the number and the characteristics of the NWRMs needed to prevent pluvial floods in the territory of the two partner municipalities, as a basis for the following benefit-cost analysis. The simulations were implemented using the bidimensional flood routing model FLO-2D, a physical process model that routes rainfall-runoff and flood hydrographs over unconfined flow surfaces or in channels using the dynamic wave approximation to the momentum equation. FLO-2D is a model approved by Federal Emergency Management Agency (FEMA) of the United States, for both riverine studies and unconfined alluvial fans, and it is used worldwide to simulate river overbank flooding, unconfined alluvial fan floods, urban flooding, watershed rainfall/runoff, coastal flooding, tsunamis/storm surges, mud and debris flows, ground/surface water interaction and Storm Drain/surface water interaction (Figure 1).

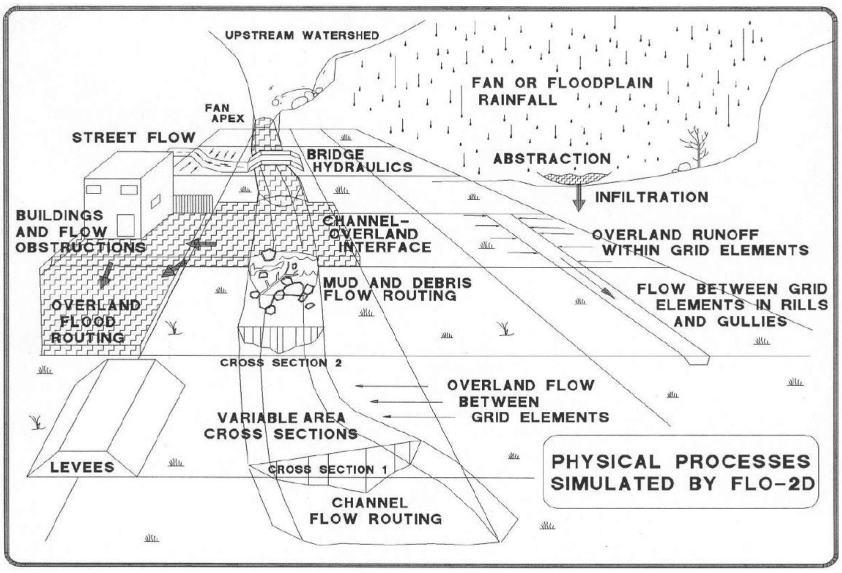

Figure 1. Physical Processes Simulated by FLO-2D[1].

In this case, hydrological-hydraulic modelling was used to estimate the amounts of water run-off generated by design rainfall events and to compute the flow conditions, such as flow velocity, flow depth and the size of possible flooded area in the municipalities of Santorso and Marano Vicentino. These output data have been used to identify the number and the dimension of the NWRMs, which are necessary to mitigate the flooding risk in the study area, and to run the benefit-cost analysis (see Section 3).

The adopted model takes into consideration the following information: a time series of precipitation data, topography, surface roughness, soil type, and land use-land cover conditions.

[1] FLO-2D Software, Inc., FLO-2D Reference Manual (build no. 19, 2019).

Precipitation data. Frequency analysis has been carried out in order to define the probabilities of future occurrences of rainfall events in the study area. Daily time series for the period 1987 to 2020 are analysed, by considering the rainfall station of ARPAV, located in Monte Summano (coordinates 1687851 m East, 5069238 m North, EPSG:3003) and located in the simulated area (northern area)-. For the analysis, Gumbel Type I Extreme Value distribution has been used to fit the data of annual maximum precipitation. The design rainfall used in the simulations considers a rainfall duration of one-hour. This duration was selected because short duration rainfalls can be considered the most critical ones, knowing the short concentration times of the considered urban watersheds. The result of the analysis is showed in Table 1.

Table 1. Rainfall depths for the different return periods: results from the probabilistic analysis.

Return period (years)	1-hour rainfall (mm)
2	40.1
5	54.3
30	78.2
50	84.7
100	93.6

Considering the return period of the rainfall events which caused damages in the past years in the two Municipalities (see Section 3.1.2), and the dimensioning criteria adopted to project the interventions, the simulations consider the events with a return period of 2, 5, and 30 years (i.e., M2, M5, and M30).

Topography. The topography of the area is described by the Digital Terrain Model (DTM), resolution 1m, obtained by a Lidar survey commissioned by the Italian Ministry for the Environment and the Conservation of Land and Sea within the project PST-A (Agreement 140 – Figure 2). DTM was used to compute the cell elevation values in the computational domain of the simulations. For this purpose, an aggregation and a conversion into an ASCII grid file of the original DTM has been realized (aggregation method: mean value; raster output resolution: 10-meter). Grid Computation was obtained from this resulting ASCII file and the grid size creation for the simulations was defined to be 10 m. As reported in Figure 2, a little area located in the mountain part of the Santorso Municipality has been excluded by the simulations. This is for the following reasons:

- no flooding events was reported within this area in the past years;
- the water runoff generated by the area does not contribute to the pluvial flooding of other parts of the Municipality; water runoff from that area flows directly into the Timonchio river passing along the western border of the municipality, and the BEWARE Project and this analysis does not consider river flooding;
- the study considers the application of NWRM in rural and agricultural areas, not in mountain areas.

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Figure 2. Digital Terrain Model resolution 1m used as base topography for the numerical simulations.

Roughness. To reproduce terrain roughness, different Manning's *n* values were assigned on the basis of land use (as classified by the Third edition of the Soil Coverage Map of the Veneto Region - 2018) based on Table 2. Figure 3 reports the map of the assigned values.

Table 2. Manning's n value adopted in the simulated area according to the values suggested in the FLO-2D Reference Manual (Build no. 19, 2019).

Land use	**Manning's *n* value ($s\ m^{-1/3}$)**
Roads and associated surfaces	0.013
Bare rocks and cliffs	0.017
Urban areas	0.035
Argricultural areas, urban parks, sports areas, and grasslands	0.040
Rivers, streams and canals	0.050
Active mining areas, areas in transformation, uncultivated urban areas, landfills and deposits of quarries, mines, industries	0.055
Sparse vegetation areas and shrublands	0.100
Forests	0.125

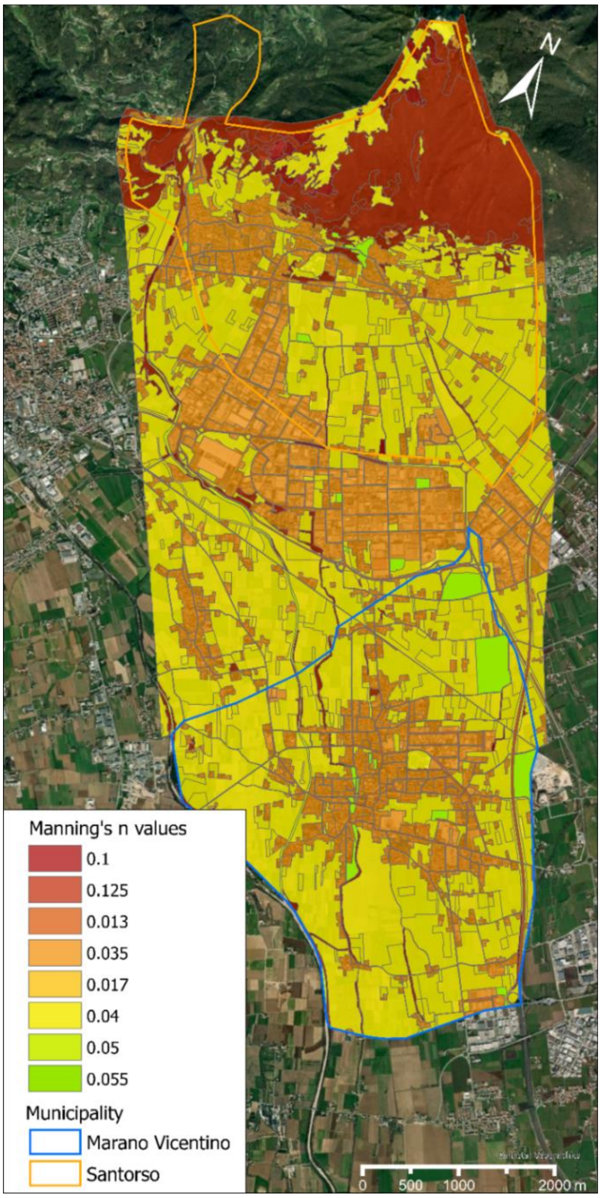


Figure 3. Map of the adopted Manning's n values (s m-1/3).

