IMPLEMENTATION OF NATURE-BASED SOLUTIONS ON THE ISLAND OF LEFKADA – GREECE

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Abstract

This research work investigates flood risk management on the Greek island of Lefkada. Using the Earth Observation Browser, three subbasins of the island are selected based on the frequency of water mass accumulation, covering areas of 46 km^2, 38 km^2, and 12 km^2 respectively. The hydrological analysis utilizes the Hydrologic Modeling System (HEC-HMS) employing the time-area diagram method for Unit Hydrograph (UH) definition to calculate the flood hydrograph at the outlet of each basin. Two Nature-Based Solutions (NBS) have been implemented in the subbasins to reduce flood risks. Findings show that the land cover changes solution (i.e. replacing areas characterized by sclerophyllous vegetation, sparsely vegetation, mixed forest, transitional woodland-shrub with broad leaved forests) has resulted in a reduction of peak discharge by 20% to 29%, while the retention pond solution has led to a decrease of approximately 4.5% to 5%.

Key words: EO Browser, Hydrological analysis, NBS, land cover change, Lefkada

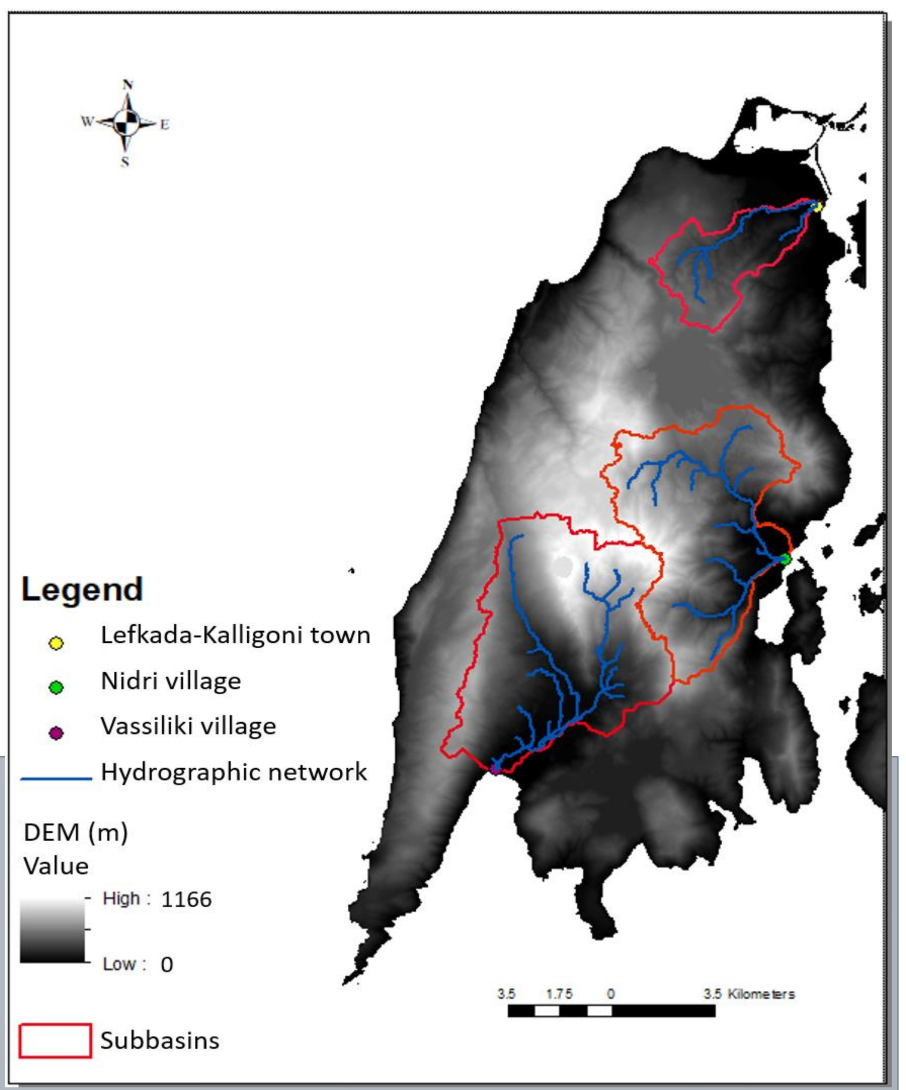
Materials and Methods

Study area

- Vassiliki 46 km^2
- Nydri 38 km^2
- Lefkada-Kalligoni 12 km^2

Data used

- *Polygon layer:* CORINE Land Cover (2018)
- *Raster:* DEM (digital elevation model)
- *Point Layer:* rainfall Intensity-Duration-Frequency (IDF) curves



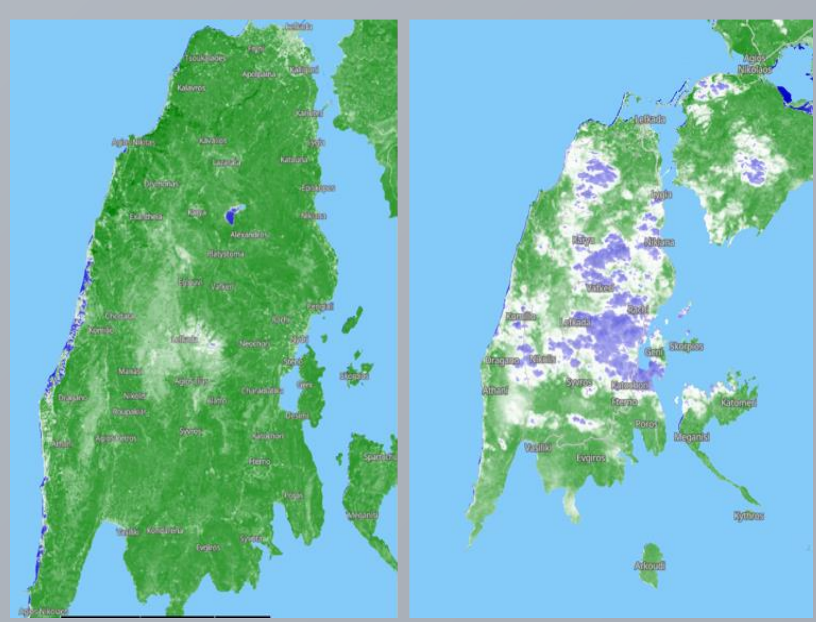
