HyMoCARES Project

WPT3. Effects of hydromorphological management and restoration measures

D.T3.3.1 – ES assessment

Case studies: Isarco, Talvera and Adige (Autonomous Province of Bolzano)

Project: HyMoCARES

Work package: WPT3 - Effects of hydromorphological management and restoration measures

Activity: A.T3.4 – Evaluating effects of ES on management/restoration works, applying the overall ES framework, based on A.T3.1 to A.T3.3.

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1 Case studies

The case studies targeted for the analysis in the HyMoCARES project for the province of Bolzano are the Isarco River, the Adige River and the Talvera River. The Isarco and the Adige Rivers are divided into two sub-units and the Talvera Torrent into four sub-units.

1.1 Isarco River

The case study is located between the Loreto-bridge and shortly upstream the MeBo-bridge in the centre of the city of Bolzano. This case study was divided into two sub-units according to the methodological standard of hydromorphological quality assessment, i.e. the river sections identified in the MQI Index calculation (Rinaldi, 2016).

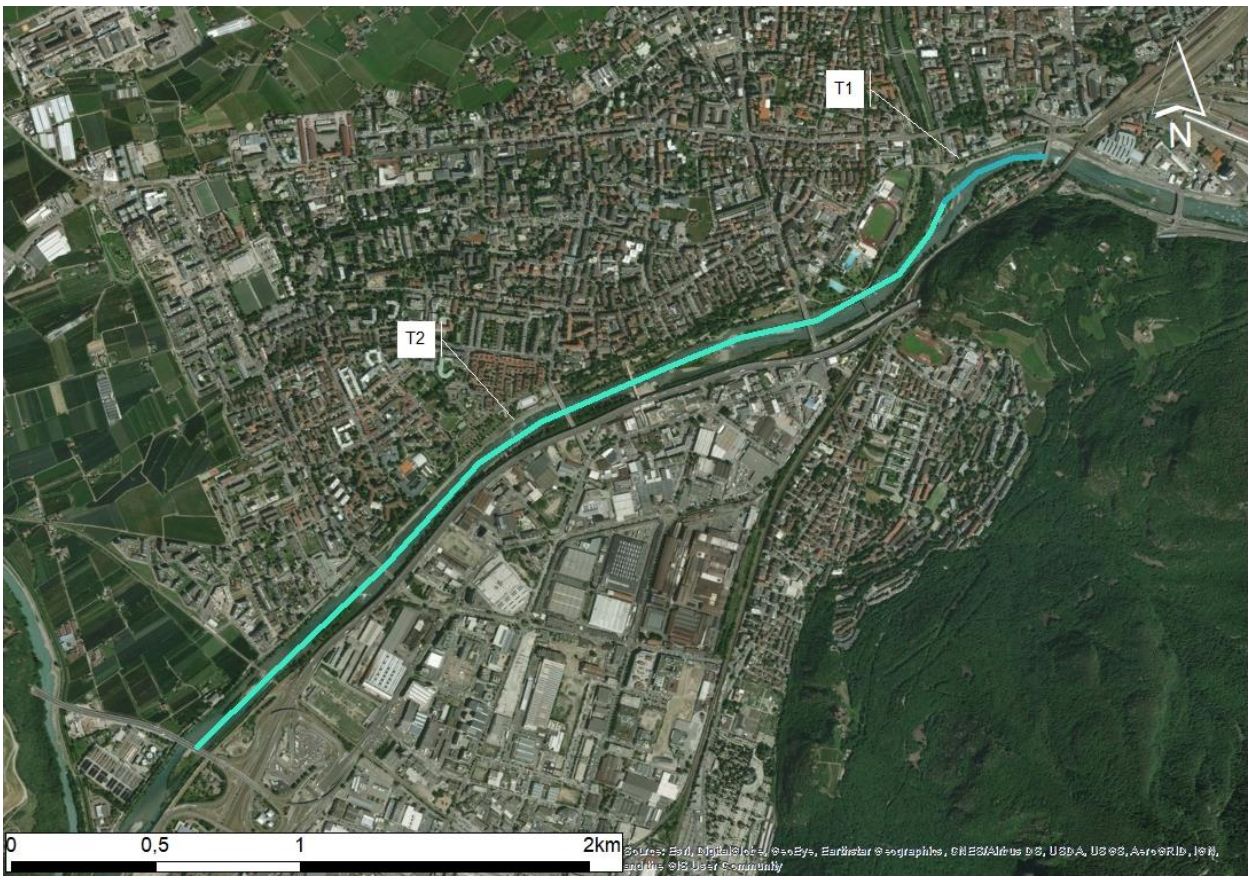

Figure 1 *Sub-units of Isarco case study.*

Table 1 *Length and percentages of sub-units.*

ID	Lenght (m)	% Lenght
T1	391,22	10,6
T2	3295,2	89,4

The most important problems of the Isarco River in this sections was riverbed erosion caused by sediment deficiency due to the effect of check dams and hydropower plants located in the sections upstream.

