AN HOLISTIC APPROACH TO NATURE BASED SOLUTIONS AS A MEANS TO ADAPT TO AND MITIGATE CLIMATE CHANGE INDUCED RISKS: THE CASE STUDY OF SPERCHIOS

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ABSTRACT

The European Commission defines “Nature Based Solutions (NBS) to societal challenges” as solutions that are inspired and supported by nature, are cost-effective, provide environmental, social and economic benefits and help build resilience. (EC, 2016). The concept of NBS has been adopted in the research programme HORIZON 2020 (EC, 2015), as well as in the OPERANDUM principles, aiming to provide science-based evidence for the usability of NBS, ranging from local to landscape scales, and foster the market opportunities, upscaling and replicating in Europe and Worldwide. NBS is a complex process of nature that requires a range of methods and tools aligned with all possible procedures such as co-design, implementation, evaluation and monitoring, policies and regulations.
***Keywords*:** NBS, Climate Change, Hydro-Meteorological Risk, Co-Design

ΜΙΑ ΟΛΙΣΤΙΚΗ ΠΡΟΣΕΓΓΙΣΗ ΤΩΝ ΦΥΣΙΚΩΝ ΛΥΣΕΩΝ ΩΣ ΜΈΣΟ ΠΡΟΣΑΡΜΟΓΗΣ ΚΑΙ ΜΕΤΡΙΑΣΜΟΥ ΤΩΝ ΚΙΝΔΥΝΩΝ ΤΗΣ ΚΛΙΜΑΤΙΚΗΣ ΑΛΛΑΓΗΣ: Η ΠΕΡΙΠΤΩΣΗ ΤΟΥ ΣΠΕΡΧΕΙΟΥ

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ΠΕΡΙΛΗΨΗ

Η Ευρωπαϊκή Επιτροπή ορίζει ως «Φυσικές Λύσεις, προσανατολισμένες στις κοινωνικές προκλήσεις», τις λύσεις που εμπνέονται και υποστηρίζονται από τη φύση, οι οποίες είναι οικονομικά αποδοτικές, παρέχουν περιβαλλοντικά, κοινωνικά και οικονομικά οφέλη και επιπλέον βοηθούν στην οικοδόμηση ανθεκτικότητας. (EC, 2016). Η έννοια των Φυσικών Λύσεων ενσωματώθηκε στο ερευνητικό πρόγραμμα HORIZON 2020 (EC, 2015), όπως επίσης και στην φιλοσοφία του OPERANDUM, με στόχο την παροχή επιστημονικής γνώσης που θα ενδυναμώσει τη χρήση των Φυσικών Λύσεων, από το τοπικό έως μεγαλύτερης κλίμακας τοπίο, την προώθηση νέων ευκαιριών στην αγορά και την αναβάθμιση και αναπαραγωγή τους στην Ευρώπη και παγκοσμίως. Οι Φυσικές Λύσεις (NBS) είναι μια σύνθετη διαδικασία η οποία μιμείται τη φύση και απαιτεί μια σειρά από μεθόδους και εργαλεία ευθυγραμμισμένα με όλες τις διαδικασίες όπως τον από κοινού σχεδιασμό, την υλοποίηση, αξιολόγηση και την παρακολούθηση, τις πολιτικές και τη νομοθεσία.

Λέξεις κλειδιά: Φυσικές Λύσεις, Κλιματική Αλλαγή, Διακινδύνευση, Από κοινού σχεδιασμός

1. INTRODUCTION

Extreme hydro-meteorological events such as heavy rainfall, flooding, drought, storm surge, leaching of suspended solids and nutrients have high negative impacts on ecosystems and man-made infrastructures in Europe and worldwide. The frequency of these events is expected to increase in the future due to climate and land use changes, and to further increase the risk of negative impacts. The employment of Nature Based Solutions -NBS- can be used to mitigate the risk of these hydro-meteorological phenomena. The concept of NBS was introduced towards the end of the 2000s by the World Bank (MacKinnon et al., 2008) and International Union for Conservation of Nature (IUCN, 2009) to focus on the importance of biodiversity conservation for climate change mitigation and adaptation.