Methodological Framework

❑ Pilot survey using Earth Observation Browser

- ESA's Sentinel satellites, part of the Copernicus program, allow public observation of Earth.
- In order to monitor the flood and drought in the study area, years 2021 and 2022 are selected.
- For each month of the year, satellite data are visualized considering less than 50% cloud cover.
- This percentage cap ensures that water mass readings remain clear, as higher cloud cover makes them indiscernible.
- The bodies of water are depicted in deep blue, the urban tissue in white, while in green vegetation and areas in which no accumulation of water has been observed on the visualized day.

Analyzing the survey results revealed that Lefkada-Kalligoni, Nydri, and Vassiliki are the subbasins most prone to frequent water accumulation.

Screenshot of the water visualization with 0.9% cloud cover (left) and 48.5% cloud cover (right) (source: EO Browser)



❑ Hydrological Analysis

Identification of geomorphological features of the subbasins through GIS processes → Determination of design precipitation for return periods T=100 years → Distribution of rainfall depths, P, and calculation of the design rainfall hyetograph according to the Alternating Block Method → Selection of Snyder Synthetic Unit Hydrograph method for the transformation of rainfall to runoff → *Computation of precipitation losses using the Soil Conservation Service (SCS) Curve Number (CN) method* → HEC-HMS simulation → Determination of flood hydrographs for the three subbasins