The restoration actions which are taken into consideration for this area are sediment recharge, channel widening and creation of macroforms, and were constructed starting in 2013. Consequently, according to D.T1.2.1, the hydromorphological processes that are affected by these actions are hydraulics, lateral connectivity, sediment continuity, river morphology, vertical connectivity, biotic communities, physical habitat, presence and composition of riparian vegetation, instream flow regime and biochemical cycling of chemical compounds.

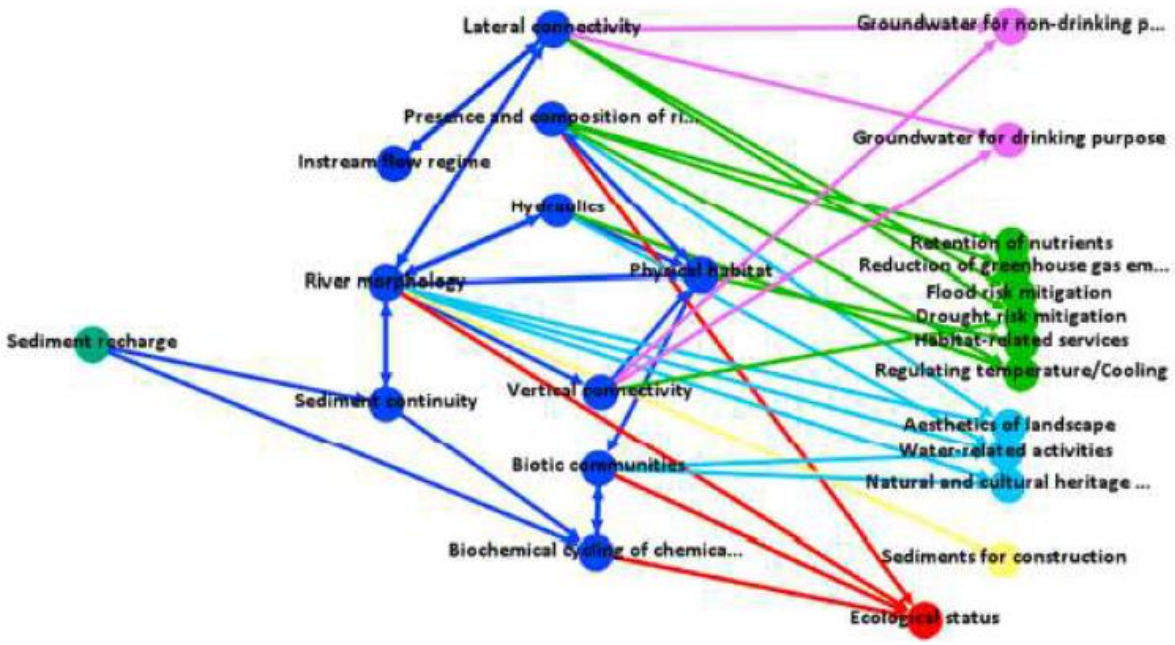

Figure 2 *Hydromorphological processes and ES for "Sediment recharge" restoration action.*