Soil Curve Number (CN). Precipitation losses, abstraction (interception) and infiltration has been simulated in the FLO-2D model using the SCS Curve Number (CN) method. In order to compute the soil curve number values, the land use-land cover map (Third edition of the Soil Coverage Map of the Veneto Region - 2018) was combined with the map of the USDA soil hydrological groups (updated by ARPAV in 2018). Land use-land cover descriptions of the regional map was matched with descriptions and CN values derived from the standard tables. As the flood hazard simulation is to forecast the maximum discharge of the considered rainfall events, CN (III) values was used (this CN = CN(III) assumes that soil moisture is already high before the design rain event). The formulation of Chow et al. (1988) has been applied to obtain CN(III) from CN(II) (standard/intermediate soil moisture before the rain event):

$$CN(III) = \frac{23\, CN(II)}{10 + 0.13\, CN(II)}$$

Figure 4 reports the map of the obtained CN(III) values used in the simulations.

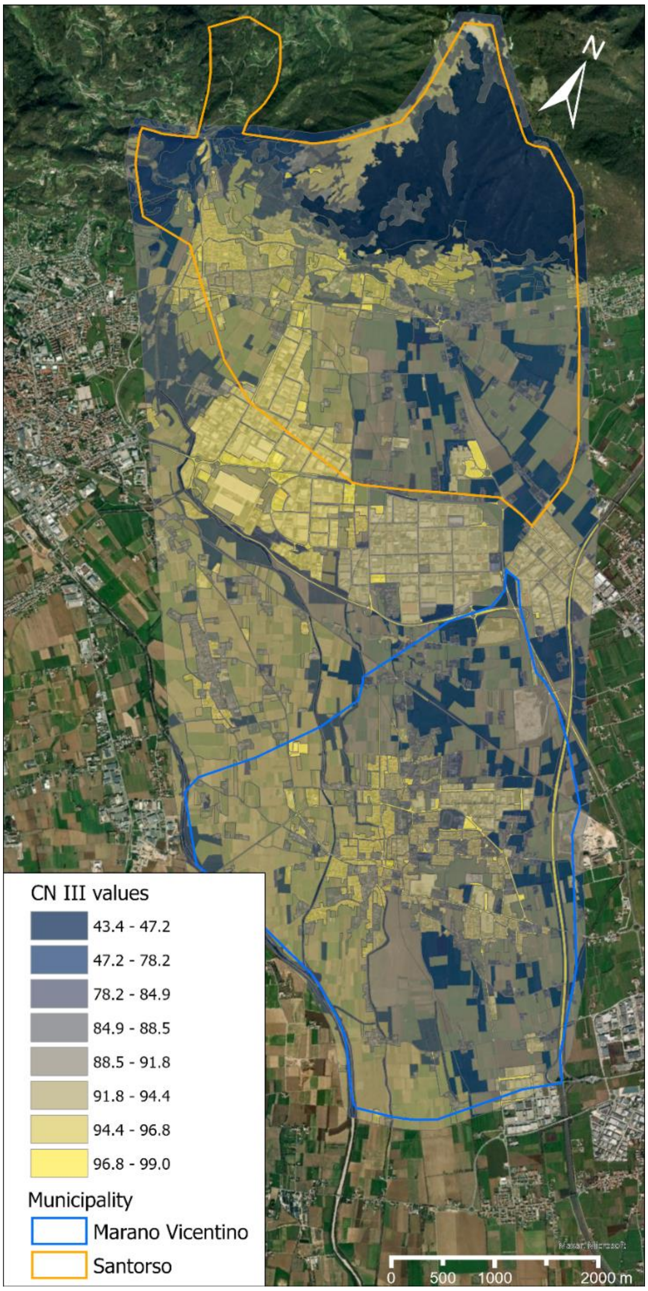


Figure 4. CN(III) values assigned to the computational domain.

3.1.2 Assessing number, location and costs of the NWRMs

In order to define the number and location of the structures required to mitigate the hydraulic risk of the two Municipalities, the results of the hydrologic-hydraulic simulations have been used in combination with the administrative databases of the flooding events occurred in Santorso and Marano Vicentino in the timespan 2010-2019 (the database was described in the "Report about ex-ante flood-related damage evaluation", already delivered). The flooding events (associated to very different RPs, ranging from 1.5 to 32.2 years) documented in the databases have been mapped and used to carry out a basic validation of the numerical modelling. For each flooding area resulting from modelling and database, a NRWM has been assigned. NWRMs have been located upstream to the flooding areas, according the flow directions highlighted by the model, intercepting the flow that causes each flooding. This process allowed the identification of 30 NWRM areas, seven of which are the locations where the infrastructures of the BEWARE Project (Actions C3 and C4) have been already realized.

For each NWRM location, a cross section measuring runoff volumes and flow hydrographs has been implemented in the model, and simulations has been repeated in order to obtain this information.

The investment cost of the realized NWRMs has been used to identify the cost of the 23 additional NWRMs, which are identified as previously described. In particular, with regard to the existing NWRMs, a relationship between investment cost and volume of water runoff managed by each NWRM is calibrated. Data about the volume of water runoff have been obtained directly form the cross sections implemented in the model.

In addition to the initial implementation costs, which are borne only at Year 0, also the average yearly maintenance and operational (M&O) costs has been estimated and included in the analysis. In order to provide a reliable value of M&O costs, we decided to relate them to the size and type of the structure (approximated based on their implementation cost). This decision is supported by preliminary observations of the real costs incurred for the implementation and maintenance of the realized BEWARE structures, and by data reported in literature.

Moreover, the extraordinary maintenance costs - which occur at Year 30 - are also estimated. These costs are needed to ensure the full operativity of the NWRMs after the 30th year. For example, they can include the costs for the replacement of drainage layer in infiltration trenches, substrate and vegetation in rain gardens, or waterproof geomembrane in retention ponds. In this study, the value of the extraordinary maintenance costs has been considered equal to the 20% of the investment cost. This value has been obtained comparing the estimated extraordinary maintenance costs of the seven structures realized by the project BEWARE (Actions C3 and C4) with their implementation cost (20 % is the mean percentage of the ratio observed for the seven structures).

Finally, simulations have been repeated in order to analyse the effect of the identified 30 NWRMs structures on the surface flow characteristics. Considering the results of the hydrological monitoring carried out on the realized structures (Action D1), we decided to considers the structures able to manage all the water runoff intercepted and generated by rainfall events with RPs of 2, 5, and 30 years. As a consequence, the hypothesized structures have been implemented in the model using outflow elements at the structure locations (assumption of an optimal functioning of the NWRMs). The results of this simulations run have been used to evaluate the flood protection benefits of NWRMs as described in section 3.1.4.

3.1.3 Climate change scenario

To improve the assessment of future rainfall events in terms of frequency of occurrence and their magnitude, we developed a future scenario that includes the effect of climate change, since it is well recognized in literature that intense rainfalls are expected to increase in frequency (Gobiet et al, 2014; Beniston et al., 2011). At this purpose, we analyzed the yearly maximum rainfall height for the duration of 1 hour. Data have been recorded by the meteorological station located in Monte Summano, 2.5 km Northern from the Libertà square of the municipality of Santorso. The time period under analysis is 1987 – 2020 for a total of 30 observations. Plotting the precipitation height referred to the year of occurrence it is possible to notice an increasing linear trend (Figure 5). The coefficient of the linear model indicates that on average there is an increase of 0.53 mm per year in terms of the most yearly severe precipitation observed. To predict the increase in frequency and magnitude in a future climate-change scenario (time period 2021 – 2050), we derived the mean and the standard deviation of the historical series, respectively equal to 41.2 mm and 16.5 mm. We then generated a normal distributed random sample using the historical series parameters. The values of precipitation referred to the period 2021 – 2050 have been increased in accordance with the fitted linear model (Figure 5).