SUBBASIN	AREA (km^2)	CN	CN AFTER NBS
Vassiliki	46	78	70
Nydri	38	76	69
Kalligoni-Lefkada	12	75	65

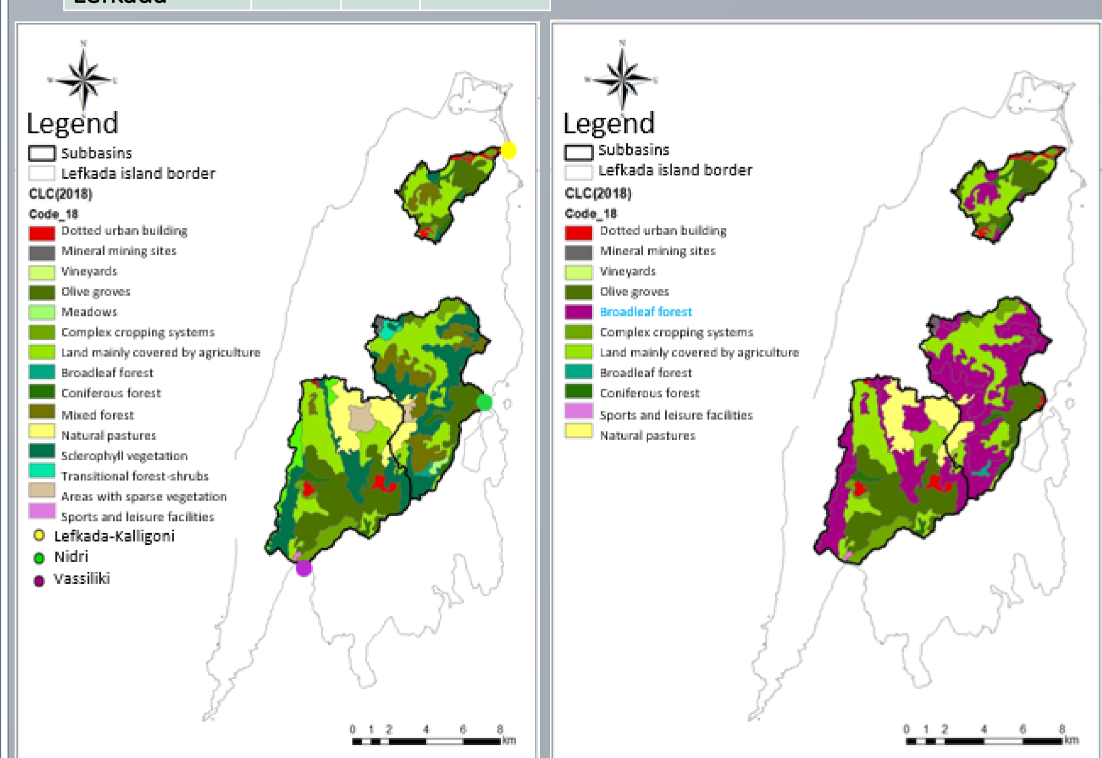
❑ Implementation of Nature-Based Solutions (NBS)

➢ Land cover changes (NBS1)

- Unutilized land cover areas in three subbasins are identified for conversion to broadleaved forests.
- The land cover change is expressed through the alteration of the CN, whose value is reduced according to the changes corresponding to each subbasin.

➢ Construction of retention ponds (NBS2)

