HYDROLOGICAL ANALYSIS AND IMPLEMENTATION OF COMBINED NATURE-BASED SOLUTIONS IN KARDITSA REGION-GREECE

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Abstract

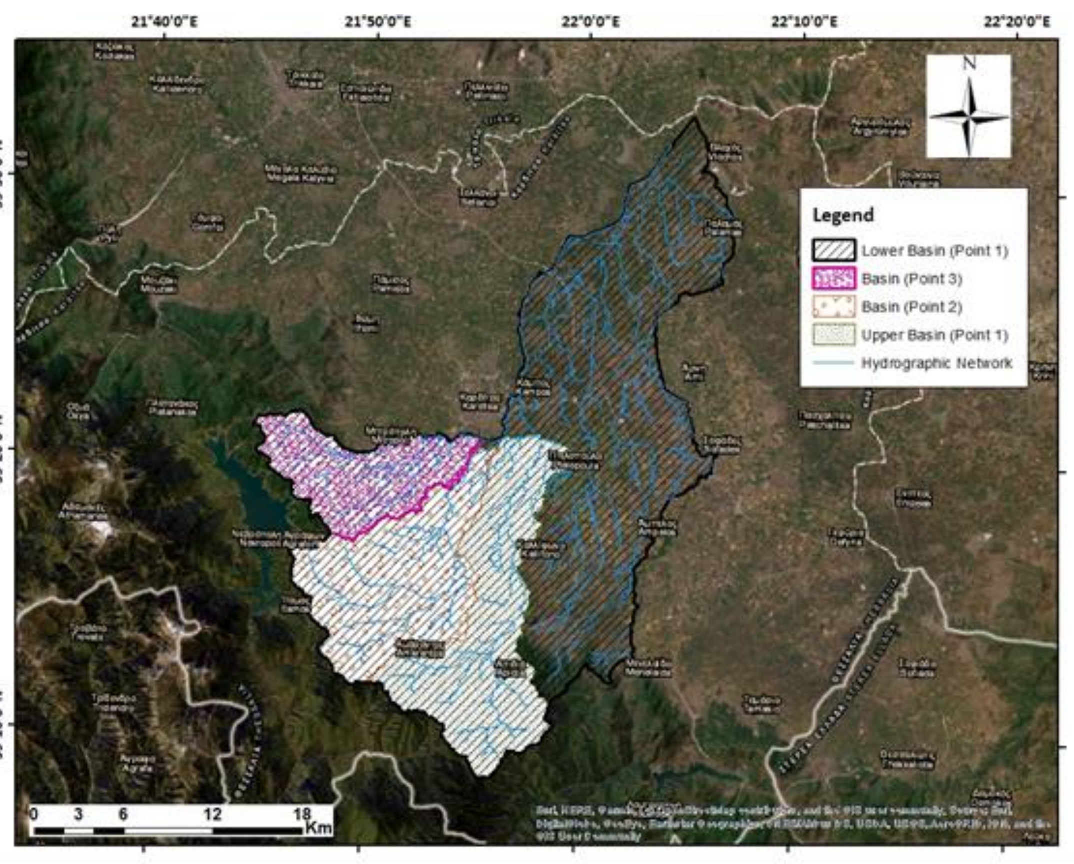
This research work focuses on hydrological analysis in four basins that collectively cover an area of 123 km^2, 617 km^2, 111 km^2, and 68 km^2, respectively, in the Karditsa region of Central Greece. The hydrological analysis utilizes the Hydrologic Modeling System (HEC-HMS) to generate flood hydrographs for three different return periods, employing the time-area diagram method for Unit Hydrograph (UH) definition to calculate the flood hydrograph at the outlet of each basin. Subsequently, a combination of land cover changes and altering river roughness as a Nature-Based Solution (NBS) has been implemented in the study basins as effective strategies to reduce flood risks. The research findings indicate that, following the implementation of NBS, the peak discharge in the flood hydrograph has decreased by approximately 28% in most basins, and the time to peak has increased in most cases by one hour.