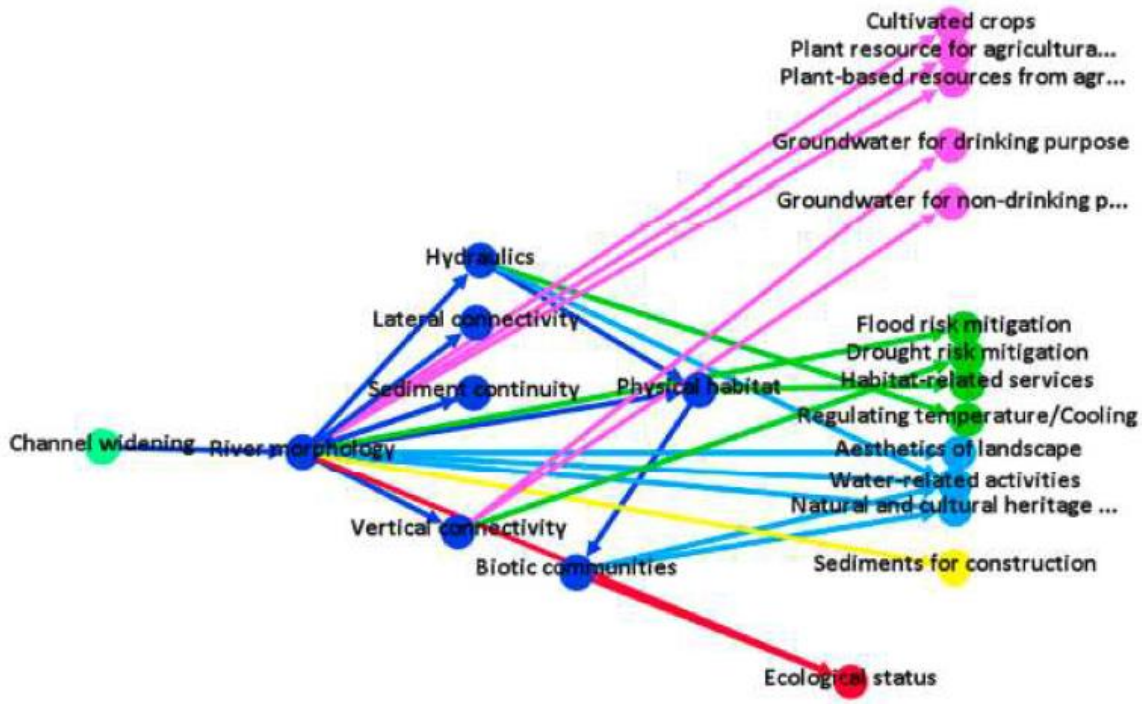

Figure 3 *Hydromorphological processes and ES for "channel widening" restoration action.*

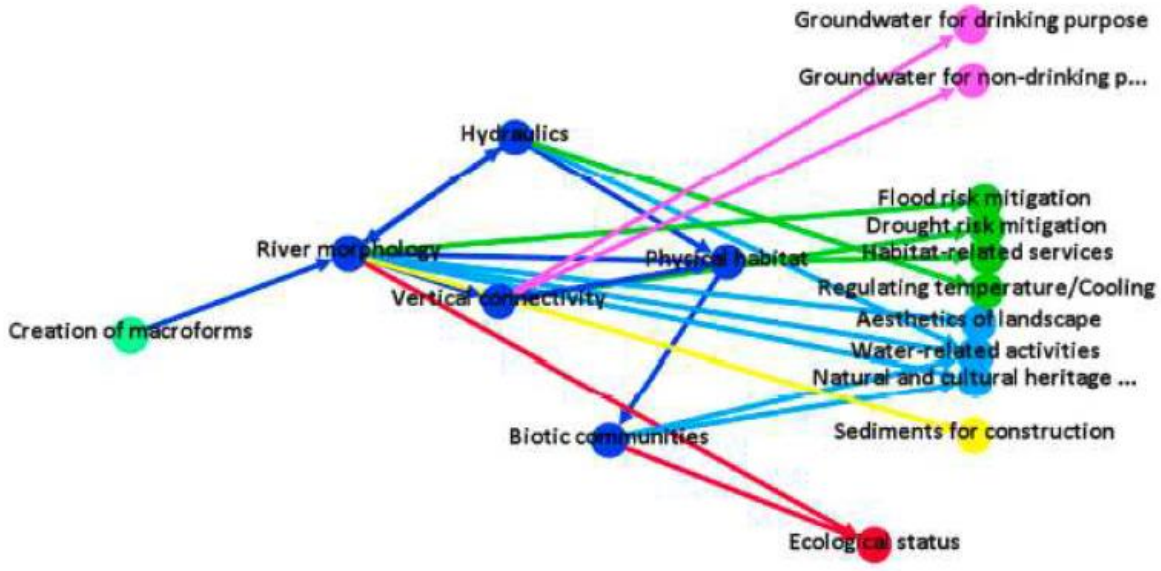

Figure 4 *Hydromorphological processes and ES for "creation of macroforms" restoration action.*

1.2 Talvera River

The case study is located between the Sill dam and the confluence with the Isarco River. This case study was divided into four sub-units according to the methodological standard of hydromorphological quality assessment, i.e. the river sections identified in the MQI Index calculation (Rinaldi, 2016).

