Landscape Dynamics in the Riparian Zones of Mediterranean River catchments, [Western Greece]

Eva **P**apastergiadou

& **UPAT** Freshwater Research Group

University of Patras, Dept. of Biology, Patras, Greece

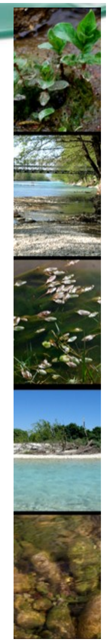
COST 2018
Action
CONVERGES
Meeting

Rennes, 6-7/02/18

RIVERS & Riparian Landscapes

are among the most fragmented, degraded & threatened ecosystems in the world (Millennium Ecosystem Assessment, 2005).

- **Rivers** provide direct benefits to human wellbeing by supporting a number of *regulating, provisioning & cultural Ecosystem* ***S****ervices*.
- The *functioning* of rivers & riparian ecosystems depends primarily on the maintenance of a *natural Hydrologic Regime & Biodiversity* (Brauman et al. 2007), that ensure the delivery of ***Ecosystem Services*** (Mace et al. 2012).
- However, human activities have altered ***river ecological integrity***, especially in the Mediterranean, mainly through the effects of land cover/use (**LCLU**) changes, global climate change & biodiversity.

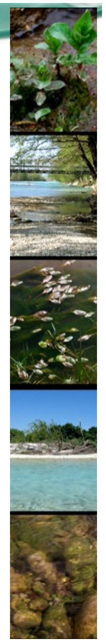


RIVERS & Riparian Landscapes

•Such changes (**LCLU**) impact the capacity of ecosystems to provide goods & services to the human society (Burkhard et al. 2012).

The individual **ecosystem capacities** to supply **services** are strongly linked *to natural conditions & human impacts*

Conceptual framework linking ecosystem integrity, ecosystem services and human well-being as supply and demand sides in human–environmental systems (Burkhard et al. 2012)



- Thus, **understanding & predicting** response of rivers to **LCLU** changes is **critical** for managing aquatic resources & ecosystem services & consists an emerging area of research.

Up today, there are few documented approaches & guidelines on how to undertake such an Exercise.

EU-Policy context of **E**cosystem-based **M**anagement for Aquatic **E**cosystems

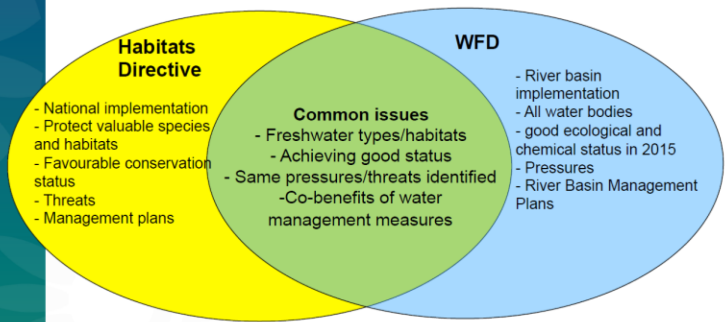
The **WFD 2000/60** introduced a legal framework to protect and restore the **W**ater environment across Europe and ensure its long-term, **S**ustainable **U**se.

The **EU Biodiversity Strategy** recognizes the need to incorporate **E**cosystem **S**ervices into land-use management, conservation, and restoration actions.

Birds & Habitats Directives

EU POLICIES ON FRESHWATER ENVIRONMENT, NATURE & BIODIVERSITY

Cross-walk between Habitats Directive 92/43 & WFD 2000/60

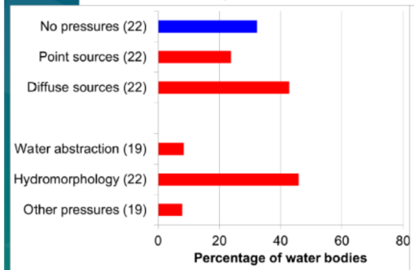


Coordinated activities under the Habitats directive and WFD may help to ensure better protection of freshwater ecosystems and water management

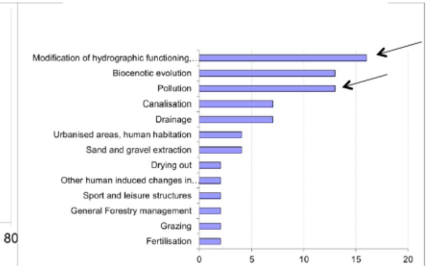
Source: *European Freshwater Assessment* , ETC/ICM 2015

WFD pressures and HD threats: EU-level

WFD: Rivers affected by specific pressures



Freshwater Habitat types affected by specific pressures

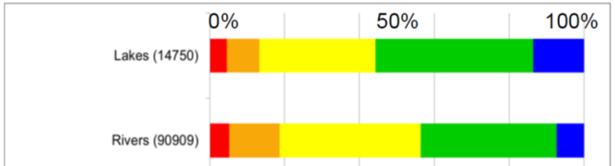


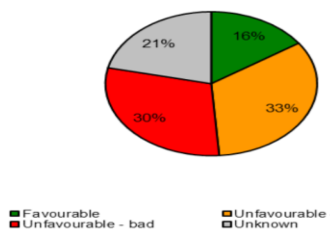
Pollution (mainly nutrients) and hydromorphological modifications most important in both directives

Source: *European Freshwater Assessment* , ETC/ICM 2015

WFD and HD status – EU level

WFD – ecological status in classified rivers: 55% < good, 40% of lakes < good

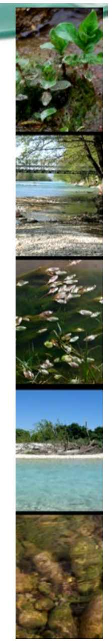




Habitats Directive – Conservation Status of freshwater habitats: 63% unfavourable or 80% of classified freshwater habitats