NBS is a complex process of nature that requires a range of methods and tools aligned with all possible procedures such as design, co-design, implementation, evaluation and monitoring, policies and regulations. Nowadays, an increasing number of NBS projects are being implemented across Europe (EU) and worldwide. The European Commission adopted the concept of NBS for its research programme HORIZON 2020 (EC, 2015) with a defined focus mainly on urban areas. The ambition of OPERANDUM EU (HORIZON 2020) is to provide science-based evidence for the usability of NBS focused on rural areas. Ranging from local to landscape scales, fostering the market opportunities, upscaling and replicating in Europe and other non-European territories, OPERANDUM EU –project fosters a set of co-designed, co- developed, co-deployed, tested and demonstrated innovative NBS for the mitigation of the impacts of extreme weather events. In this paper, the NBS concept will be presented as a holistic approach, which can be used as means to mitigate climate change induced risks and the demanding process needed for the co- design of set up of the potential NBS at the OAL Greece in Spercheios River, will be reported.

2. NBS CONCEPT AND PROCESS AS A MEANS TO MITIGATE AND ADAPT TO SEVERE HYDROMETEOROLOGICAL RISK

NBS has broad definition, constituents and scope, with a broad view on nature and an emphasis on participatory processes in creation and management (Pauleit et al., 2017). Cohen-Shacham et al. (2016) described NBS as an umbrella concept that covers a whole range of ecosystem-related approaches, all of which address societal challenges.

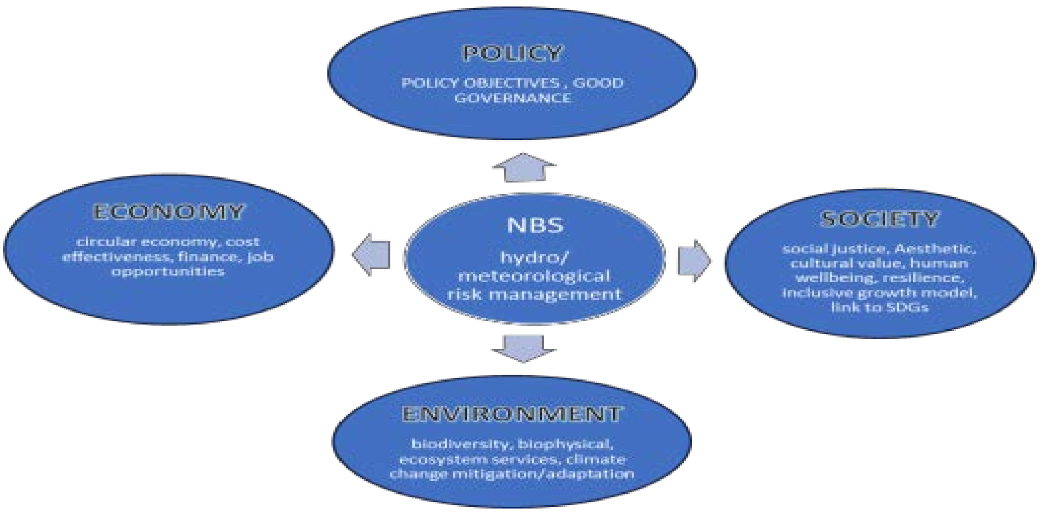


Fig. 1: Schematic overview of multi benefit impacts of NBS for hydro/meteorological risk management

A great range of definitions can be found in the literature. For example, IUCN defines nature-based solutions (NBS) as “actions to protect, sustainably manage and restore natural or modified ecosystems, which address societal challenges (e.g., climate change, food and water security or natural hazards) effectively and adaptively, while simultaneously providing human well-being and biodiversity benefits.” (Cohen-Shacham et al. 2016). The European Commission understands: “… nature-based solutions to societal challenges as solutions that are inspired and supported by nature, which are cost-effective, provide environmental, social and economic benefits and help build resilience. (European Commission, 2016, p. 1). This means that apart from the human (socio-economic) or technical system around the problem, the ecological one should also been considered. As the concept of NBS is defined in many ways, there is confusion, overlapping and partly complement among the definitions; although these relationships are seldom acknowledged explicitly (EC, 2015). However, the availability of many ways to frame and define the concept is not necessarily problematic, as long as each case is explicit in its rationale for particular interpretation of NBS (Nesshöver et al., 2017).

NBS is a complex process of nature that requires a range of methods and tools aligned with all possible procedures such as design, co-design, implementation, evaluation and monitoring, policies and regulations. Thus, in order to set up the implementation of NBS, the research teams have to follow a co-creation process, which combines generative or exploratory research with development design. Co- creation includes four phases:

Co-design: Co-creation starts with co-design, a process where the problem and the target area are identified as well as the stakeholders, their aspirations, shared values or common interests and aims regarding the project and the target area.

Co-development: In this phase, by using the variety of the expertise and knowledge of the group, potential solutions for the problem are jointly developed, with the help of some research if needed.