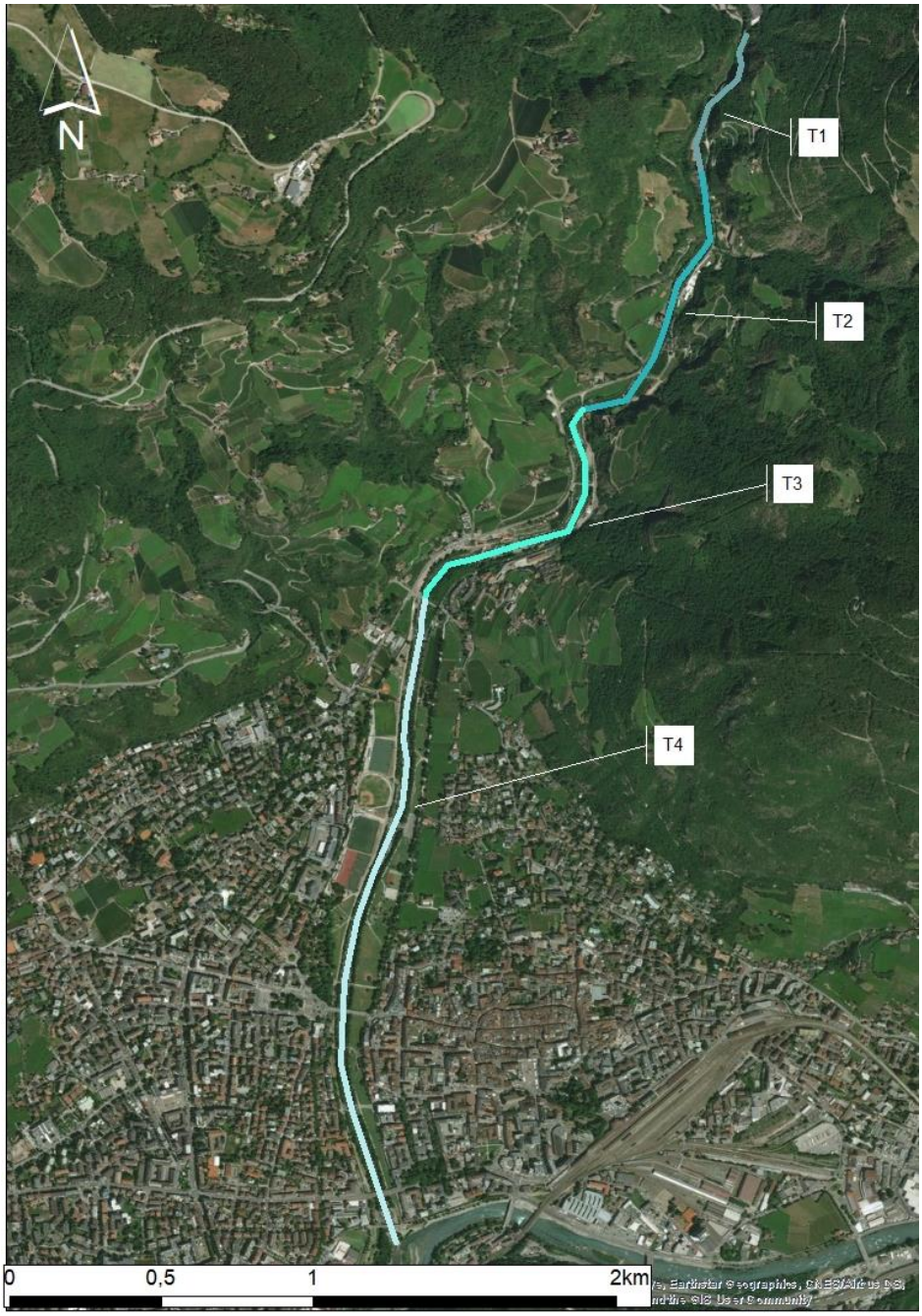

Figure 5 *Sub-units of Talvera case study.*

Table 2 *Length and percentages of sub-units.*

ID	Lenght (m)	% Lenght
T1	517,59	11,1
T2	970,47	20,8
T3	988,90	21,2
T4	2185,44	46,9

On the Talvera River, the re-establishment of sediment continuity was one of the main goals of the restoration actions. The restoration actions taken into consideration on this site were sediment recharge, check dam removal, creation of macroforms, ensuring ecological flows and weir removal. These actions were implemented starting from 2014. Consequently, according to D.T.1.2., the hydromorphological processes that are affected by these actions are hydraulics, lateral connectivity, sediment continuity, river morphology, vertical connectivity, biotic communities, physical habitat, presence and composition of riparian vegetation, instream flow regime and biochemical cycling of chemical compounds.