Source: *European Freshwater Assessment* , ETC/ICM 2015

WFD Implementation & Ecosystem Services



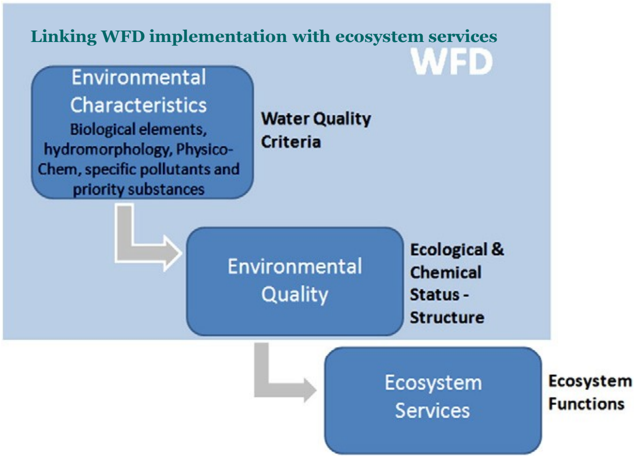
The goal of **WFD** implementation is the **sustainable management of water resources** through the assessment of the **E**cological **S**tatus, by taking due account of environmental, economic & social considerations.

Ecological status is defined as "*an expression of the quality of the structure and functioning of aquatic ecosystems associated with surface waters"* (European Commission 2000).

A major link between **WFD implementation** & **E**cosystem **S**ervices is provided by those **E**cosystem **F**unctions which give **rise** to **S**ervices & the assumption that ***Good Ecological Status*** is a prerequisite for ***E****cosystem* ***F****unctions*.

The capacity of ecosystems to *provide ecosystem services* that satisfy **human well-being** depends on its *ecosystem functions* (De Groot et al. 2002).

The link between environmental characteristics of surface waters & Ecosystem Services in the **WFD**



Source: Vlachopoulou et al. / Science of the Total Environment 470–471: 2014

RIVERS & Riparian Landscapes

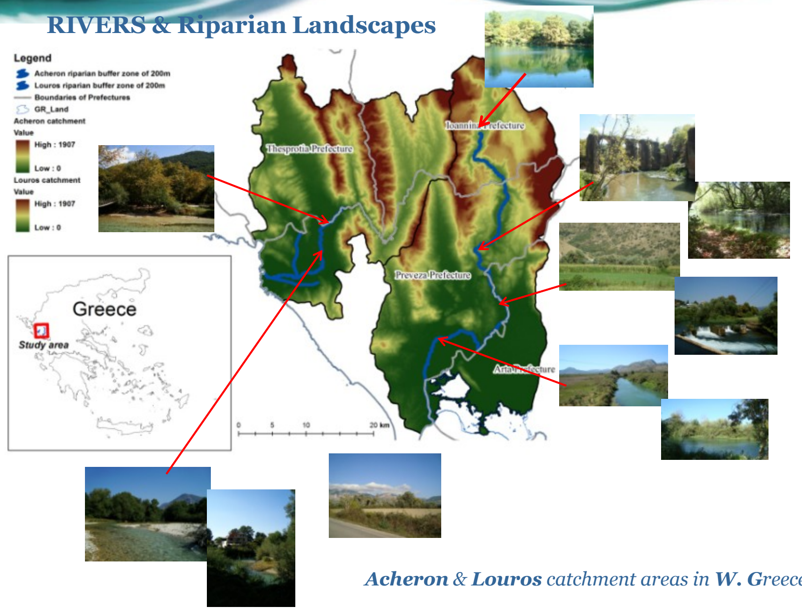
Mapping has become a popular tool for achieving different environmental objectives and the "*visualization" of ecosystem services distribution* (Hauck et al. 2013, Trabucchi et al. 2012a; Maes et al. 2012).

De Groot et al. (2010) identified a long list of challenges for the integration of the concept of **ecosystem services & values** in landscape planning, management, & decision making. One of these **key** challenges **was how to map values** (ecological, social & economic) so as to facilitate the use of ecosystem services in spatial landscape planning.

Land cover information from remote sensing, land survey & GIS with data from monitoring, statistics, simulation models, & statistical data are appropriate for spatial & temporal scales maps.

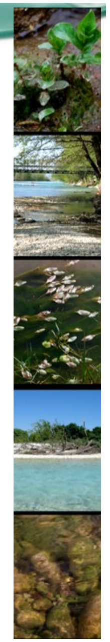
The results reveal **patterns of natural conditions** & human activities *over time* & the *capacities of different ecosystems* to supply **ecosystem services** considering current states and real or potential changes in **land use** (Burkhard et al. 2012).

RIVERS & Riparian Landscapes



***Acheron** & **Louros** catchment areas in **W.** Greece*

RIVERS & Riparian Landscapes in W. Greece



- an **integrated approach** for assessing *the impact of human intervention* to river landscapes of W. Greece was conducted by *incorporating different aspects of ecological integrity* such as habitat quality, species biodiversity & trophic status.