Co-deployment: In this phase, the solutions are implemented.

Monitoring: Monitoring is an essential part of the co-creation. It can focus on the outputs/outcomes of the processes (NBS) as well as the process itself. It shapes the way the process is structured and resourced, ensuring that it is reflective and adaptive as much as it is generative. Monitoring and associated assessment is also an important element for learning.

The Co- creation process helps the definition of the problem by considering different perspectives and knowledge. Experts from various sectors (diversity of knowledge) engage stakeholders (any person or group who influences or is influenced by the project) to work together(collaborate) throughout all the stages of the life cycle of the project, in a planned and conscious form.

3. SETTING UP NBS AT OPEN AIR LABORATORY: THE CASE STUDY OF OAL GREECE SPERCHIOS RIVER

3.1 The current hydro- meteorological and socio- economic status

Spercheios River Basin which is located in the Region of East Central Greece, has a length of 82 kilometers, an average annual runoff of 0,703 km^3 and is the main feeder of Maliakos Gulf (Skoulikidis, 2009). The steep slopes, which are present within approximately 2/3 of the total length of the river course, form a rather mountainous topography (streamy with crucial flooding peaks and very intense sediment yield). Only in the downstream part of Sperchios course, the topography gradually changes into a lowland relief, with an extent at the river mouth of 1830 km^2. In the last third of the route, Spercheios changes in a lowland river and crosses low areas that are often flooded (Gounaris, 2012). Spercheios has a mean annual water discharge of 62 m³/s, varying between 110 m³/s in January and 22 m³/s in August (Therianos, 1974). Furthermore, the total annual sediment load of the River Sperchios has been estimated to be in excess of 1.5 x 10^6 tonnes/year (Poulos et al., 1997). It is estimated that the total annual loss is 2,850,000 t/y, while the total annual quantity of sediment that arrives in Spercheios delta is of 1,140,080 m^3 (Gounaris, 2012).

The hydro-meteorological and socio-economic indicators below provide background and reference values for understanding the hazards related to extreme hydro- meteorological conditions at the OAL GR.

- **Location in climatic zones and biogeographical regions**

According to Köppen-Geiger climate classification for observed 1976-2000 period, the OAL-Greece (Csa) has warm temperate climate with dry hot summers. Similarly, the western tip of the OAL-Greece belongs to the Csb region. The location of the OAL Greece to the European biogeographical is in Mediterranean region

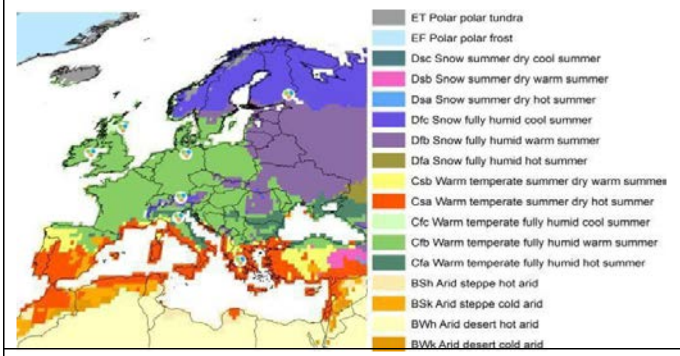


Fig2. Modified from: Rubel and Kottek (2010).

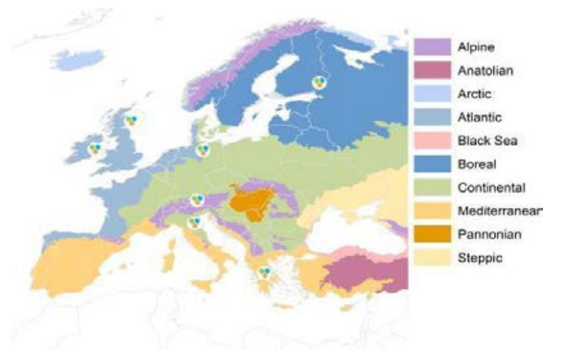
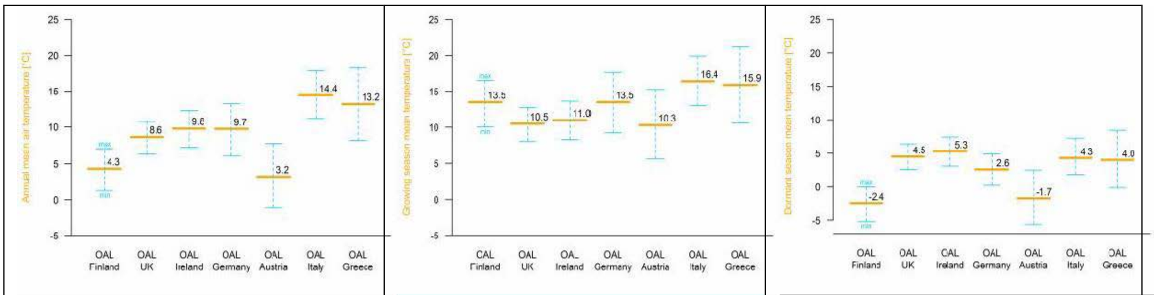