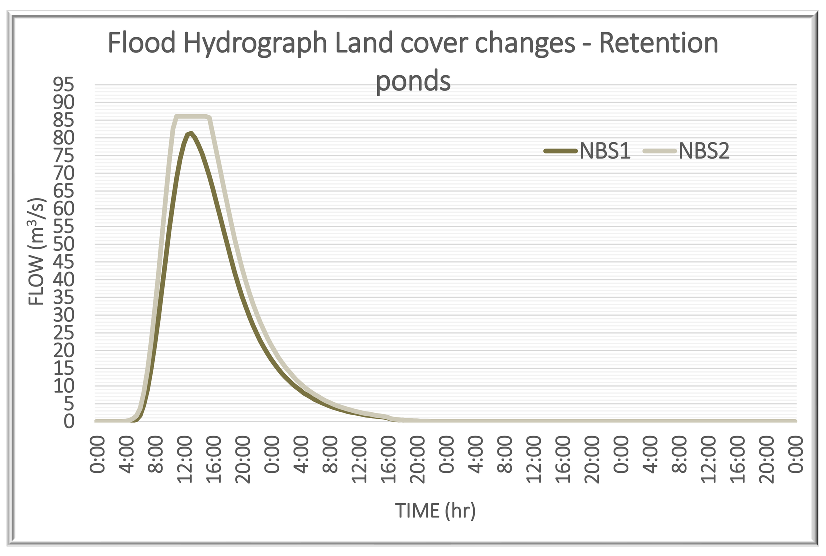
- The design ensures that they retain water for 14 to 21 days until it naturally drains through the soil.
- Retention ponds are planned along the main flow paths within unused land areas of the subbasins, designed for worst-case scenarios with a 100-year return period to manage peak discharges.
- It is expected to reduce total flood volumes by 5% in each subbasin's main watercourse.
- To limit environmental and financial impacts, these ponds will have a working depth of 2 meters, minimizing excavation needs.
- Elliptical ponds covering 3000 m² are proposed.



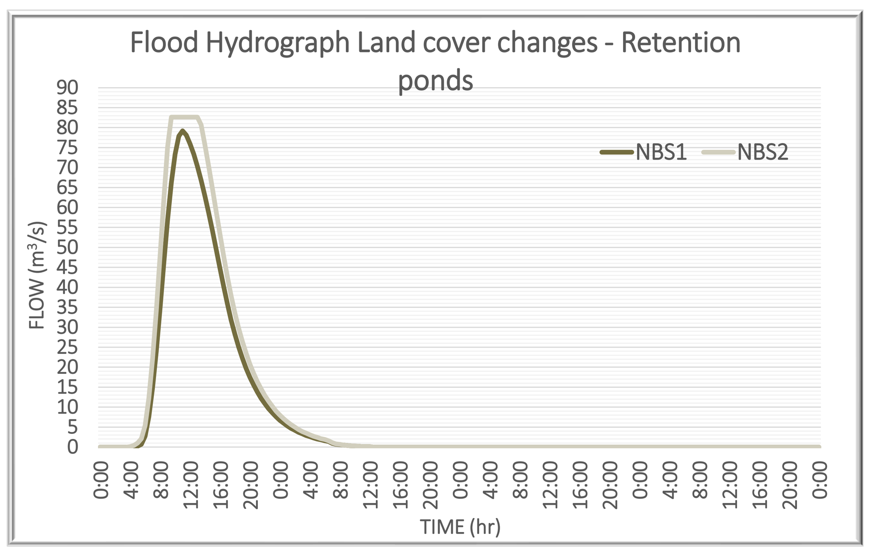
Initial land cover polygons (left) and changed land cover polygons (right).

Results

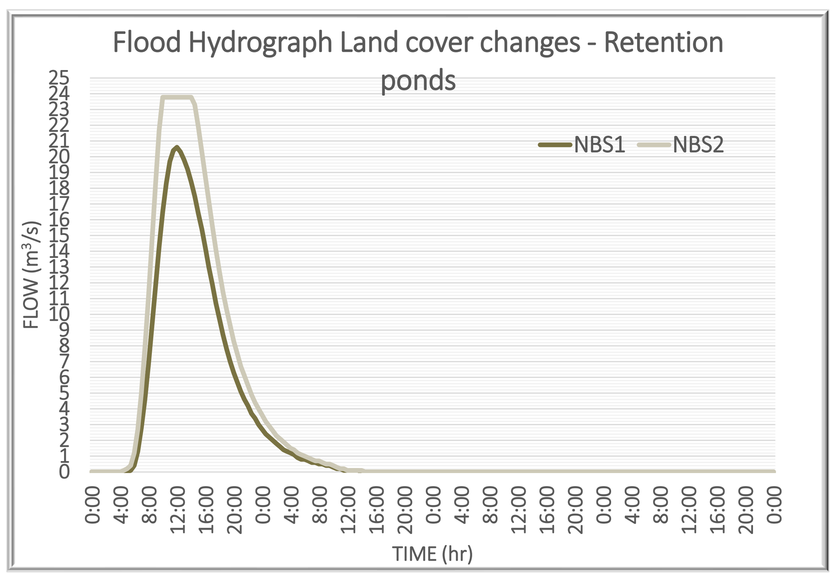
•Flood hydrographs before and after NBS in all subbasins