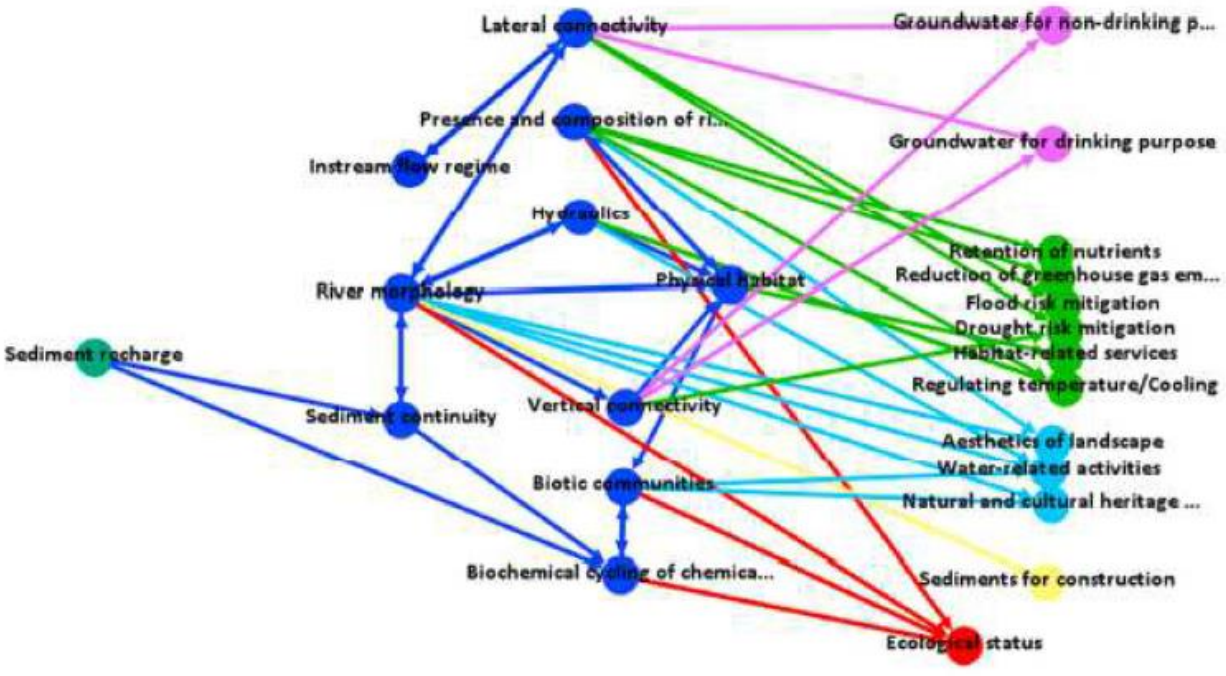

Figure 6 *Hydromorphological processes and ES for "sediment recharge" restoration action.*