Fig3. Figure modified by using information of the European Environment Agency 2016

- **Current climate at OALs**

The climate of Maliakos Gulf and its surrounding area is a typical Mediterranean climate, with dry periods in summer and early autumn and precipitation mainly in winter and spring.



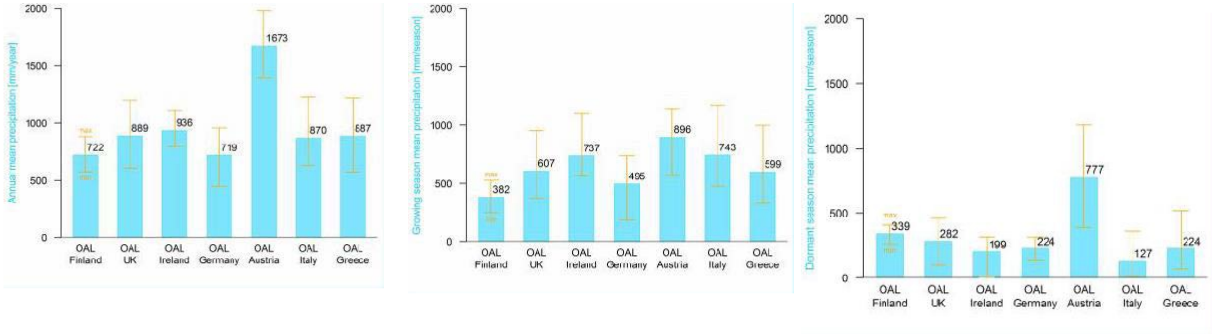


Fig. 5. Mean total annual, growing season and dormant season precipitation at the OALs. The bars indicate minimum and maximum total annual precipitation. (Deliverable D4.2, OPERANDUM 2019)

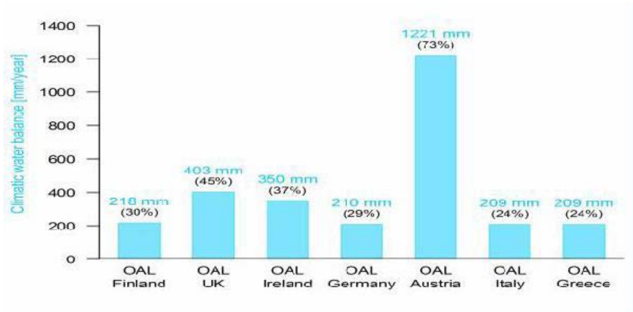
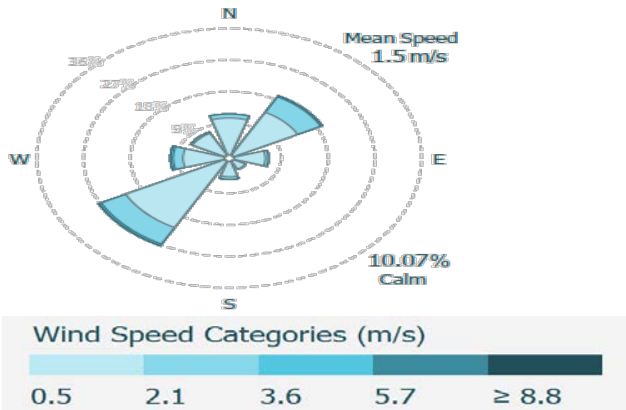


Fig. 6. The mean climatic water balance and the percentage of evapotranspiration out of precipitation at the OAL GR(Deliverable D4.2, OPERANDUM 2019)



The predominant wind components are mostly from the east and west, following the localized east-west trend of the Spercheios valley. Average wind speeds are 1-2,5 m/s for the westerly winds and 2,5-4,5 m/s for those from the east (Poulos et al., 1997a).