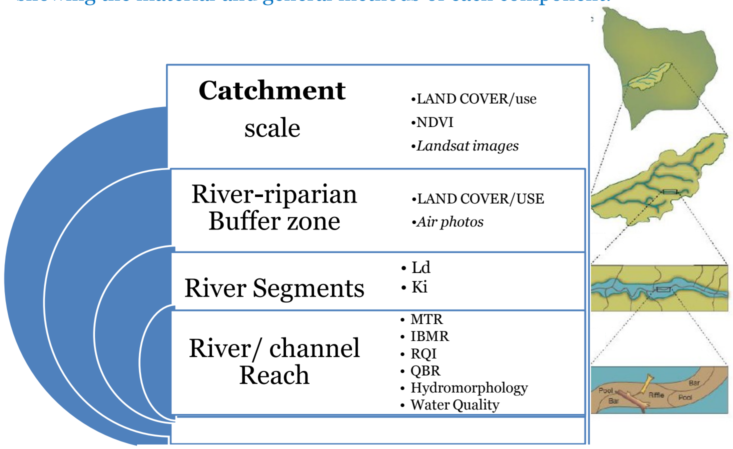
- we integrate the information collected at **landscape** & **local scale levels** in order to gain a holistic understanding of the rivers & riparian vegetation ecosystem

- Landsat-TM imagery, air photos, GIS & Remote Sensing techniques for detecting the spatiotemporal dynamic patterns of LCLU changes were applied.

The utmost goal of the study was the examination of the **degree** in which **LCLU** changes affect the ability of the riparian ecosystems to ***deliver ecosystem services.***

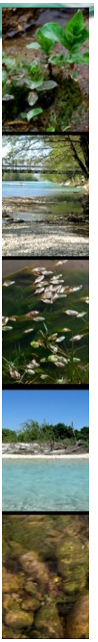
- This is a **preliminary approach** for assessing & valuing ***ecosystem services*** relevant for **W**ater **R**esource **M**anagement, considering the links between pressures, ecological status & ecosystem services.

Illustration of the conceptual basis of the methodological approach, showing the material and general methods of each component.



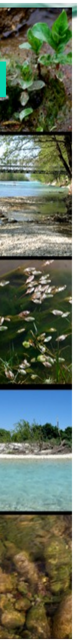
Change of land use structure

The intensity of land use & its change

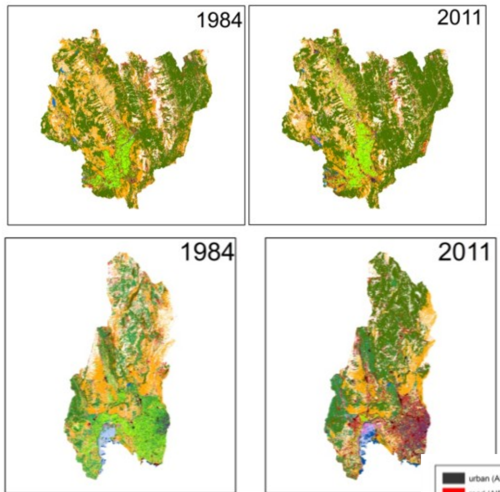


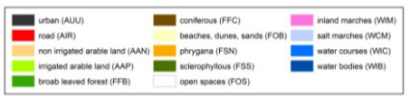
GIS spatial geo-database- CORINE land cover Classification System

Level 1	Level 2	Level 3	Abbr	
1. Artificial surfaces	1.1. Urban	1.1.1 Urban Fabric	AUU	Artificial surfaces
	1.2 Industrial, commercial and transport units	1.2.2 Road and rail networks and associated land	AIR	
2. Agricultural areas	2.1 Arable land	2.1.1 Non irrigated arable land	AAN	Cultivations
		2.1.2 Permanently irrigated land	AAP	
	2.2 Permanent crops	2.2.2 Fruit trees	APF	
		2.2.3 Olive groves	APO	
	2.4 Heterogeneous agricultural areas	2.4.1 Agro forestry areas	AHF	
3. Forests and semi natural areas	3.1 Forests	3.1.1 Broad-leaved forest	FFB	Natural Land
		3.1.2 Coniferous forest	FFC	
	3.2 Shrub / herbaceous vegetation associations	3.2.1 Natural grassland	FSN	
		3.2.3 Sclerophylous vegetation	FSS	
	3.3 Open spaces with little or no vegetation	3.3.1 Beaches, dunes and sand plains	FOB	Bare Land
		3.3.3 Sparsely vegetated areas	FOS	
4. Wetlands	4.1 Inland wetlands	4.1.1 Inland marshes	WIM	Wetlands
	4.2 Coastal wetlands	4.2.1 Salt marshes	WCM	
5. Water bodies	5.1 Inland waters	5.1.1 Water courses	WIC	Water
		5.1.2 Water bodies	WIB	
	5.2 Marine waters	5.2.1 Coastal lagoons	WME	



Spatiotemporal Land cover/use changes at the Catchment level of Acheron-Louros rivers (Satellite Landsat TM Images 1984–2011)





Natural vegetated areas, which are dominated by sclerophyllus vegetation & phrygana, cover a significant part of the catchment.

On the lowland areas urban areas expanded enormously during the few last years due to human activities

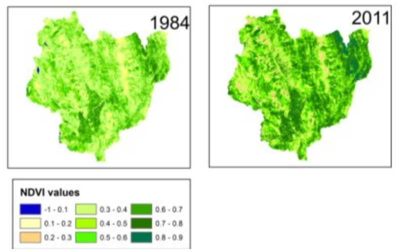
Irrigated and non irrigated arable land continuously increased mainly due to the land consolidation, to proliferation of drainage channels, the drying and shrinkage of wetlands.

Salt marches restrictive drastically due to the expansion of urban and agricultural land.

The negative effect of these interventions has a significant influence on degradation of wetland habitats and cause loss of valuable ecosystems.