Flood Hydrographs of Vassiliki subbasin for NBS1 and NBS2



Flood Hydrographs of Nidri subbasin for NBS1 and NBS2



Flood Hydrographs of Kalligoni – Lefkada town subbasin for NBS1 and NBS2

For the Vassiliki subbasin

- Implementing retention ponds leads to a 17.10% reduction in peak flow.
- Reducing the CN by 8 units significantly lowers the flood peak, as the reduced runoff is absorbed by dense vegetation instead of flowing over the surface. This vegetation effectively dampens the flood's impact, leading to a runoff volume of 3.36 hm³ for the scenario with altered CN, a reduction from the base scenario's 4.28 hm³.

For the Nidri subbasin

- The base scenario shows a peak discharge of 99.4 m³/s.
- The introduction of retention ponds achieves a flood peak reduction of approximately 16.90%.
- Changing the land cover results in a further reduced peak discharge with a 20% reduction.

For the Kalligoni-Lefkada subbasin

- With the implementation of retention ponds, the peak discharge is reduced to 23.78 m³/s and the flood volume decreases to 0.998 hm³, compared to the base scenario's 29 m³/s and 1.05 hm³.
- This subbasin also saw the greatest decrease in the loss factor by 10 points, with a reduction of 29% in peak discharge.

- Effectiveness of Nature Based Solutions

Nature Based Solutions	Flood Data	Vassiliki subbasin	Nidri subbasin	Kalligoni-Lefkada town subbasin
NBS1	Peak discharge (m3/s)	81.3	79.2	20.6
	Flood volume (m3)	3.36	2.65	0.75
NBS2	Peak discharge (m3/s)	86.05	82.6	23.78
	Flood volume (m3)	4.09	3.14	0.998
Base Scenario	Peak discharge (m3/s)	103.8	99.4	29
	Flood volume (m3)	4.28	3.29	1.05
Change due to NBS1	ΔQ	-21.68%	-20.32%	-28.97%
	ΔV	-21.50%	-19.45%	-28.57%
Change due to NBS2	ΔQ	-17.10%	-16.90%	-18.00%
	ΔV	-4.44%	-4.56%	-4.95%

Conclusions

- Among the subbasins, Vassiliki consistently exhibits the highest values due to its extensive coverage and longer time delay.
- For the base scenario, Vassiliki records peak discharge of 103.8 m3/s and volume of 4.28 hm^3, while Nydri has 99.4 m^3/s and 3.29 hm^3, and Kalligoni-Lefkada has 29 m^3/s and 1.05 hm^3, respectively.
- Land cover change significantly impacts peak discharge and flood volume by influencing soil permeability and surface runoff.
- Land cover changes resulted in notable reductions in initial flood peak and volume across all subbasins, making it a more efficient solution than constructing retention ponds.
- Land cover changes result in peak discharge reductions of 21.68%, 20.32%, and 28.97% for Vassiliki, Nydri, and Kalligoni-Lefkada, respectively, compared to the base scenario.
- Retention ponds decrease peak discharge by 4.43%, 4.63%, and 4.83% for the three subbasins.

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