Fig. 7. Mean wind speed, frequency of calm winds < 0.5 m/s, and frequency of different wind speeds by direction at the OAL GR (Deliverable D4.2, OPERANDUM 2019)

3.2 Socio-economic status including land use

Land cover and land use are essential for our human life and socio-economic welfare. Both are affected by current and future hydro-meteorological hazards. The current socio- economic structure of the OAL GR is characterized by the following indicator.

- **Area and land cover**

In the OAL-Greece forests and semi-natural areas are the main land cover type and their proportion is higher than the average European cover. at the OAL- Greece the state owns two thirds of the land.

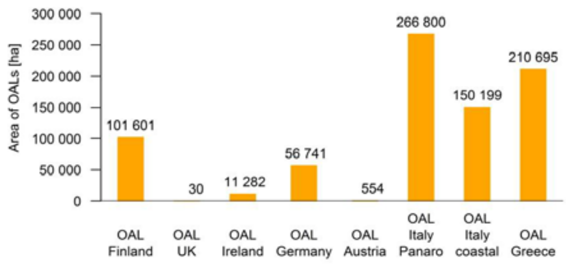


Fig. 9. The land area of the OALs.

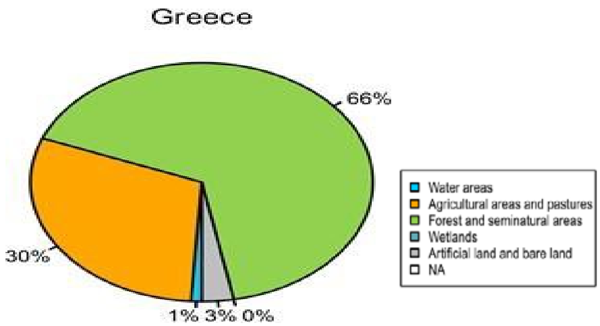


Fig.10. Proportions of different land cover types at the OAL GR according to CORINE.

- **Transportation channels**

In the OAL-Greece, roads exposed to hazards comprise <20% of all roads

- **Number of Inhabitants**

In the OAL-Greece less than 20% of the inhabitants are exposed to the hydro-meteorological hazards. It is important to mention that according to the information gathered from the OALs, hazards have an impact on the feelings of security and on the social relationships of the people living at the OALs

- **Life of people**

Agriculture is the most important means of livelihood in the OAL-Greece even though the forests and semi-natural areas cover larger land area than agricultural areas in those OALs. Services and administration are the second important means of livelihood in the area. Fishery is among the means of the livelihood in the OAL-Greece, although it is not highly important. Finally, recreation and tourism are important too. These activities are mostly related to activities taking place in nature. As a result, recreation and tourism may be affected by the hydro-meteorological hazards. There are different kinds of nature conservation areas and cultural heritage sites, probably used for recreation and tourism, which are exposed to hazards. In the OAL-Greece the proportion of nature conservation areas exposed to hazards is 23%.

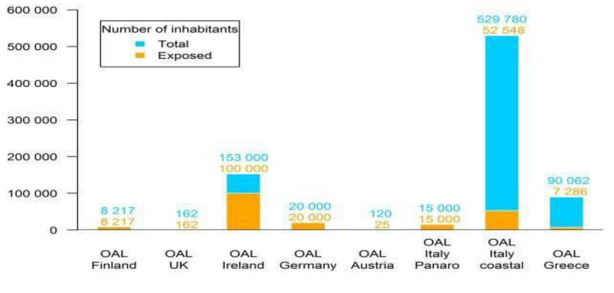


Fig. 11. Total number of inhabitants and the number of inhabitants exposed to hazards at the OALs. (Deliverable D4.2, OPERANDUM 2019)

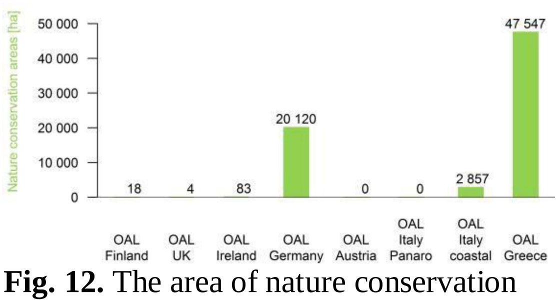


Fig. 12. The area of nature conservation areas exposed to hazards at the OALs. (Deliverable D4.2, OPERANDUM 2019)

3.3 The Current Hydro-Meteorological Hazards and primary risk assessment

The two main hydro-meteorological hazards that OAL Greece identified in the specific area are floods and droughts. In the context of OPERANDUM, the conceptual framework for vulnerability and risk assessment of Socio Economic System was preliminarily developed through review of existing vulnerability and risk assessment frameworks found in scientific literature. Then the framework was further enhanced incorporating stakeholders' priority and needs in OALs which are obtained through Focus Group Discussion and questionnaire survey (Deliverable D6.2, OPERANDUM 2019).