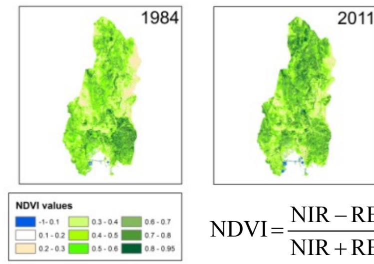
Source: Kostara et al. 2013, 2015

The Normalized Difference Vegetation Index - (NDVI), at the Catchment level of Acheron-Louros rivers



NDVI represents one of the most sensitive landscape components to environmental degradation.

- ✓ High values of NDVI were obtained in the upper part of the catchment at middle and high altitude areas, where sclerophyllous vegetation is placed and human activities are restricted.
- ✓ regeneration of the natural vegetation seems to happen in middle and higher altitudes areas especially due to abandonment of shipping. These areas including the low hills, which surrounding the valleys
- ✓ Sclerophyllous vegetation replaced areas without or with no dense vegetation cover, like open spaces and phrygana and furthermore agricultural land replace broad leaved forest in riverine area.



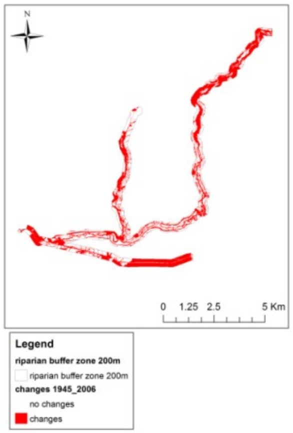
$$NDVI = \frac{NIR - RED}{NIR + RED}$$

This index ranges from -1 to 1, (values 0.5 =dense vegetation and values < 0 = no vegetation represents the combination of its normalized difference formulation & use of the highest absorption & reflectance regions of chlorophyll

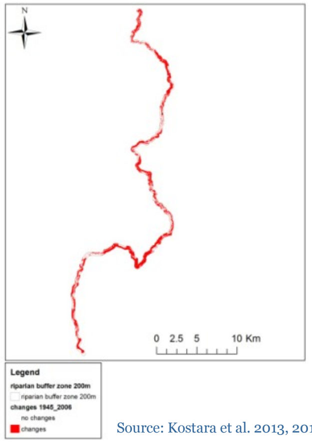
Source: Kostara et al. 2013, 2015

Spatiotemporal **Land cover/use changes in the Riparian Buffer zone** level of the studied rivers (Aerial Photo's 1945–2006)

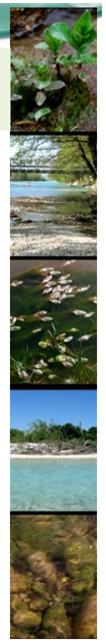
Acheron river



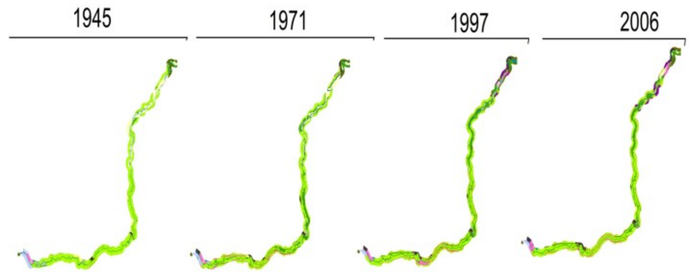
Louros river



Source: Kostara et al. 2013, 2015

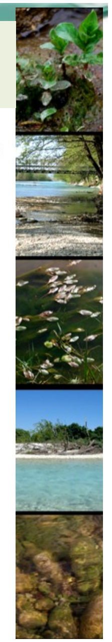


Spatiotemporal **Land cover/use changes in the Riparian Buffer zone** level of the **Acheron** river (Aerial Photo's 1945–2006)

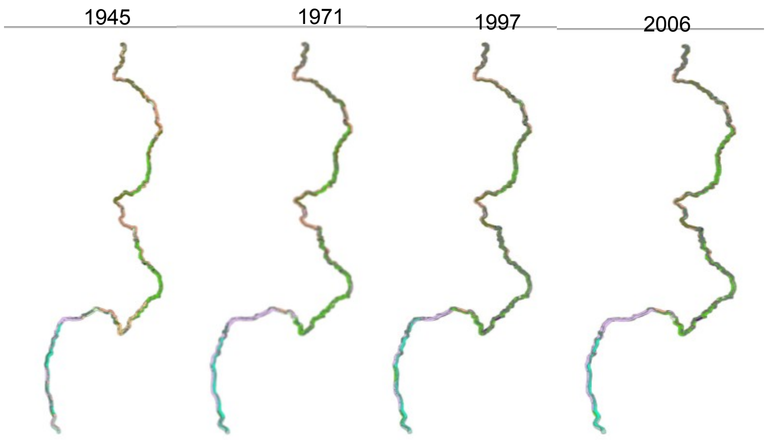


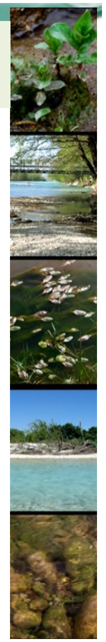
- Urban Fabric
- Road
- Non irrigated arable land
- Permanently irrigated land
- Fruit trees
- Olive groves
- Broad-leaved forest
- Coniferous forest
- Sclerophylous vegetation
- Beaches, dunes and sand plains
- Sparsely vegetated areas
- Inland marshes
- Salt marshes
- Water courses
- Water bodies
- Coastal lagoons