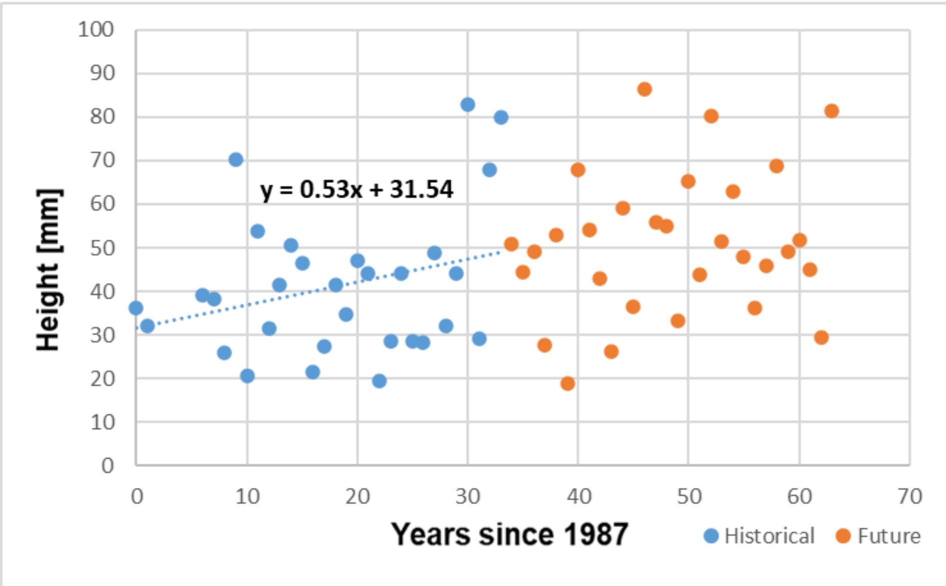


Figure 5: Scatterplot of the yearly maximum rainfall events of the duration of 1 hour referred to the historical series (years 1987 – 2020) and the future one (2021 – 2050).

To better appreciate the increase in frequency of the intense rainfall events, we separately analyzed the two rainfall series, adopting the EV1-Gumbel probability distribution. The analysis reported the decrease of the return period in the future series, compared with the historical one. In particular the distinctive current rain depths, associated to RPs of 2, 5 and 30 years decreased in the future series to 1.31, 3.08 and 22.39 years respectively.

Regarding the possible increase in the frequency and the duration of the drought events, due to climate change, we based on the results of two reports provided by ARPAV. The first is entitled "Studio della siccita' in Veneto negli anni 1961-2004: SPI (standardized precipitation index)" (Cacciatori et al.,2005). In the document, the authors investigated the Standardized Precipitation Index (SPI) values of the period 1961 – 2004 for 20 meteorological stations located in the Veneto region. In particular, they selected the events having a SPI < -1 (threshold value between moderate and incipient drought, estimated in a RP of 5 – 7 years). Considering the weather station "Turcati" (which is located 16.5 km Eastern from the Libertà square in the municipality of Santorso), no significant trend regarding the increase or decrease in frequency of drought events is observed in the period 1961 – 2004. The second document entitled "Considerazioni sul regime pluviometrico e sulla frequenza di accadimento degli eventi siccitosi in Veneto" written by Fabio Zecchini (ARPAV agency) analyzed the drought events (also in this case represented by a SPI value lower than -1) in the period 1993 – 2021. Also in this case, there is not a significant trend involving the frequency of drought events. In conclusion we can affirm that the frequency of drought events has not shown a significant increasing or decreasing trend for the area of interest of the project since 1961. Therefore, in the climate change scenario, we decide not to consider any trends for the drought frequency.

3.1.4 Assessing unit benefits

3.1.4.1 Pluvial flood-related avoided costs

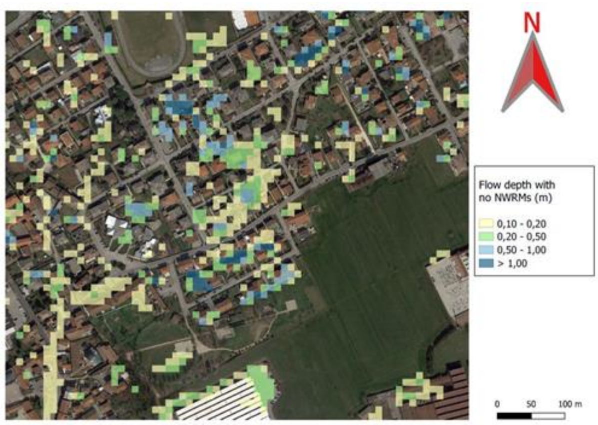
Flood protection benefits represent the most important benefits delivered by the NWRMs implemented by the BEWARE Project. This is quite common for this type of interventions (Bianchini and Hewage, 2012).

To assess the flood protection benefits - expressed as avoided damage, hence avoided restoration costs - the following strategy is implemented. By analysing the runoff water raster maps and comparing the two situations (i.e., with and without NWRMs), the buildings that experience a significant reduction in the flow depth level are first identified. Then, we compute benefits as differences between damage in the two situations according to their main characteristics. This procedure is repeated for each different RP, considering both the current scenario and the climate change one.

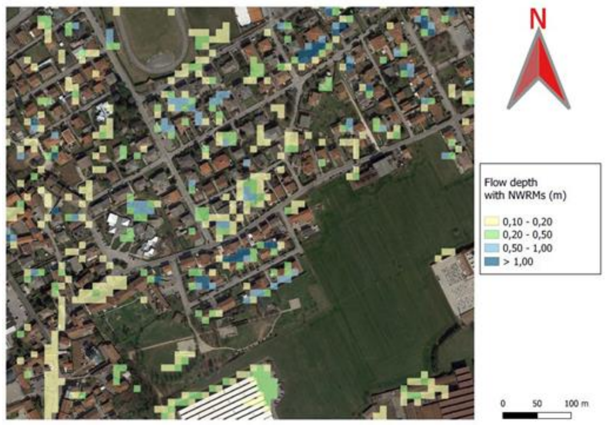
Flow depth variation and buildings' location

First, the raster maps returned by the hydrological-hydraulic simulations and showing the flow depth of runoff water are analysed: they return both the flooded areas and the flow depth registered in each cell of the computational domain. Different pluvial flood maps are processed for rainfall events with different RPs (i.e., 2, 5, and 30 years) in order to compare the baseline situation with no NWRMs and the one with the NWRMs. Figure 6 provides an example of such a comparison: the case without NWRMs is shown in Figure 6a, while the case with the NWRMs is shown in Figure 6b. As expected, the implementation of the NWRMs leads to a reduction of the flow depth, especially in the areas downstream of each NWRM. Figure 6c shows the differences in the flow depth in each cell of the showed portion of the computational domain: the highlighted pixels are the areas where the benefits represented by the pluvial flood-related avoided costs are expected to concentrate.

a)



b)



c)

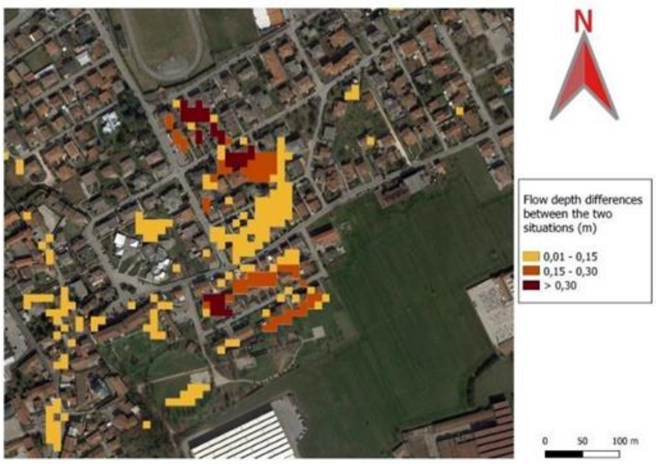


Figure 6: Outcome of the 30-years RP simulation model in an urban area of Marano Vicentino: a) baseline situation (no NWRMs); b) situation with NWRMs; c) difference in the flow depth comparing the two cases.