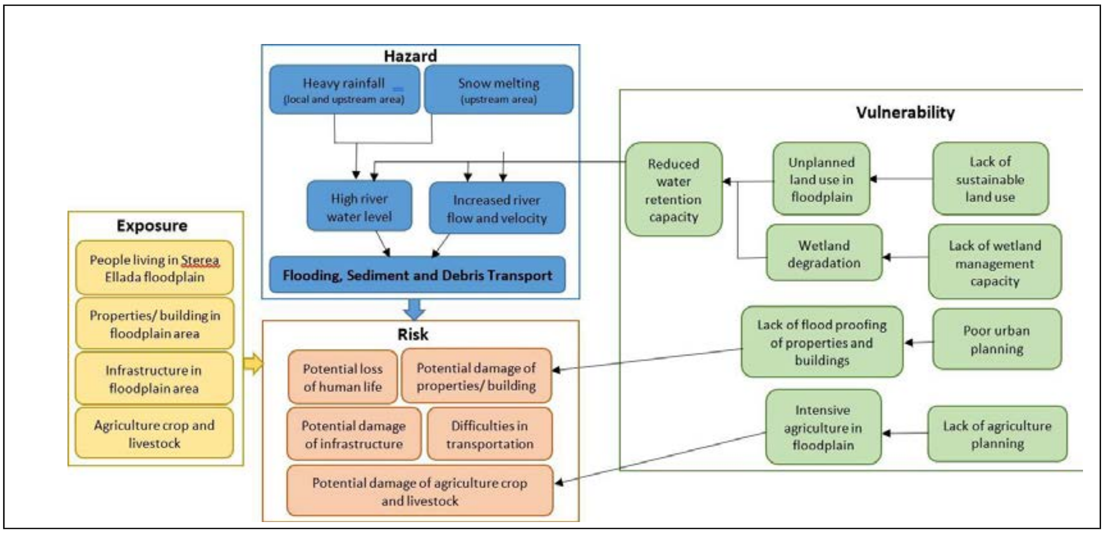


Fig. 13: The impact chain for Sterea Ellada region showing linkage between the hazard, exposure, vulnerability and risk

3.4 The identification of climatic and socio- economic drivers for future hazards

Comprehensive climate change projections will be modelled for OAL GR based on the selected IPCC scenarios

- **Climatic drivers at the OAL-Greece**

As it is mentioned above the OAL-Greece is located in the Mediterranean region, where the air temperatures are predicted to increase especially during summer and autumn seasons and cause hot extremes. Precipitation may decrease especially during summer.

- **Socio economic drivers at the OAL-Greece**

At the OAL-Greece agriculture is the main means of livelihood in the Spercheios River. Possible reduction of agricultural land may occur in the future due to the determination of the management measures of Directive 92/43 /EEC and by the protection of water systems zones, used for water supply. Some indirect pressures on land use are expected due to the restructuring of agricultural production or the imposition of stricter operating rules in production facilities. Regarding the transportation infrastructure, no major change is expected. The reduction of flood events will protect residential and agricultural properties and protect the access roads between the villages and the main city of the area (Lamia). The sense of safety will improve the relationships in the local society and will leverage trust between local community and the State, which owns 3/4 of the land in the OAL area. It will also preserve and enhance the recreational use of the area, including visits by tourists.