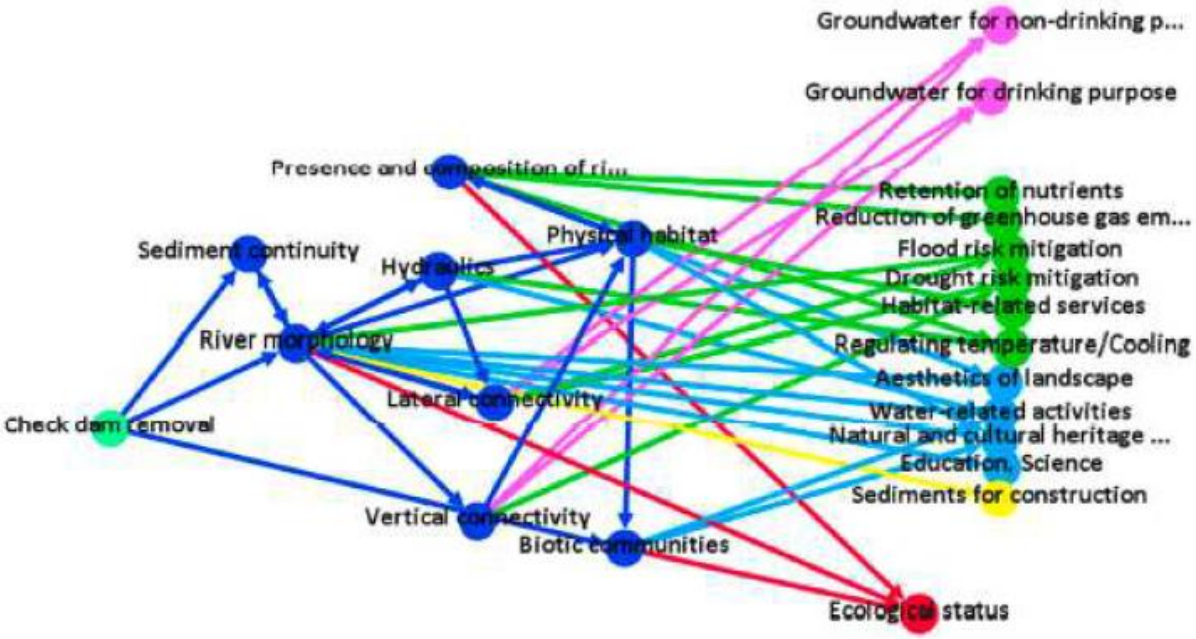

Figure 7 *Hydromorphological processes and ES for "check dam removal" restoration action.*

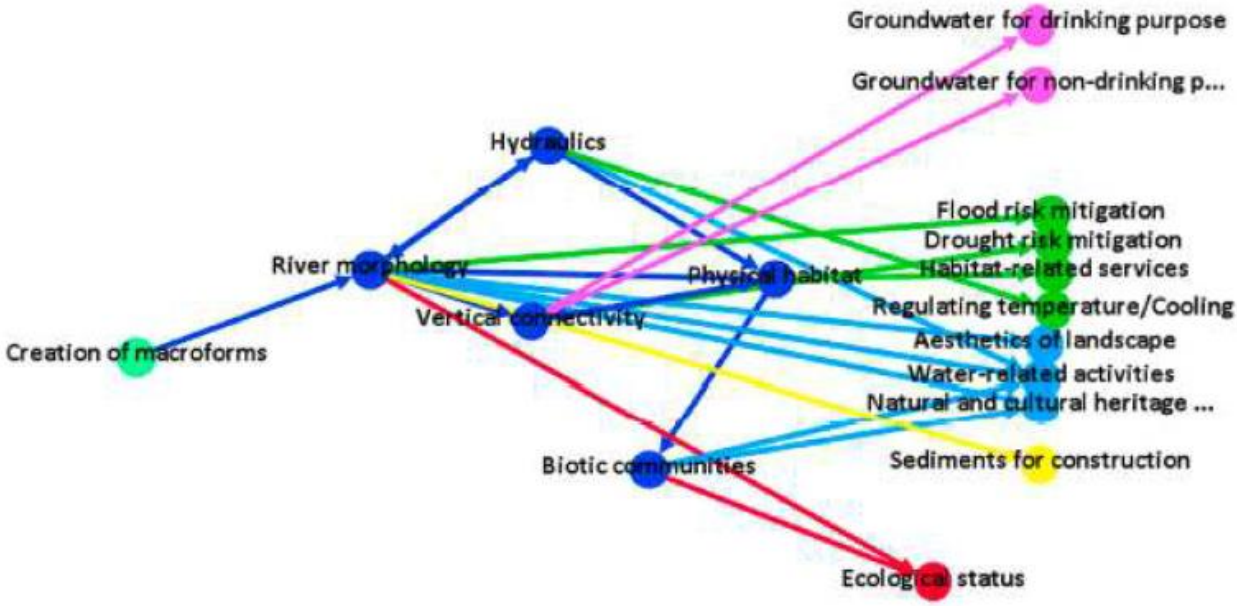

Figure 8 *Hydromorphological processes and ES for "creation of macroforms" restoration action.*