Key words: Hydrological analysis, NBS, land cover change, altering river roughness, Karditsa

Materials and Methods

Study area

- Upper basin (Point 1) 123 km^2
- Lower basin (Point1) 617 km^2
- Basin (Point 2) 111 km^2
- Basin (Point 3) 68 km^2



Data used

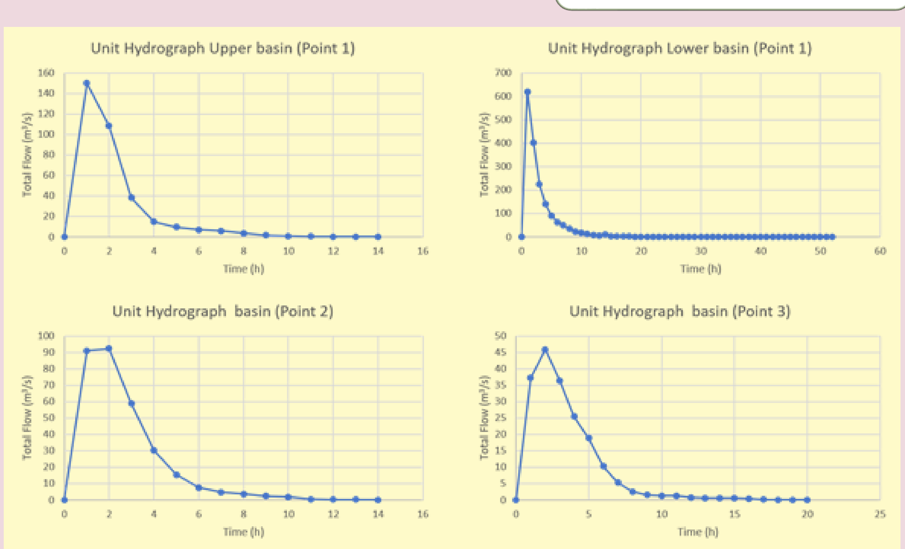
- *Polygon layer:* CORINE Land Cover (2018)
- *Raster:* DEM (digital elevation model)
- *Polygon Layer:* geology
- *Point Layer:* rainfall Intensity-Duration-Frequency (IDF) curves
- *The basemap of National Cadastre & Mapping Agency of Greece*

Methodological Framework

❑ Hydrological Analysis

Determination of design precipitation for return periods T=50, 100, 200 years and rainfall duration of d=24hr → Distribution of rainfall depths, P, and calculation of the design rainfall hyetograph according to the Alternating Block Method → Calculation of Unit Hydrograph for the four basins applying the time-area diagram method in GIS environment → HEC-HMS simulation → Determination of flood hydrographs for the four basins

Computation of precipitation losses using the Soil Conservation Service (SCS) Curve Number (CN) method



- CN of basins before and after Nature-Based Solution (NBS)

BASIN	AREA (km^2)	CN	CN AFTER NBS
Upper Basin (Point 1)	123	70	62
Lower Basin (Point 1)	617	78	71
Basin (Point 2)	111	75	70
Basin (Point 3)	68	70	67

❑ Implementation of Nature-Based Solutions (NBS)

- A combination of land cover changes and altering river roughness as a NBS has been employed in study basins as effective strategies to mitigate flood risks.

The land cover change and river roughness are expressed through the alteration of the CN, whose value is reduced according to the changes corresponding to each basin

A lower CN value indicates a greater infiltration capacity, whereas a higher CN value indicates a greater potential for runoff.

➢ **Land cover changes**

Lower basin (Point1):
- 12 km^2 of permanently irrigated land are replaced with broad-leaved forest
- 3 km^2 of non-irrigated arable land are replaced with mixed forest

Upper basin (Point1):
- 3.5 km^2 of permanently irrigated land are replaced with broad-leaved forest
- 1.48 km^2 of pastures are replaced with broad-leaved forest

Basin (Point 2):
- 1 km^2 of non-irrigated arable land is replaced with mixed forest