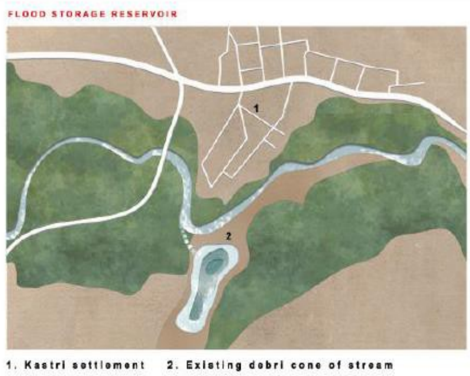
4. RESULTS: THE POTENTIAL NBS TO BE IMPLEMENTED THROUGH CO-DESIGN PROCESS

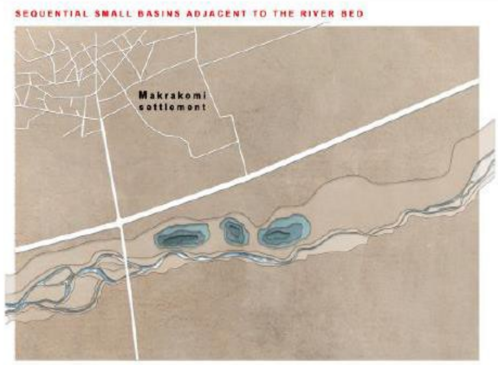
The appropriate NBS solutions to be implemented, have been proposed after following the process of the co-creation framework designed in the process of OPERANDUM. Through the co-design process the research team had explored several NBS options, such as retention ponds, sedimentation ponds, removal of longitudinal barriers, restoration and reconnection of seasonal stream, stream bed re-naturalization, natural bank stabilization and infiltration trenches to mitigate the impact of flooding and drought in Spercheios River. The above potential NBS solutions have been assessed as it is essential for the pilot project to demonstrate the effectiveness of NBS and the positive outcomes of any cost benefit analysis

applied to them. Finally, at this stage of the project, the following solutions are proposed:

A. Construction of Flood Storage Reservoirs (FSR) adjacent to the river

The intervention involves the construction of one or more Flood Storage Reservoirs (FSR), which will be filled with the river water by controlled overtopping along the river during flood events.





The location of the intervention should fulfil the following criteria:_

- ➢ Wide enough area in order to store a significant water volume.
- ➢ Area without vegetation or agricultural use.
- ➢ Proximity to the river to avoid connectivity works. Non-permeable ground, to avoid leakage of the stored water

The advantages of this solution are:

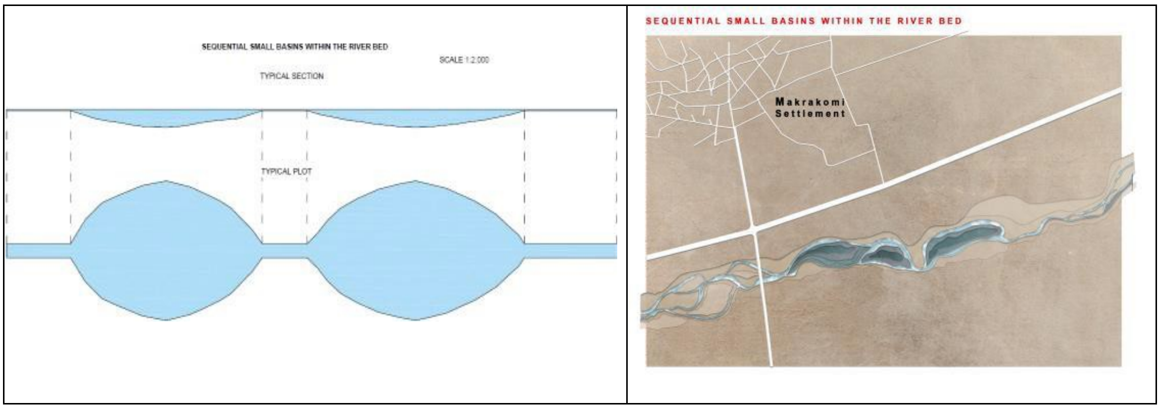
- ✓ Attenuation of the flooding water volume and gradual release downstream, resulting to reduction of velocities and smooth routing of the flood waves during severe events.
- ✓ Lower risk of erosion of the FSR.
- ✓ Longer life span of the intervention.
- ✓ Habitat creation in and around the FSR.
- ✓ Possibility of use for recreational and educational purposes.
- ✓ Easier installation of water level monitoring systems.
- ✓ Lower risk of debris deposition and consequently reduction of the storage capacity.

The hazards associated with this solution are:

➢ Deforestation and change of use of agricultural land.
➢ Reactions from the local inhabitants.
➢ Higher construction cost.

B. Construction of sequential small basins within the river bed

This intervention will be located within the main river, where sequential small basins will be created by widening and deepening the bed in several location. These basins will hold the water until they are full, when it will flow to the next pond.



The advantages of this solution are:

✓ No need for change of use for any of the adjacent land.
✓ No need for deforestation.
✓ Depending on the size of the intervention, significant amount of water can be stored, to be used for irrigation.
✓ Enrichment of the ground water aquifer.
✓ Reduction of high velocities during flood events.
✓ Lower initial financial cost compared to Solutions A and C.