To quantify these benefits, the territorial allocation of these areas must be analysed together with the location of the existing buildings in the two municipalities. To this extent, we consider the digital regional technical map (CTRN 1:5000) published by the geoportal of the Veneto Region (https://idt2.regione.veneto.it/), and in particular the shapefile for all the existing buildings. The shapefiles for the two municipalities under analysis have been uploaded into the free and open-source application QGIS (https://www.qgis.org/en/site/) and they have been superimposed onto the raster file showing the differences in the runoff water flow depths after the implementation of the NWRMs. Considering jointly the two layers, it is possible to associate existing buildings with the reduction of the runoff water flow depth (represented by the underlying cells of the raster file). Thus, this set of buildings represents those showing a change in the water runoff flow depth (Figure 7). In particular, each building is assigned the maximum value of the reduction of the runoff water flow depth. Thanks to this choice, it is possible to remove from the set of the buildings those with a difference in the runoff water flow depth of less than 1 centimetre.

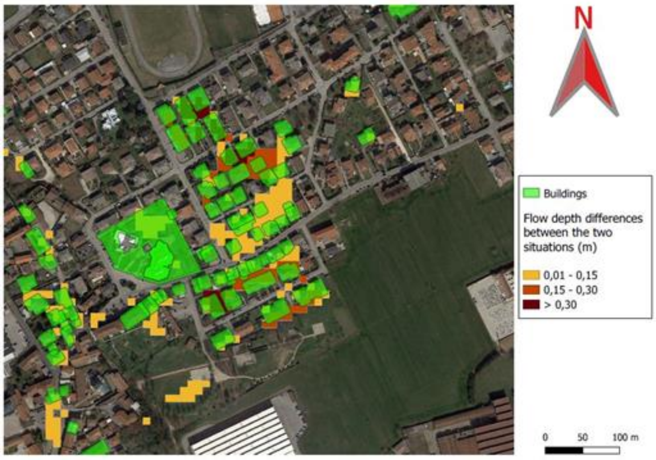


Figure 7: Superimposition of the shapefile with the existing buildings and the differences in flow depth of the runoff water

This procedure was carried out for the rainfall events associated to each different RP (2-, 5-, and 30-years) and for every case, the baseline situation with no NWRMs and the one with the NWRMs are compared.

Buildings classification

We consider that the pluvial flood-related avoided costs largely vary across different buildings. As main parameters to quantify these differences, in this analysis we take into account: the type of building, its land surface, and the reduction of the flow depth.

First, using the shapefile provided by the Veneto Region, residential buildings have been distinguished from public buildings (i.e., schools and hospitals) and from production facilities. However, the regional database only provides scarce pieces of information about the characteristics of the existing buildings. Thus, an exploratory survey has been carried out directly in the two municipalities, in order to identify the different types of existing buildings, and to eventually group them into relatively homogeneous areas. More in detail, residential buildings have been classified into four sub-groups:

- large detached houses (with gardens/private land);
- terraced houses and/or semi-detached houses;
- small blocks of flats/small condominiums;
- residential buildings located in the historic city centres.

In addition, given the purposes of the analysis, those residential buildings with shops or commercial activities located on the ground floor were disentangled as well.

Such a classification is important to assign each type of building an average number of households living in at the ground floor, as well as an average number of garages and basements, according to the average land surface of each building.

Defining flood damage functions

The dataset for carrying out the benefit-cost analysis has been obtained by merging the information provided by the shapefile of the existing buildings with the one provided by the simulation models about flooded areas and flow depth (in the baseline situation and in the one with implemented NWRMs, for each RP under analysis here, i.e., 2-, 5-, and 30-years) and the building shapefile. Given that the avoided damage in each building is a key component of the benefit-cost analysis, the reduction of the flow depth due to the NWRMs implementation is crucial. To this regard, we prudentially assume no damage occurrence under a 10-cm threshold. This choice is also due to the fact that sump pumps are largely diffused in the two municipalities' buildings (see the "Report about ex-ante flood-related damage evaluation"). Similarly, if the flow depth is still higher than 50 cm in the NWRMs implementation situation, irrespective of any reduction, we consider no benefits (i.e., no damage avoidance). So, the adopted damage function actually ranges from 10 to 50 cm. In this range, three-step damage functions are implemented. Each of them depends on the type of building, its characteristics, and its surface.

The unit damage estimates for each building component (e.g., garages, basements, holdings at the ground floor) are valued in terms of restoration costs and are based on the surveys carried out by the BEWARE Project (see the previous "Report about ex-ante flood-related damage evaluation", already delivered). The reliability of these estimates has been checked with public information available on the monetary damage claims from private citizens in the Region Veneto (https://www.regione.veneto.it/web/gestioni-commissariali-e-post-emergenze/post-emergenze-normativa). Actually, after an adverse natural event, local governments in Italy can issue a public state of emergency (*richiesta di stato di emergenza*, according to the Italian regulation), and those citizens who have suffered damage to their properties may claim for a public compensation.

3.1.4.2 Benefits to agricultural production in case of drought

Among the pilot interventions implemented by the BEWARE project, a Water Retention Basin (WRB) was created in a farmland area in 2019. Being installed on a private agricultural plot, it retains up to 2,500 m^3 of water and it is connected to the secondary water network managed by Consorzio di Bonifica Alta Pianura Veneta. According to the purposes of the BEWARE Project, the WRB mostly supply additional water for agricultural needs, especially during summer time and drought periods, and contributes to the reduction of the peak discharge during extreme rainfalls events.

Actually, the Altovicentino area not only suffers from heavy and concentrated rainfall (Sofia et al., 2017): it has also experienced a large number of drought events and heat spells (Bonzanigo et al., 2016), even if a significant trend is not identifiable as described in Section 3.1.3. Considering the latest 20 years, several drought events occurred. In particular, year 2003 was a very dry year: according to the ARPAV data, during the warm season of that year, rainfall amount did not exceed 150 mm, showing a rainfall deficit equal to 50-60% in comparison to the rainfall amount in an average year (source: https://www.arpa.veneto.it/temi-ambientali/climatologia/dati/meteo-estate-2003).

In order to assess the positive impact of the WRB in reducing the negative effects of drought on agricultural production, an ad-hoc survey was administered to the agricultural holdings directly benefitting from the WRB. In March 2021, a semi-structured questionnaire was administered to both the owner of the plot in which the WRB was created and to two neighbouring agricultural holders who can also take advantage from it. The questionnaire is aimed at pointing out the structural characteristics of these holdings, considering both the agricultural area managed by the agricultural holding (disentangling each type of production) and the average yield. In addition, the average price of each product was retrieved from ISMEA (http://assincampo.ismea.it/) and RICA (https://rica.crea.gov.it). The questionnaire and the following analysis prudentially focus only on the average losses suffered by the agricultural holdings in case of a severe drought event (e.g., the one suffered in 2003) (see Annex 1).

Due to the characteristics of the WRB, which allows more frequent irrigation activities than the ones allowed by the average irrigation shift, we consider the positive impact of the stored water during the growing season not in terms of increasing the average yields but rather as a tool to make the yields stable, with irrigation activity being more in line with the production needs.

Thus, as an additional benefit from the WRB, we consider the reduction of agricultural production's economic losses caused by a severe drought, with a 20-years RP.

3.1.4.3 Drinkable water saving

In addition to the benefits directly related to pluvial flood (and similarly to the benefits related to drought periods), it can be noticed that installing NWRMs such as rainwater collection tanks in the two municipalities makes it possible to generate a reserve of water to replace the use of drinkable water for all those private uses that do not require it, such as car washing and watering gardens.