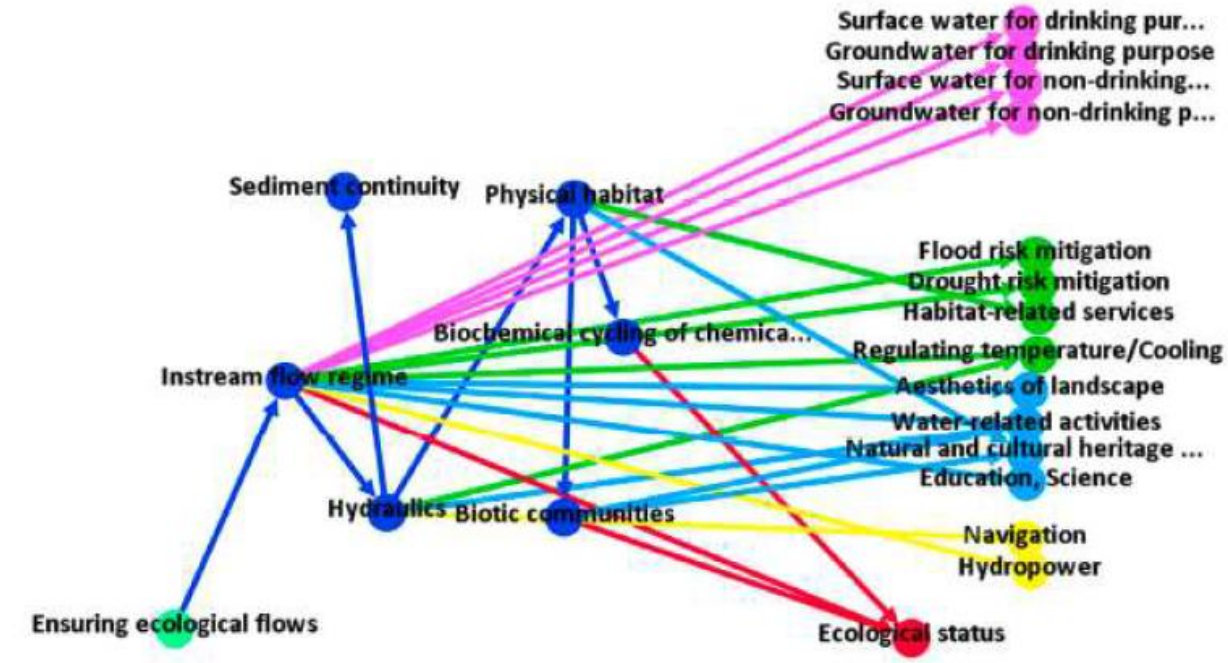

Figure 9 *Hydromorphological processes and ES for "ensuring ecological flows" restoration action.*

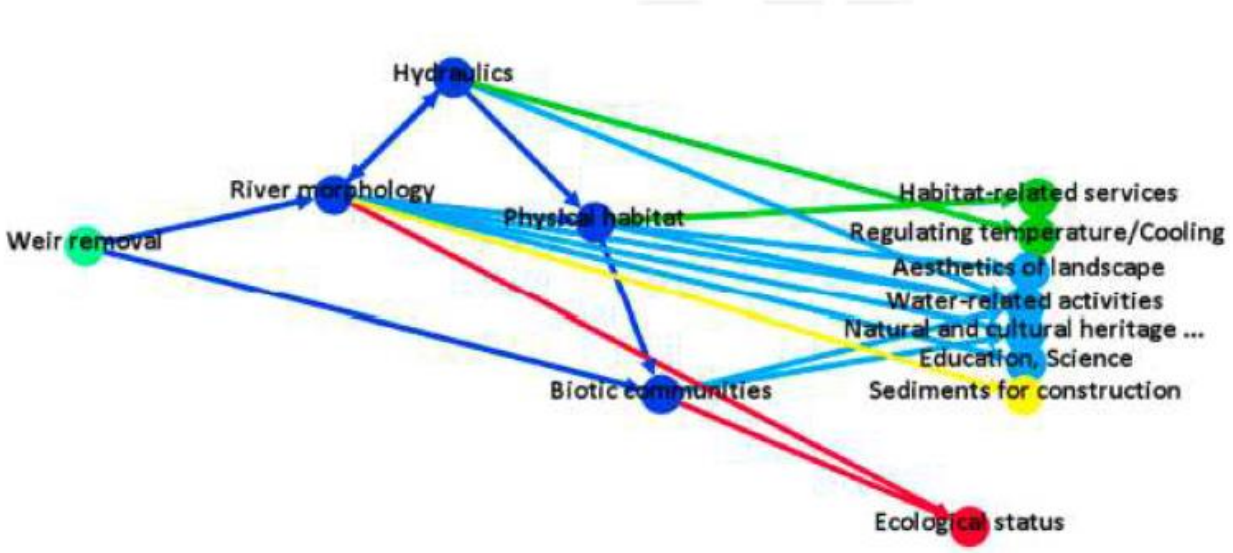

Figure 10 *Hydromorphological processes and ES for "weir removal" restoration action.*

1.3 Adige

This case study was divided into two sub-units, which are located away from each other, one is located in Postal/Burgstall between km 79 and 81 (km calculated from the source of the river) and the other is located in Ponte-Adige/Sigmundskron between km 97 and 99.