The hazards resulting from this solution are the following:

➢ As no hard structure will be constructed for this solution, the most upstream pond will be filled with sediment and debris, especially during winter and flood events.
➢ The basins' banks will not be protected with hard structures and therefore can be eroded during flood events or by local interventions.
➢ For the efficient operation of the solution, continuous monitoring and restoration will be needed.

C. Use of Spercheios' old river bed

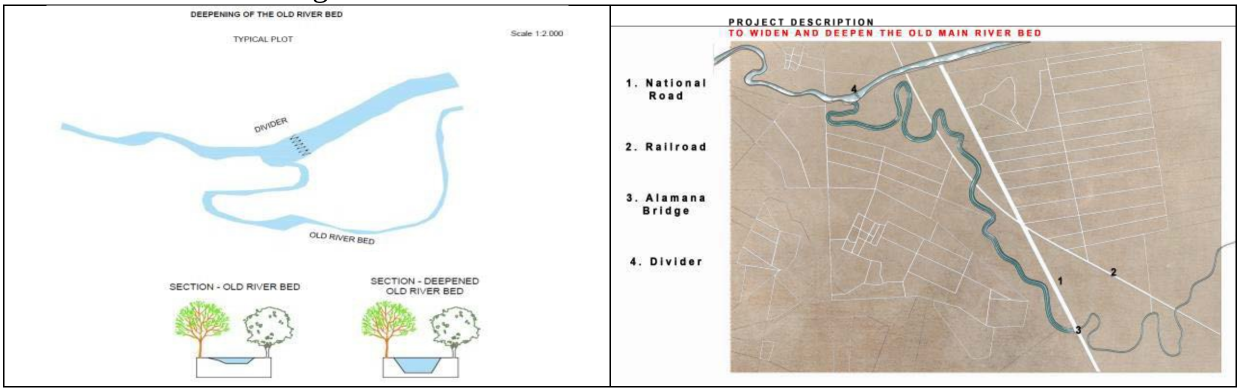
The deepening and widening of the old river bed can increase the stores water volume and provide water for irrigation throughout summer. Moreover, this solution will provide enrichments of the ground water levels.

The merits of this solution are:

✓ No need for change of use for any of the adjacent land.
✓ No need for deforestation.
✓ Depending on the size of the intervention, significant amount of water can be stored, to be used for irrigation. Enrichment of the ground water aquifer.

Lower initial financial cost compared to Solution A. The disadvantages are the following:

- Due to the water velocity reduction, there will be increased possibility of sediment and debris accumulation, especially during flood events. This can change significantly the spatial distribution of the river and the banks and reduce the intervention storage capacity.
- For the efficient operation of the solution, continuous monitoring and restoration will be needed. Due to the fixed location of the intervention, which is downstream of the location of solutions A and B, there is no protection of the upstream areas. Idf this solution is adopted, there should be extensive study of the hazards that can be caused to the upstream areas and especially of the possible water level increase due to blockage of the flow through the intervention.



5. CONCLUSIONS

A growing body of literature and experience supports NBS effectiveness for adaptation and mitigation of hydro-meteorological hazards. Climate change is expected to accentuate hydro-meteorological hazards such as extreme temperature, torrential rains, flooding, droughts, sea level rise and other hydro- meteorological extremes in term of frequency, intensity and magnitude (IPCC, 2018).) Conventional risk mitigation measures, based on engineering structures only, such as dykes, embankments, dams, levees, storm barriers, and sea-walls amongst others, have not provided adequate risk reduction solutions (Bubeck et al. 2015; Day et al. 2007; van Wesenbeeck et al. 2014), nor fit easily into long-term sustainability goals. At the same time, the implementation of purely green infrastructures at the small-scale level for hydro-meteorological risks management, though offering short and long-term benefits, might not be sufficient to meet the scale of predicted future hydro-meteorological hazards (Kabisch et al., 2016). As a best solution, Kabisch et al. (2016)

Nature-based solutions (NBS) have developed in recent years (Bowler et al. 2010; Kabisch et al. 2016; MacKinnon et al. 2008; Rizvi 2014), showing promising results in terms of risk reduction especially in urban areas. The OPERANDUM project aims to reduce hydro-meteorological risks in rural areas through co-designed, co-developed, deployed, tested and demonstrated innovative green and blue/grey/hybrid NBS, and push business exploitation. However, the process is still at early stages. Research will be continued in order to systematically analyse their (long-term) effects, effectiveness for natural hazards (hydro-meteorological risks) reduction and supplying of co-benefits. Moreover, research will be conducted to foster the wider uptake of NBS, measuring the effectiveness and how the existing evidence can be translated into management strategies and when policy instruments are needed.

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