To assess this type of benefits, we estimate the volume of water collected annually from rainwater harvestings and attenuation storage tanks. To do this, we prudentially assume that 5% of the total runoff water managed by all NRWMs implemented in the two municipalities, excluding the WRB, can be saved for private uses. The financial benefit connected with it can be estimated by taking the average cost of drinkable water for private uses. This value is obtained from a direct survey delivered in the two municipalities.

3.1.4.4 Residual value of the NWRMs

Given the time framework of the analysis (i.e., a 30-year calculation period for the analysis), the residual values of the implemented NWRMs are included at the end of the period of analysis. This value reflects the capacity of the remaining service potential after the calculation period (Sartori et al., 2014). The residual value of each NWRMs is expressed net of the extraordinary maintenance cost, occurring at year 30, able to fully restore the initial service potential of the NWRMs.

3.1.5 Benefit-cost analysis

The benefit-cost analysis is carried out considering a 30-year timeframe, according to the European Commission guidelines for water-related projects (Sartori et al., 2014). We assume that the implementation costs are borne at Year 0, whereas any M&O costs as well as all the expected benefits occur at Years 1-30. Moreover, as suggested by the European Union for any investment operations that is co-financed by the European Structural and Investment Funds, a discount rate of 4% is used in this analysis (Reg. (EU) n. 480/2014).

According to the aforementioned parameters, the net present value (NPV) is computed according to the following equation:

$$NPV = \sum_{t=0}^{30} \frac{CF_t}{(1+r)^t} = \sum_{t=0}^{30} \left(\frac{B_t}{(1+r)^t} - \frac{C_t}{(1+r)^t} \right) \quad (1)$$

Where:

CF_t = cash flow at year t;

B_t = values of the benefits, at year t;

C_t = values of the costs, at year t;

r = discount rate (i.e., 4% in this analysis);

t = time in years, from 0 to 30;

According to this equation, the net benefits are summed over the 30-year timeframe. An investment is profitable if the NPV is greater than zero.

The BCR is also suggested as an indicator to show the relationship between the relative costs and the benefits of the implemented interventions. The total cash benefits over the 30-year timeframe are divided by the total cash costs, by taking the net present values of both of them, as shown in the following formula:

$$BCR = \frac{\sum_{t=0}^{30} \left(\frac{B_t}{(1+r)^t} \right)}{\sum_{t=0}^{30} \left(\frac{C_t}{(1+r)^t} \right)} \quad (2)$$

Where, *B, C*, *r*, and *t* are defined as in (1).

If BCR is greater than 1, the interventions under analysis are expected to deliver a positive NPV.

Lastly, the IRR is computed. IRR is defined as the discount rate *d* that makes the NPV of all cash flows equal to zero, such as:

$$0 = NPV = \sum_{t=0}^{30} \frac{CF_t}{(1+d)^t} \quad (3)$$

Where, *CF* and *t* are defined as in (1).

As well known, the IRR provides a discount rate threshold under which the overall discounted benefits delivered by the considered interventions are higher than the overall discounted costs. As a consequence, the IRR decision rule sets that an intervention is financially sustainable when the IRR is greater than the cost of financing it.

In the benefit-cost analysis, the benefits associated to the rainfall events for each different RP, as well as for drought events, are expressed as expected annual avoided damage as a function of the overall avoided damage and the exceedance probability, which is the inverse of the RP. For example, for a pluvial flood with a RP = 5, the expected annual avoided damage in each year in the 30-year timeframe is 1/5 of the overall estimated avoided restoration costs for that RP (Molinari et al., 2021).

We also assume that the total benefits computed in section 3.2 and associated to each return-period situation simultaneously occur, according to the exceedance probability of each pluvial flood event in one single year (i.e., a half, one fifth, and one thirtieth, respectively).[2]

All the analyses about costs and benefits are based on 2019 prices. We have not considered more recent prices, due to the occurrence of exogenous shocks that have affected the following years (i.e., the Covid-19 pandemics and the high inflation rates that have characterised the following periods). It has to be pointed out that, in this specific analysis, the choice of the baseline price level does not radically impact on the BCA indicators, given that the benefits are valued in terms of avoided damages, proxied by the restoration costs. Consequently, the price increase is expected to similarly affect both the costs and the benefits.

3.2 Results of the benefit-cost analysis

3.2.1 Hydrologic-hydraulic simulation results

The main results of the numerical simulations are the flow characteristics at cell of the computational domain. This data can be converted into maps as showed in Figure 8. The main output variable considered in the study is the flow depth at cell at the end of the simulations. As mentioned in the previous sections, this output is used to identify the buildings benefitting of the implementation of NWRMs.

Simulations shows that final flow depth has a mean value equal to 0.27, 0.28, and 0.33 m respectively for the simulation with RPs of 2, 5 and 30 years. The flooded area (here considered as the surface with final flow depth greater than 0.1 m) reached values of 0.79, 1.54, and 2.61 km^2, respectively for the simulation with RPs od 2, 5 and 30 years. The implementation of the NWRMs does not have relevant effects on the mean flow height, which decrease of about 0.01 m in each simulation. However, the most important effect from the implementation of NWRMs involves the flooded area extension. Thanks to their

[2] In the last 10 years, from 2010 to 2019, pluvial flood events causing damage have occurred with very different RPs (see Section 3.1.2).

implementation, flooded areas are reduced by 0.05, 0.12 and 0.26 km^2 respectively for the simulation with RPs of 2, 5 and 30 years.

Figure 8: Map of the final flow depth (m) for the simulation with a RP of 30 years.

3.2.2 Costs of the interventions

Flow hydrographs at NWRMs locations are another important result of the numerical simulations. As mentioned in section 3.1.2, this data has been used to define the investment cost of the hypothesised structures. The identified relationship between investment cost of the seven actually realized structures (Action C3 and C4) and volume of water runoff managed by the intervention (defined by the simulations) is showed in Figure 9. Knowing the runoff volume at each NWRMs cross section, the relationship has been used to identify the costs of the additional23 hypothesised structures.

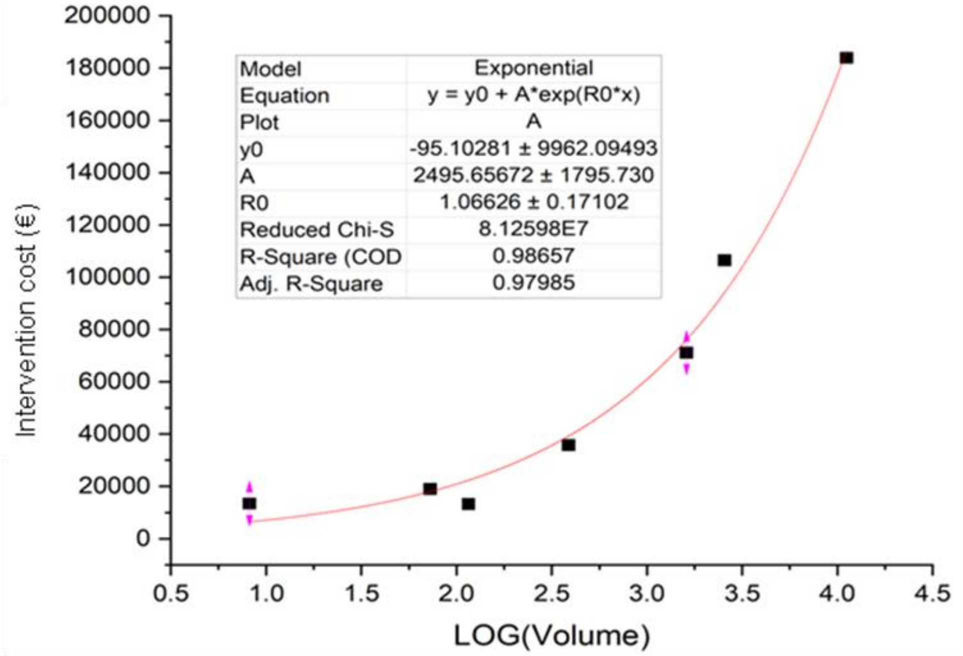


Figure: 9 Relationship between investment cost and volume (cubic metres) of water runoff managed by the structure, identified through a regression analysis of the data obtained by the seven actually realized structures (Action C3 and C4).