Source: Kostara et al. 2013, 2015



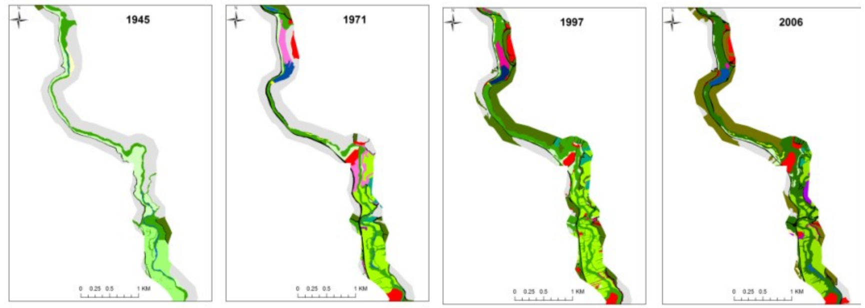
Spatiotemporal **Land cover/use changes in the Riparian Buffer zone** level of the **Louros** river (Aerial Photo's 1945–2006)





Source: Kostara et al. 2013, 2015

Riparian buffer zone (200 m) of Louros river – middle flows dam area



- Urban Fabric
- Road
- Non irrigated arable land
- Permanently irrigated land
- Fruit trees
- Olive groves
- Broad-leaved forest
- Coniferous forest
- Sclerophylous vegetation
- Beaches, dunes and sand plains
- Sparsely vegetated areas
- Inland marshes
- Salt marshes
- Water courses
- Water bodies
- Coastal lagoons

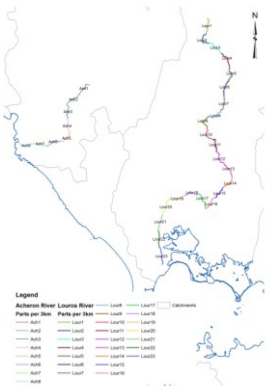
Land use disturbances in the catchment's area **are more intense in the riparian buffer zone**, with maximum habitat integrity recorded in the upper river reaches.

LCLU changes were associated with human activities that have changed the river beds, increased landscape fragmentation & led to the degradation & loss of wetland habitats.

Source: Kostara et al. 2013, 2015

Land use Intensity (Ld index) & Dynamic Degree of Land use (Ki index) in the Riparian Segments level of the studied rivers

The intensity of land use in ecosystems & its change



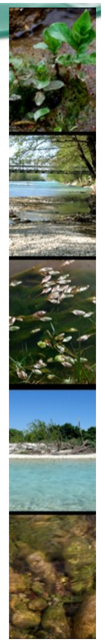
were measured in each river Segment [3 Km], with the Land use intensity (**Ld**) index & Dynamic degree of land use (**Ki**) index which are defined as human interference to ecosystems (Zhuang & Liu 1997 , Yu et al., 2010).

According to the results of interpretation and classification, *Coefficient of land use Intensity* L_d and K_i are calculated as follows (Zhuang & Liu 1997 , Yu et al., 2010b): Ld ∈ [100, 400]

$$L_d = 100 \times \sum_{i=1}^{n} A_i C_i$$

Where A_i is the grading index of *i*th land use degree in the study region, C_i is the percentage of grading area of *i*th land use degree, and *n* is the amount of grading land use degree.

Based on the land use types, the unutilized land can be graded as **degree I;** the forest land, grassland, and water area can be graded as **degree II**; the arable land can be graded as **degree III**; and residential, industrial, and mining areas can be **graded as IV** (Zhang et al. 2002).



Land use Intensity (Ld index) & Dynamic Degree of Land use (Ki index) in the Riparian Segments level of the studied rivers

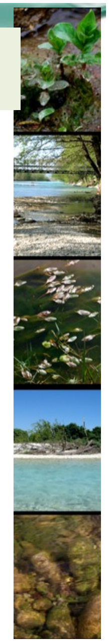
- Land use dynamic degree (Ki %) of Acheron & Louros riparian buffer zone (1945-2006).

ACHERON	1945-1971	1971-1997	1997-2006
LAND COVER/USE	ki	ki	ki
AUU	10.90	1.97	-0.61
AIR	38.05	3.21	-2.07
AAP	0.11	0.06	0.26
APF	0.00	31.67	5.88
APO	2.94	-0.13	13.54
AHF	-1.97	-0.04	-2.85
FFB	3.00	-0.11	-0.60
FFC	0.00	-0.77	0.14
FSN	8.22	-2.55	8.01
FSS	-1.46	0.73	-0.67
FOB	-1.26	-3.18	7.39
WIM	-2.83	5.28	-2.04
WCM	-1.48	-1.54	7.46
WIC	0.05	-0.81	-2.58

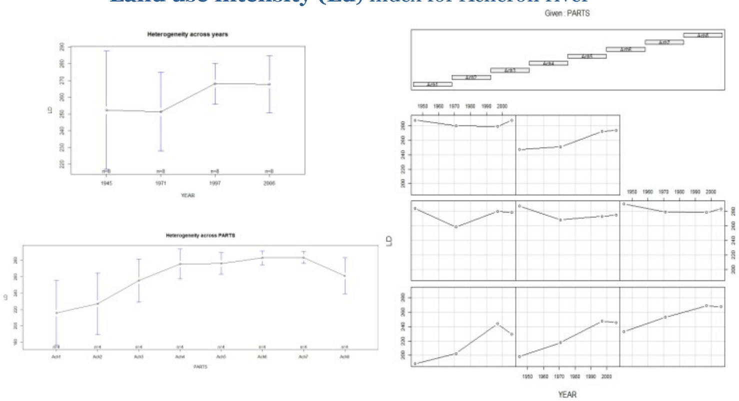
LOUROS	1945-1971	1971-1997	1997-2006
LAND COVER	ki	ki	ki
AUU	25.86	3.63	14.73
AIR	5.65	0.73	11.47
AAN	-3.24	0.57	10.03
AAP	1.56	-0.05	9.90
APF		4.80	9.29
APO	3.17	9.14	8.01
FFB	0.06	1.10	10.65
FSN	-2.05	-1.11	16.33
FSS	-0.80	0.64	12.43
FFB	-1.20	-2.10	7.10
FOS	-0.94	-1.02	8.14
WIM	4.66	-1.05	13.95
WCM	-3.36	-0.74	8.11
WIC	0.10	-0.77	15.55
WIB	24.00	-0.43	11.33
WCL	-0.81	0.43	12.20