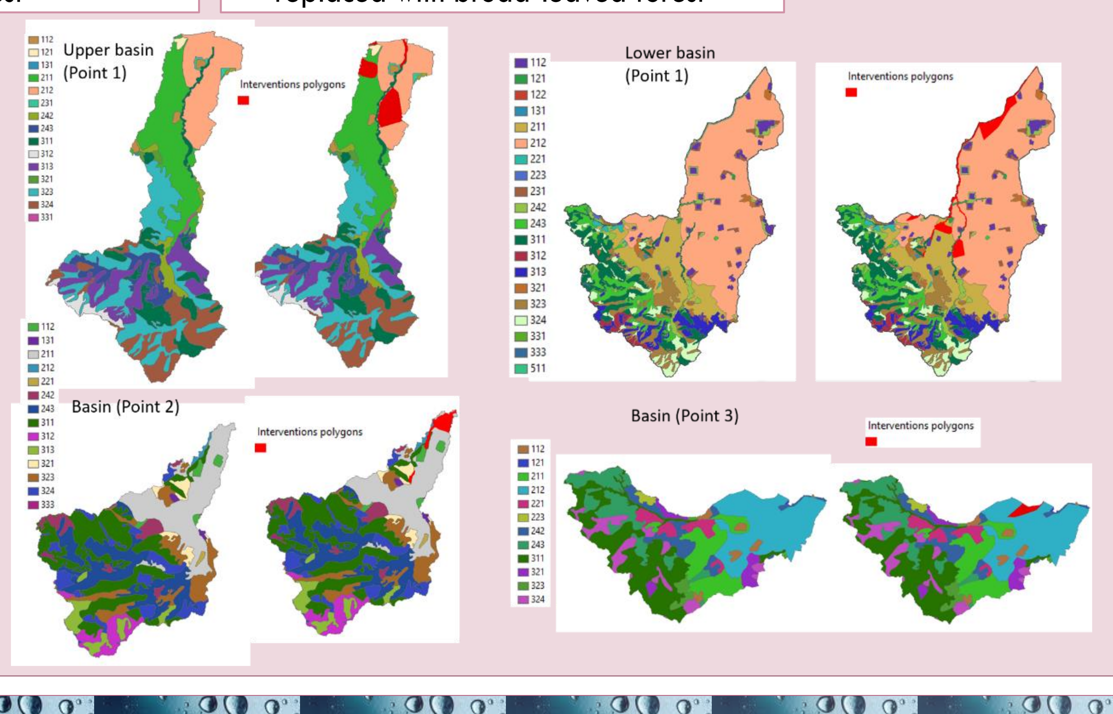
Basin (Point 3):
- 1 km^2 of permanently irrigated land is replaced with broad-leaved forest

➢ **Altering river roughness**

Lower basin (Point1):
- A river segment with a length of 79.6 km and an area of 6 km^2

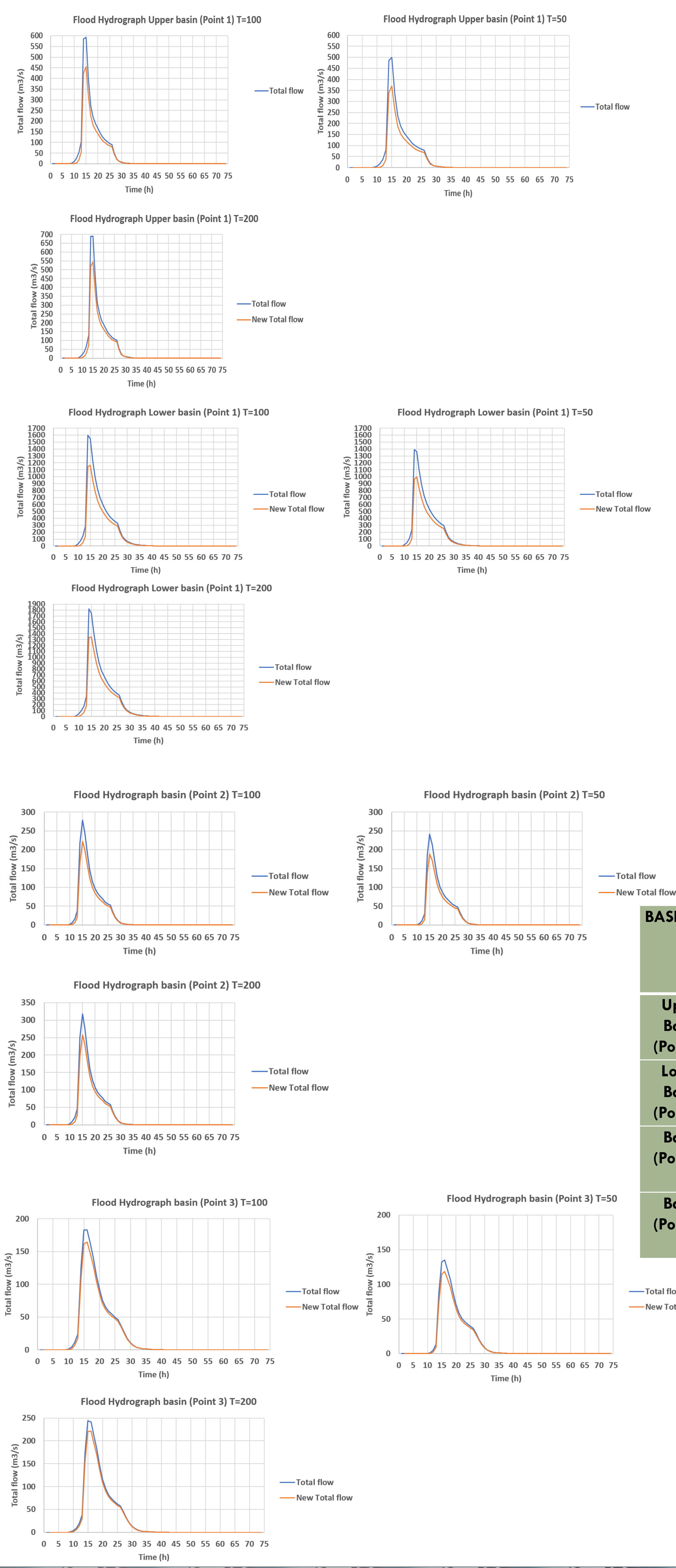
Upper basin (Point1):
- A river length of 4.8 km, covering an area of 0.36 km^2