3.2.3 Benefit-costs analysis appraisal under the current scenario

According to the results of the hydrological-hydraulic simulation models, we assume the implementation of 23 NWRMs in addition to those implemented as pilot interventions by the BEWARE Project (30 interventions in total). The benefit-cost analysis is implemented on a reference period of 30-years.

The total implementation cost for these interventions, at Year 0, is equal to € 2,1 million. In addition, M&O costs are borne from Year 1 to Year 30 (€ 70,204 each year).

Regarding the benefits, pluvial flood-related avoided costs, benefits in case of drought, and water saving benefits occur every year, from year 1 to year 30. Table 3 shows the overall pluvial flood-related avoided costs by type of premises (garages, residential apartments, industrial buildings & shops, and public buildings) and by RP. An upward trend in the benefits is generally observed as the RP increases. This highlights that the assessed benefits are higher, the longer the RP, which is related to more relevant pluvial flood events, albeit less frequent, with only a few exceptions (e.g., for industrial buildings & shops in the case of the 30-year RP events).

Table 3: Pluvial flood-related avoided costs, for the different return-period cases, by type of premises (in thousand €)

	Underground garages	Residential apartments	Industrial buildings & shops	Public buildings	Total
2 year RP	79.20	228.50	12.00	3.60	323.30
5 year RP	156.20	585.00	22.45	7.20	770.85
30 year RP	278.85	946.00	2.65	37.00	1,264.50

In the benefit-cost analysis, the total values shown in Table 3 are assigned to each year, according to the exceedance probability of a pluvial flood event in one single year, i.e., by taking the inverse of the RP itself. Accordingly, each year the pluvial flood-related avoided costs amount to €161,500 for the events with RP of 2 years; to € 154,200 for the events with RP of 5 years, and to € 42,167 for the events with RP of 30 years. The values to be included in the benefit-cost analysis represent the yearly average of the pluvial flood-related avoided costs: as we take the inverse of the RP (1/RP), for longer RPs these values are smaller.

In the case of the benefits to agricultural production during dry periods (see Annex 1 for details on the results of the survey), we consider one twentieth of the total benefits, i.e., € 12,559 each year.

Lastly, overall drinkable water savings (considering the 2-, 5-, and 30-year RPs) contributes to the total benefits with € 1,338 each year.

As an additional benefit, which only occurs at year 30, we consider the residual value of the NWRMs. This is obtained by considering an extraordinary maintenance intervention (whose cost is equal to €376,243) that brings the NWRMs back into full operation. Thus, we can estimate a residual value for the NWRMs equal to € 1,749,585, as an additional benefit of the project, at year 30.

Table 4 shows the cost and the benefit flows by year of occurrence, which are included in the financial benefit-cost analysis, under the current scenario.

Table 4. Costs and benefits flows (in €), by year of occurrence, under the current scenario

	Type	Value (€)	Years of occurrence (time)
Costs	Investments	2,125,828	0
	M&O	70,204	1-30
Benefits	Pluvial flood-related avoided costs, for 2-year RP (yearly average)	161,500	1-30
	Pluvial flood-related avoided costs, for 5-year RP (yearly average)	154,200	1-30
	Pluvial flood-related avoided costs, for 30-year RP (yearly average)	42,167	1-30
	Benefits to agricultural production in case of drought, for 20-year RP (yearly average)	12,559	1-30
	Overall drinkable water saving, for 2-, 5-, and 30-year RP (yearly average)	1,338	1-30
	Residual value	1,749,585	30

Considering all these costs and benefits together, a NPV for this set of interventions can be estimated as being equal to € 3,628,178, assuming a discount rate of 4%. The benefit-cost ratio is 2.30, showing that the overall discounted benefits are more than two times higher than the overall discounted costs. The IRR of the considered interventions is 14,1%, i.e., the overall NWRM interventions are financially sustainable for costs of financing them lower than 14.1%. This result is obtained even under the precautionary assumptions that are made throughout the analysis (e.g., the step damage function, adopted in the assessment of the pluvial flood-related costs). It has to be pointed out that the financial sustainability of the interventions in the study area ignores the occurrence of the other socio-economic co-benefits provided by ecosystem services delivered by the NWRMs (see section 3.2.4).

3.2.4 Benefit-cost analysis appraisal, under climate change scenario

To take climate change into account, a different benefit-cost analysis has been carried out, by changing some of the parameters used to estimate benefits, according to the impact of climate change in the RP of pluvial floods (as shown in sub-section 3.1.3).

In particular, we assume that the three different RPs for pluvial floods are shortened, due to climate change, from 2, 5 and 30 years to 1.31, 3.08, and 22.39 years, respectively (sub-section 3.1.3.). This affects the annual benefits (assigned to each year according to the different exceedance probabilities) with regard to the pluvial flood-related avoided costs and to the drinkable water saving.

Conversely, with regard to the benefits to agricultural production of the NWRMs in case of drought, these do not show changes under the climate change scenario. In the Veneto region, no specific trends have been observed for the main drought indicators for the last 60 years (see section 3.1.3).

Table 5 shows the cost and the benefit flows by year of occurrence, which are included in the financial benefit-cost analysis, under climate change scenario.

Table 5. Costs and benefits flows (in €), by year of occurrence, under climate-change scenario

	Type	***Value (€)***	***Years of occurrence (time)***
Costs	Investments	2,125,828	0
	M&O	70,204	1-30
Benefits	Pluvial flood-related avoided costs, for 2-year RP (yearly average)	246,565	1-30
	Pluvial flood-related avoided costs, for 5-year RP (yearly average)	250,325	1-30
	Pluvial flood-related avoided costs, for 30-year RP (yearly average)	56,498	1-30
	Benefits to agricultural production in case of drought, for 20-year RP (yearly average)	12,559	1-30
	Overall drinkable water saving, for 2-, 5-, and 30-year RP (yearly average)	2,040	1-30
	Residual value	1,749,585	30

Considering all these costs and benefits together, a NPV for this set of interventions can be estimated as being equal to € 7,148,107, assuming a discount rate of 4%. The benefit-cost ratio is 3.52, showing that the overall discounted benefits are more than 3 times higher than the overall discounted costs. The IRR of the considered interventions is 23,4%, i.e., the overall NWRM interventions are financially sustainable for costs of financing them lower than 23.4%. It has to be pointed out that the financial sustainability of the interventions in the study area is higher and higher than under the current scenario, when the impact of climate change is taken into account.

3.2.4. Other socio-economic co-benefits

In addition to the set of direct monetary benefits which have been considered in the benefit-cost analysis, it should be reminded that the implementation of NWRMs can deliver additional social, economic, and environmental benefits (Ruangpan et al., 2020). By referring to the well-consolidated taxonomy of ecosystem services, which distinguishes them in provision, regulating, supporting and cultural services (TEEB, 2011), NWRMs can deliver several of them in all the identified groups. For example, Evans et al. (2022); Ersoy Mirici (2022); Shakya and Ahiablame (2021); Veerkamp et al. (2021); Ruangpan et al. (2020) provide reviews of estimated values for the services delivered by the NWRMs. In particular, the NWRMs considered by the BEWARE project might deliver co-benefits such as:

- provision services:
  - provision of fresh water (already considered in the benefit-cost analysis);
- regulating services:
  - local temperature regulation (thanks to the presence of vegetation and/or water bodies), thus reducing the risk of heat stress during the hot season. While NWRMs are usually expected to reduce the urban heat island effect (Shakya and Ahiablame, 2021), green roofs are expected to deliver even more significant benefit at the building level (Teotónio et al., 2018);
  - air quality and water quality regulation, due to the presence of vegetation that reduces pollutant concentrations both in the air and in the water/soil;
  - carbon sequestration and storage;
  - pollination, also improving biodiversity through animal-mediated pollination;
  - water (and stormwater) regulation, during heavy rainfall events (already considered in the benefit-cost analysis);
  - other services: noise management; biological control;
- supporting services:
  - provision of habitats for animal species, hence favouring the maintenance of genetic diversity, which is usually endangered in widely urbanised areas, strongly affected by the presence of economic activities;
  - supporting nutrient cycling;
- cultural services:
  - recreation services, thanks to the presence of green and blue spaces, that provide possibilities for recreational activities (such as biking, running), hence favouring mental and physical health. This is particularly the case of the larger NWRMs, such as the WRB

in the case of the BEWARE Project, which also favours the creation of new economic opportunities for the farmers involved in their implementation (e.g., touristic services);
- aesthetic appreciation and beautification of the existing urban areas, facilitating contact with natural areas.