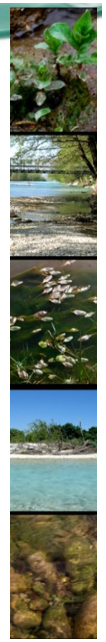
$$K_i = \frac{U_b - U_a}{U_a} \times \frac{1}{T} \times 100\,\%$$

Where U_a is the quantity of *i* type land use at the beginning of the period, and U_b at the end. *T* is the period (Yu et al. 2010)



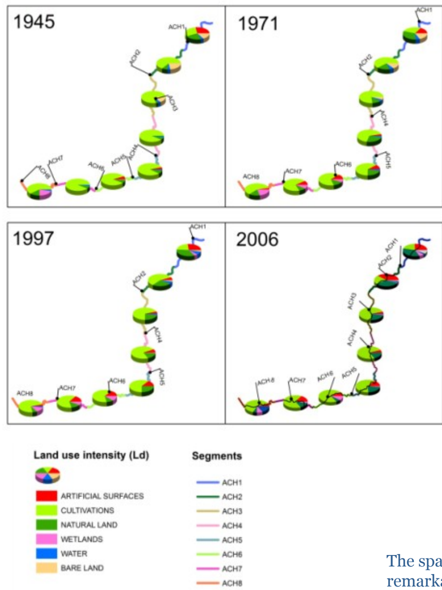
A) Patterns of natural conditions &human activities over time
Land use intensity (Ld) index for Acheron river



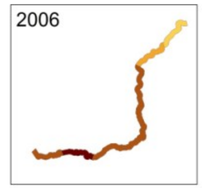


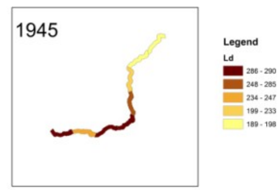
The coefficient of land use intensity is the key to determine the **grade & the grading index** of land use degree & can reflect the structural differences of land use types in different regions and different periods. [It is an indicator to measure the land use change].

The results showed that, the pattern & intensity of land use changed greatly due to intense human activities since the 1970s especially at the lowlands & a series of ecological effects followed them.



Land use intensity (Ld) index for Acheron river

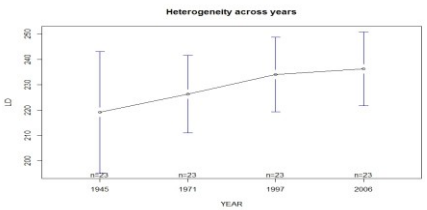


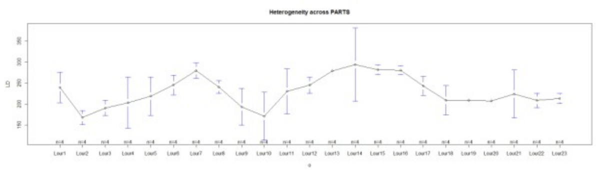


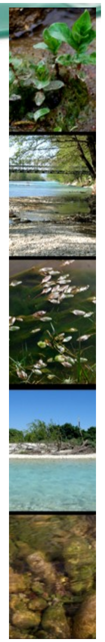
The spatial variation of land use intensity is remarkable in the study region.

Land use Intensity (Ld index**)** & **Dynamic Degree of Land use (Ki** index**) in the Riparian Segments** level of the studied rivers

B) Patterns of natural conditions &human activities over time
Land use intensity (Ld) index for Louros river