Basin (Point 2):
- A river length of 8.15 km and an area of 0.4 km^2



Results

- Flood hydrographs before and after NBS in all basins



The land cover changes have led to increased infiltration and retention of rainwater, which have reduced surface runoff and peak flow.

The modification of river roughness has decreased flow velocity, increased channel capacity and reduced the risk of channel erosion.

The combination of these two measures has proved to be an effective and sustainable solution for flood mitigation in the study area.

For T=200 years:
the percentages have decrease and range between 8.43% and 26% in all basins.

The time to peak is increased in most cases by one hour across all basins.

These measures can significantly reduce the flood risk in the study area.

A NBS approach, which combines multiple interventions, could offer a highly effective strategy for flood risk reduction.

The implementation of this combination, it is observed a reduction in surface runoff and an increase in infiltration, leading to lower peak discharge and a delay in the time to peak.

- Characteristics of flood hydrographs for all basins

BASINS	Return period	Peak discharge (m^3/s)	Peak discharge (m^3/s) after NBS	Time to peak (hr)	Time to peak (hr) after NBS
Upper Basin (Point 1)	100	592.3	454.5	13	13
	50	486.3	370.6	12	13
	200	689.9	543.7	13	13
Lower Basin (Point 1)	100	1599	1165.3	12	13
	50	1392	997.6	12	13
	200	1817.4	1343.2	12	13
Basin (Point 2)	100	278	199.9	13	14
	50	241	188.4	13	13
	200	317.3	257.7	13	13
Basin (Point 3)	100	183.2	164.4	14	14
	50	135	118.5	14	14
	200	241.2	221	14	14

For T=100 years:
the time to peak in the flood hydrograph has been reduced by ~28% in almost all the subbasins since the NBS except for basin (Point 3) where it is reduced by 10%

For T=50 years:
the percentages show similar results for T=100 years

Conclusions

- The results emphasize the potential of NBS as an alternative to traditional engineering approaches for flood risk management in hydrological basins.
- The peak discharge in the flood hydrograph, it has been reduced by ~28% in almost all basins after NBS and the time to peak is increased in most cases by one hour.
- These methods can provide a cost-effective and sustainable approach to flood management.
- The successful implementation of these solutions requires careful planning, design, and management.
- The efficacy of these approaches relies on various factors, including the local hydrological and environmental conditions, the appropriate selection of vegetation types and river materials.
- The integration of NBS techniques, addressing land cover change and altering river roughness, offers promising solutions for flood protection and mitigation.
- The adoption of Nature-based approaches, including the restoration of natural processes, promotion of sustainable land management, and enhancement of downstream settlements resilience, not only reduce flood risks but also provide multiple co-benefits for the environment and human well-being.

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