All the aforementioned NWRMs services can turn into higher property values, if the market internalises at least some of them (Shakya and Ahiablame, 2021). However, the estimated impacts on property values have not been included in the current benefit-cost analysis, to avoid benefit double-counting errors.

More in general, taking all these benefits together in terms of ecosystem services provision, NWRMs are expected to improve the overall quality of urban life (Ersoy Mirici, 2022). Moreover, these multiple benefits can also help to achieve many of the goals of the 2030 Agenda for Sustainable Development (United Nations, 2015) and of the EU Green Deal (European Commission, 2019). Lastly, Shakya and Ahiablame (2021) also point out the creation of “green jobs” as an additional benefit coming from the NWRMs implementation, linked with both their construction and their maintenance.

4 The role of BEWARE Project in the private citizens involvement

The BEWARE Project also aims to develop information and demonstration activities to increase citizens' awareness and willingness to implement NWRMs on their private properties, as a tool to mitigate the risk of pluvial floods. To achieve this goal, in addition to the pilot interventions realised in the two municipalities, the Project has also promoted additional activities, such as seminars and festivals. Through the administration of a questionnaire and the analysis of its results, the impact of these initiatives has been tested. In particular, the willingness to implement NWRMs by private citizens is assessed, comparing those citizens who took part in the project's activities and those who did not.

4.1 Method: a questionnaire-based survey

The questionnaire was administered from July 2021 to December 2021 – i.e., before the communication of the main NWRMs benefits and costs on the dedicated project website – to citizens living in the Altovicentino area, and favouring a random approach (i.e., to take part into the survey, no specific people's characteristics were required). A mixed method was adopted to administer it (namely, both by telephone/email and in-person). More in detail, the questionnaire aims to address the following topics:

- overall knowledge of the NWRMs promoted by the BEWARE Project;
- awareness of the local citizens about the project, and their active participation to the project's activities;
- citizens' willingness to adopt NWRMs in the near future.

Excluding some incomplete responses, 219 questionnaires were collected and analysed. SPSS 27.0 and R software have been used for data analysis.

4.2 Results

According to the collected responses, the overall knowledge of the BEWARE Project is rather large across the respondents: actually, 63.3% of them are aware of it. Among those who know it, 47.8% personally took part in at least one of the project information activities, 28.3% know it by word-of-mouth or by consulting the Project website, or by seeing the NWRMs realised by the Project as a demonstration activity. Participation into the information and dissemination activities (Table 6) and direct awareness of the different pilot NWRMs (Table 7) are the most important ways to get aware of the Project.

Table 6: Direct participation to the information activities promoted by the project (in %)

Information activities	Respondents (%) *
Seminars	36.2
Festival dell'Acqua	35.5
On-line participatory process	11.6
Municipality "energy front office"	10.1
Scuola dei Beni Comuni	8.7
Teaching activities	6.5
Webinar	5.8
TED Talk	0.7
UniPD master course	0.7

** Percentages are computed out of the number of respondents who know the BEWARE Project (138 respondents)*
Note: sum of the percentages greater than 100%, due to the chance of selecting multiple options.

Table 7: Knowledge of the local NWRMs realised by the Project in the municipalities (in %)

Local NWRMs	Respondents (%) *
Rain garden (Piazza della Libertà, Santorso)	35.5
Filter drains, pervious pavements and rain gardens (Via dei Prati, Santorso)	26.1
Detention basin (via Volti, Santorso)	26.1
Swale and bioretention basin (Collina del Grumo, Santorso)	22.5
Rainwater harvesting and soakaways (Corte Acquasaliente, Santorso)	16.7
Rain gardens and pervious pavements (Elementary school, Marano Vicentino)	16.7

**Percentages are computed out of the number of respondents who know BEWARE Project (138 respondents)*
Note: sum of the percentages greater than 100%, due to the chance of selecting multiple options.

In addition to asking citizens whether they have seen the pilot interventions promoted by the Project in the municipalities, respondents of the survey were also asked to indicate whether or not they know each of the NWRM types implemented by the BEWARE Project, providing also a response on a 5-point Likert scale (1-min to 5-max) on the effect of each NWRM on flood mitigation (Table 8). The share of respondents who do not know the NWRMs under consideration is generally low. Respondents consider most of the types of NWRMs effective in mitigating the effects of floods; in particular, the median value of the Likert scale is equal to 4 (out of 5) for pervious pavements, bioretention systems, infiltration basins, and ponds and wetlands.

Table 8: Knowledge of the specific NWRM types demonstrated by BEWARE Project among the respondents of the 2021 survey

		1) I do not know the intervention (%)	2) I do not know the effect of this intervention (%) (only for people who answered yes to question 1)*	Mean value of the Likert scale (1-min to 5-max effect on flood mitigation) (only for people who answered yes to question 1 and 2)**	Median value of the Likert scale (1-min to 5-max effect on flood mitigation) (only for people who answered yes to question 1 and 2)**	No answer (%)
Grey NWRMs	Rainwater harvesting	7.3	2.3	3.4	3	9.6
	Soakaways	9.1	3.2	3.3	3	11.0
	Pervious pavements	6.4	1.4	3.6	4	11.0
	Filter drains	28.3	11.4	3.3	3	13.2
Green NWRMs	Bioretention systems	7.8	3.7	3.8	4	9.1
	Infiltration basins	11.0	4.1	3.5	4	11.9
	Ponds and wetlands	7.3	2.3	3.5	4	11.0
	Swales	5.9	4.1	3.2	3	11.0
	Green roofs	13.7	11.0	2.7	3	11.9

** only for the respondents who know the intervention*

*** only for the respondents who declared to know the intervention and its effect on flood mitigation.*

In addition, respondents are also asked about another relevant factor that can affect their willingness to adopt NWRMs in the future, namely their past direct experience of flooding in their private properties (23.3% of respondents) and having adopted or not any type of Stormwater Control Measures (SCMs), i.e., including also protective measures, such as sump pumps and flood walls. Overall, 28.3% of respondents have already implemented some protective measures in the past. Table 9 compares adoption rates in the past with respondents' direct experience of flooding. As expected, the number of respondents that have implemented those measures in the past increases largely when considering those directly affected by floods.

Table 9: Percentage of respondents that have implemented Stormwater Control Measures (SCMs) in the past, by flood direct experience

Direct experience / Already adopted	Citizens not affected by flood (%)	Citizens affected by flood (%)
Yes (%)	23.7	49.0
No (%)	76.3	51.0

Pearson's chi-squared test (1, N = 203): 11.661, p < 0.01

With regard to the respondents' willingness to adopt the NWRMs promoted by the BEWARE Project, as a mitigation measure against flood events, several factors can be considered as possible drivers. However, the most important one turned out to be knowledge of the BEWARE Project.