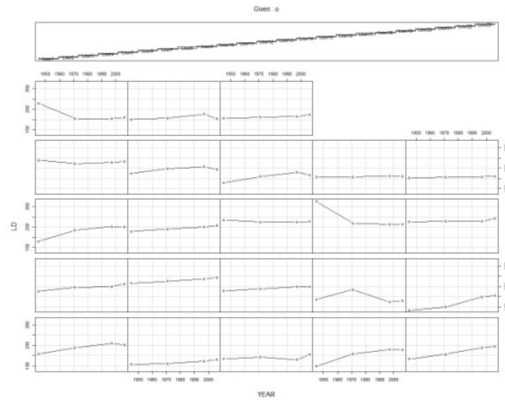


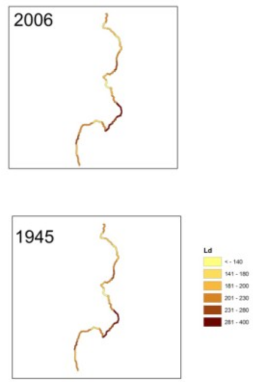


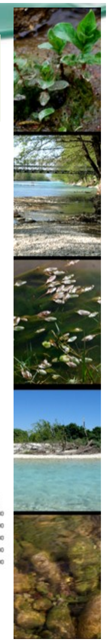


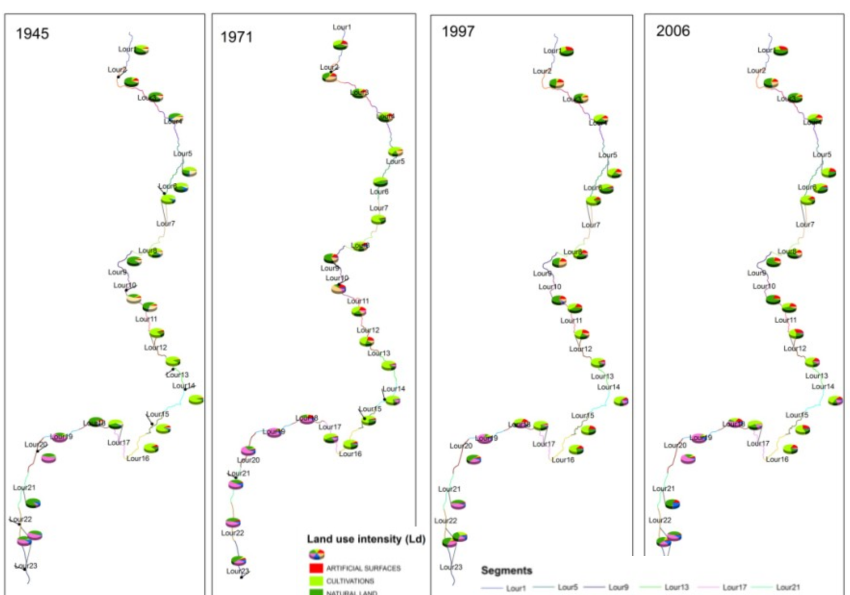
Land use Intensity (Ld index**)** & **Dynamic Degree of Land use (Ki** index**) in the Riparian Segments** level of the studied rivers

B) Patterns of natural conditions &human activities over time
Land use intensity (Ld) index for Louros river

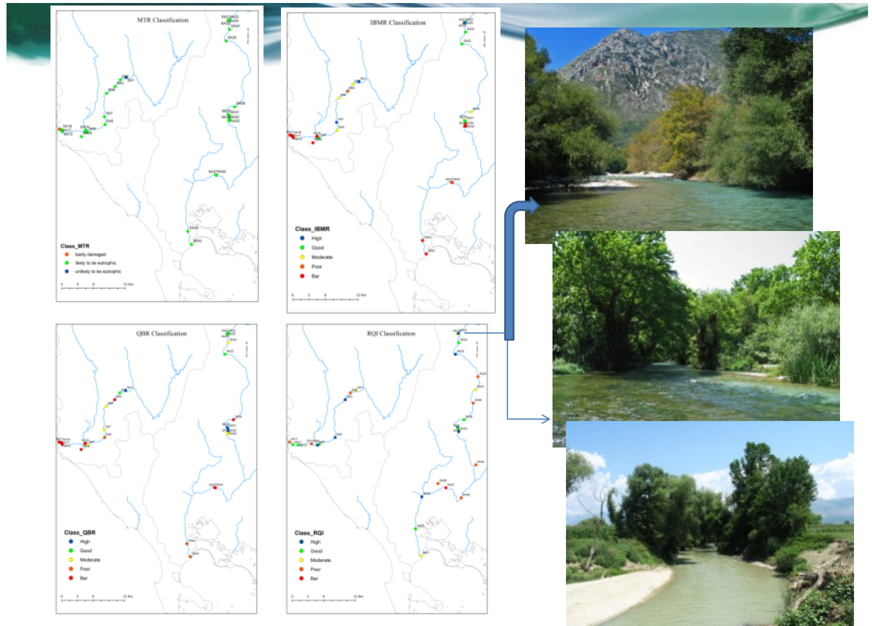








Land use intensity (Ld)
index for Louros river



Source: Papastergiadou et al. 2012, 2014, 2016

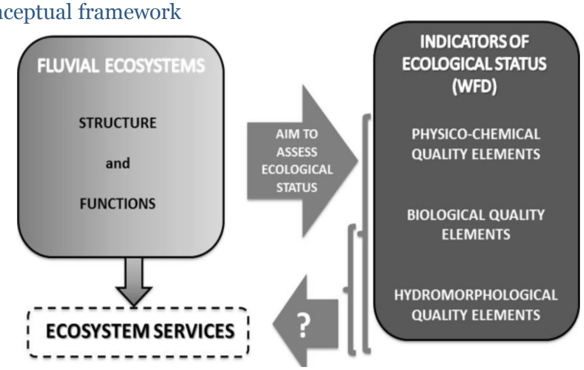
WFD Ecological Status Assessment with BQE macrophytes, Water quality & Riparian Indices in the **Channel Reach** level of the studied rivers

Correlations between site based Trophic Indices [IBMR, MTR] Riparian Quality Indices [QBR, RQI] & Land Use Heterogeneity [LD, CA]

		RQI	IBMR	QBR	MTR	LD	CA
RQI	Correlation Coefficient	1.000	0.365	0.446	0.159	**-.427***	-0.190
	Sig. (2-tailed)		0.200	0.110	0.588	0.038	0.375
IBMR	Correlation Coefficient		1.000	**.655****	**.813****	-0.083	0.087
	Sig. (2-tailed)			0.000	0.000	0.694	0.678
QBR	Correlation Coefficient			1.000	**.582****	**-.522****	0.317
	Sig. (2-tailed)				0.001	0.007	0.122
MTR	Correlation Coefficient				1.000	0.025	0.218
	Sig. (2-tailed)					0.906	0.295
LD	Correlation Coefficient					1.000	**-.428****
	Sig. (2-tailed)						0.009
CA	Correlation Coefficient						1.000

RIVERS, Riparian Landscapes & Ecosystem Services

The Conceptual framework



that aims to assess the capacity of the biological & hydromorphological indices to evaluate the ability of fluvial & riparian ecosystems to deliver **E**cosystem **S**ervices

Vidal-Abarca et al. / Environm Management 57: 2016

RIVERS, Riparian Landscapes & Ecosystem Services

- The first group of indicators describes ecosystem structure, like habitat components or biological diversity, and the processes through energy and matter budgets relevant for long term ecosystem functionality.
- The second and third groups consider regulating and provisioning services
- Indicators of cultural, recreational and aesthetic values were considered in this analysis. In each case is evaluated additionally the historical cultural monuments. Refers specifically to landscape and visual qualities of the resp. case study area (scenery, scenic beauty).

Acronyms:
ART, Artificial surfaces; CLT: Cultivations ; NTR: natural habitats; WTL: Wetland; WTR: Water; BRL: Bare land.

SOURCE: Burkhard et al. 2009, 2012/ Clerici et al. 2014

	ART	CLT	NTR	WTL	WTR	BRL
Ecological integrity						
Abiotic heterogeneity	1	2	4	4	4	3
Biodiversity	1	2	5	4	4	2
Biotic water flows	0	3	5	4	1	0
Metabolic efficiency	0	3	4	4	4	0
Exergy capture	1	4	5	4	4	0
Reduction of nutrient loss	0	2	5	4	3	0
Storage capacity	1	3	5	5	3	1
ESSc (EI)	4	19	33	29	23	6
Regulating ecosystem Services						
Local climate regulation	0	1	5	3	2	1
Global climate regulation	0	1	4	3	1	1
Flood protection	0	1	4	4	3	4
Groundwater recharge	1	2	3	3	3	2
Air quality regulation	0	1	5	3	1	0
Erosion regulation	0	1	5	1	0	0
Nutrient regulation	0	1	5	5	2	0
Water purification	0	1	4	5	3	0
Pollination	0	1	4	3	0	0
ESSc (Res)	1	10	39	30	15	8
Provisioning ecosystem services						
Crops	0	5	4	0	0	0
Livestock	0	4	3	1	0	0
Fodder	0	4	3	2	0	0
Capture fisheries	0	0	0	0	4	0
Aquaculture	0	0	0	0	4	3
Wild foods	0	0	2	0	1	0
Timber	0	1	3	0	0	0
Wood fuel	0	1	4	0	0	0
Biochemicals and medicine	0	1	1	0	0	0
Freshwater	0	0	4	4	5	4
ESSc (Pes)	0	16	20	4	11	6
Cultural ecosystem services						
Recreation & aesthetic values	0	0	3	4	5	3
ESSc	0	0	3	4	5	3

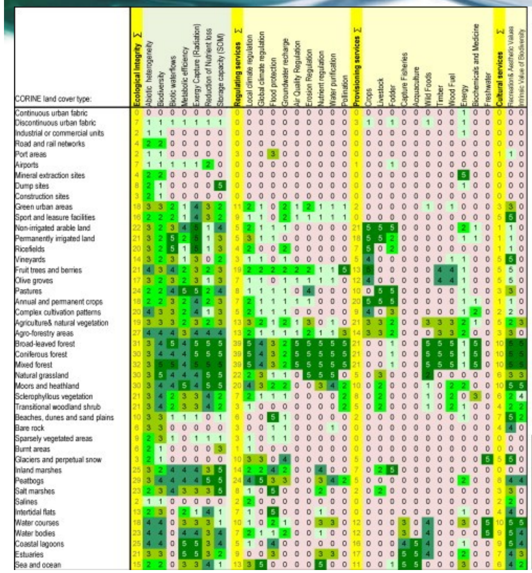
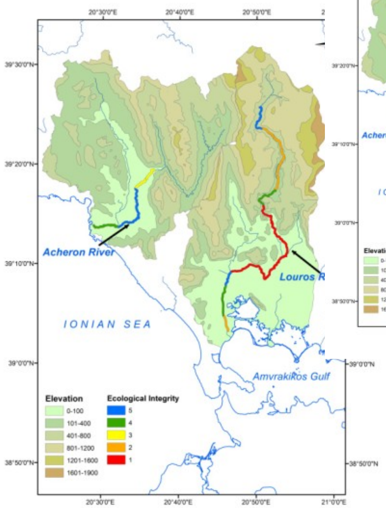


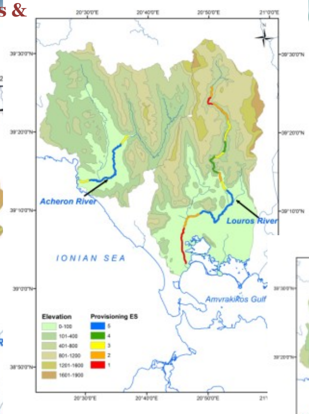
Fig. 2. Assessment matrix illustrating the capacities of different land cover classes to support ecological integrity (column at the left side) and to supply ecosystem services (the three columns at right). The values/colors indicate the following capacities:0/rosy = no relevant capacity; 1/grey green = low relevant capacity; 2/light green = relevant capacity; 3/yellow green = medium relevant capacity; 4/blue green = high relevant capacity; and 5/dark green = very high relevant capacity (after Burkhard et al., 2009).

scale for assessing capacities:

0 = no relevant capacity
1 = low relevant capacity
2 = relevant capacity
3 = medium relevant capacity
4 = high relevant capacity
5 = very high relevant capacity

RIVERS, Riparian Landscapes & Ecosystem Services





Improving the **Ecological Status** is likely to result in *Greater* **Ecosystem Benefits**.

Future **Research** should focus on reinforcing our understanding of **good ecological status, biodiversity & ecosystem services.**