The willingness to adopt NWRMs in the future shows different patterns when comparing those who are familiar with the BEWARE Project and those who are not. Table 10 shows that the knowledge of the project is positively associated with a larger willingness to adopt NWRMs. These results show the effectiveness of the BEWARE project information and dissemination activities in enhancing more proactive behaviours of local citizens in facing the pluvial flood risk. However, it is important to emphasize that getting additional key pieces of information about the NWRMs implemented in the two municipalities through the dedicated project website could generate greater interest in the population, hence increasing their willingness to adopt these types of NWRMs.

Table 10: Willingness to adopt NWRMs, by awareness of the BEWARE Project (% of the respondents)

	Not being aware of BEWARE (%)	Being aware of BEWARE (%)	Overall (%)
Willing to Adopt (%)	26.6	45.1	39.0
Not willing to Adopt (%)	60.9	38.3	45.5
Do not know (%)	12.5	16.5	15.5

Pearson's chi-squared test (2, N = 197): 9.094, p < 0.05

When asking respondents' willingness to implement a specific NWRM among those realised by the BEWARE Project, the results are more scattered. Only 54% of them focused on the adoption of some specific NWRMs. In particular, Table 11 shows that the willingness to implement NWRMs is higher among the respondents who are aware of the BEWARE Project for all the NWRMs demonstrated by the project. However, these shares are statistically significantly larger for bioretention systems and green roofs.

These results confirm the crucial role played by the information and demonstration activities in stimulating diffused and small-scale interventions to prevent pluvial flood damage.

Table 11: Willingness to implement the specific NWRM types demonstrated by BEWARE Project, by awareness of the Project

WTA		Not being aware of BEWARE (%)	Being aware of BEWARE (%)	Chi-square test
Grey NWRMs	Rainwater harvesting	14.1	20.3	1.561
	Pervious pavements	10.9	11.3	0.051
	Soakaways	7.8	12.0	1.075
	Filter drains	1.6	6.8	2.690
Green NWRMs	Bioretention systems	4.7	12.0	3.080 *
	Infiltration basins	4.7	8.3	1.052
	Ponds and wetlands	3.1	7.5	1.700
	Green roofs	0.0	6.8	4.839 **
	Swales	1.6	3.8	0.825

Note: sum of the percentages does not add up to 100%, since each respondent could select more than one option.

Chi-square test, statistically significant at: $**p<0.05$, $*p<0.1$

5 Conclusions

This report has assessed the impact of implementing 30 NWRMs in the two municipalities under analysis (including the seven pilot NWRMs, already realised by the BEWARE Project); these can manage rainfall events up to 30 years of RP. The assessment turns into direct monetary benefits accruing to either private agents or the city itself. In carrying on the benefit-cost analysis, we considered pluvial flood-related avoided costs; benefits to agricultural production in case of droughts; drinkable water saving only, even if other socioeconomic co-benefits are expected to be delivered by the implementation of the NWRMs.

Despite this precautionary choice, the benefit-cost analysis - carried out on a 30-year timeframe, adopting a 4% discount rate - returns a NPV for the implementation of all these NWRMs which is greater than € 3 million. This means that the NWRMs discounted benefits are much greater than the discounted implementation and M&O costs. Moreover, the assessed IRR (larger than 14%) points out that the implementation of the NWRMs is financially sustainable even under a higher-interest rate scenario, such as the one that is going to characterise the following years. In addition, the positive NPV of the NWRMs implementation is almost two times larger under a climate-change scenario: actually, RPs of pluvial floods are projected to become shorter, hence magnifying the amount of the pluvial flood-related avoided costs every year.

In more general terms, this analysis points out that adopting diffuse small-scale interventions implemented by private citizens and local administrations may have important spillover benefits to cope with the effects of pluvial floods. Taken individually, it may seem that each NWRM has little impact; however, taken together, they represent important tools to runoff water management. Thus, expanding their implementations across the local population represents a crucial issue. Unfortunately, the poor knowledge of the NWRMs among private citizens – but also among local practitioners – dramatically limits their implementation, especially across Southern Europe and in Italy.

To this respect, the role of a dissemination project, such as the LIFE BEWARE Project, is pivotal in enhancing local citizens' awareness of the NWRMs, hence their willingness to adopt them. In particular, the BEWARE project has carried out several information and dissemination activities (e.g., seminars, festivals, and course units), to which participation has been generally large, despite the Covid-19 pandemics. In this report, we stressed the key role played by these activities in increasing the willingness of local citizens to adopt NWRMs, confirming the idea that the main barrier that hinders NWRMs implementation is not financial but rather linked to knowledge issues.

More in general, acknowledging the existence of such a knowledge barrier points out the importance of the activities promoted by public institutions in order to increase people's awareness. To this regard, public information provision should target not only private citizens, but also practitioners. With regard to both target groups, the BEWARE Project has obtained important results. With regard to information provision to practitioners, the impact of the actions devoted to them (e.g., seminars and teaching activities) has been large (for details, see the Final report of the LIFE BEWARE project, to be delivered at the end of the project). Moreover, with regard to information provision to the local citizens, in addition to the demonstration interventions and the several dissemination activities, the Project has also published a interactive utility aimed at disseminating the costs and the benefits of the suggested NWRMs (available at the following link: http://147.162.136.168/lifebeware/). It is true that other similar demonstration tools already exist. However, they refer to different contexts which markedly differ from the Italian and the Southern Europe context. Rather, it seems of utmost importance the implementation of site-specific tools, which directly target the local Italian context.

6 References

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7 Annex: the farmers' survey

To quantify the benefits of implementing the WRB in an agricultural area, an ad-hoc survey was administered to three agricultural holdings that directly benefit from it. These are large farms, in comparison with the regional average: on average, more than 10 ha. of utilised agricultural area each, compared to 6.4 hectares (Istat, 2010)[3]. Each of these holdings can be considered as highly-specialised and high-income. One of them is a livestock farm (with 27 cows, producing milk mostly delivered to a local cooperative dairy), which also manages 21 hectares of permanent meadows and 6 hectares of cereals, to feed its animals. The remaining two farmers are mostly oriented to crops and horticulture production, producing also organic products: they grow cereals (wheat and maize), horticultural crops (e.g., potatoes, beans, carrots), and fruits (apples, apricots, peaches). Both are highly-specialised holdings. In particular, one of them allocates one hectare of the utilised agricultural area to the production of a high-quality maize (i.e., "Mais Marano"[4]), which is personally transformed into polenta flour, directly sold to the local customers in a local shop.

With regard to the irrigation systems, all these agricultural holdings are connected to the water network managed by Consorzio di Bonifica Alta Pianura Veneta. Generally, the irrigation season lasts from mid-May to the end of August, but it can be extended from early May to the end of September. Water supply is delivered on a rotational basis, i.e., at predetermined intervals or shifts (Zucaro, 2014), which in the Altovicentino area is equal to 8 days. For two of the three surveyed farmers, this shift duration is perceived as a limiting factor for production, for the production of horticulture products and fruits. Thus, farmers have modified their own irrigation systems, adopting sprinkler and other high-efficiency irrigation systems.

In particular, when asked about the damage experienced due to the drought events, the three farmers have referred to the case of a severe drought event, such as the one that occurred in 2003. The impact of drought is large for cereals (on average, maize yields drop by 70%[5]), horticulture and fruit products (on average, fruit yield reduction is equal to -45%/ -50%). With regard to the livestock activities, droughts can have negative impacts as well: actually, in the event of the complete loss of the cereal production, production costs dramatically increase, as the fodder for the animals must be bought on the market.

According to these findings, the negative effects of a severe drought, in terms of economic losses, amount to € 251,180 (i.e., € 83,730, for each of them).

In the benefit-cost analysis, this value is considered as the total benefit delivered by the use of the WRB to the agricultural production in the case of a severe drought event.

[3] The data refers to the average of the agricultural holdings in the hilly and flatland areas of the Veneto Region (Istat, 2010).

[4] This cultivar, named after the city of Marano Vicentino, was firstly selected at the beginning of the 20th century. Its average yield is limited but it is a traditional cultivar, particularly suitable for the transformation into polenta flour.

[5] As a combination of both drought and heat stress, a 100% reduction can be experienced, due to the insurgence of aflatoxins.