Figure 11 *Sub-unit 1 of Adige case study in Postal.*

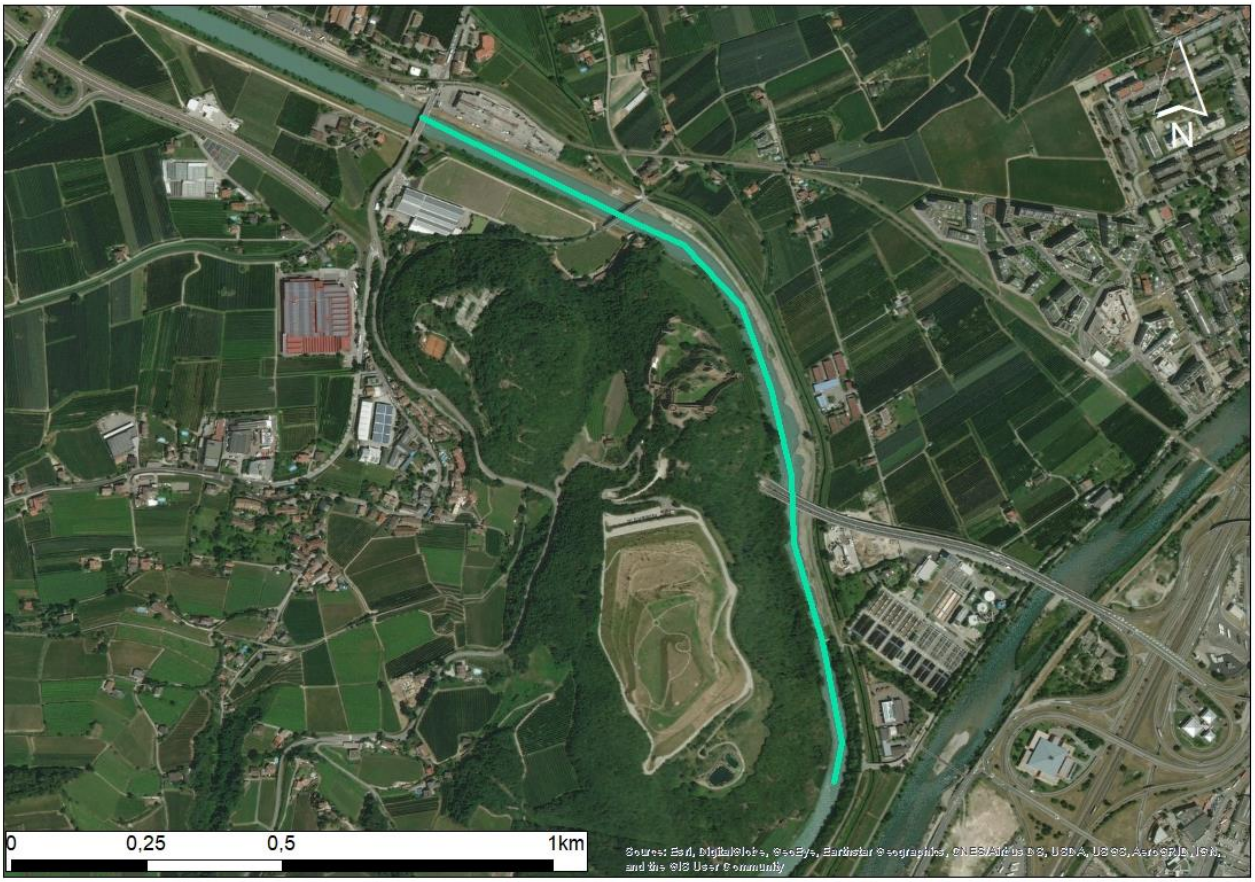

Figure 12 *Sub-unit 2 of Adige case study in Ponte Adige.*

Table 3 *Length and percentages of sub-units.*

ID	Lenght (m)	% Lenght
T1	1778,80	52,7
T2	1595,44	47,3

On both sites the restoration actions which were taken into consideration were channel widening and creation of macroforms. Consequently, according to D.T1.2.1, the hydromorphological processes that are affected by these actions are hydraulics, lateral connectivity, sediment continuity, river morphology, vertical connectivity, biotic communities, physical habitat, presence and composition of riparian vegetation, instream flow regime and biochemical cycling of chemical compounds.

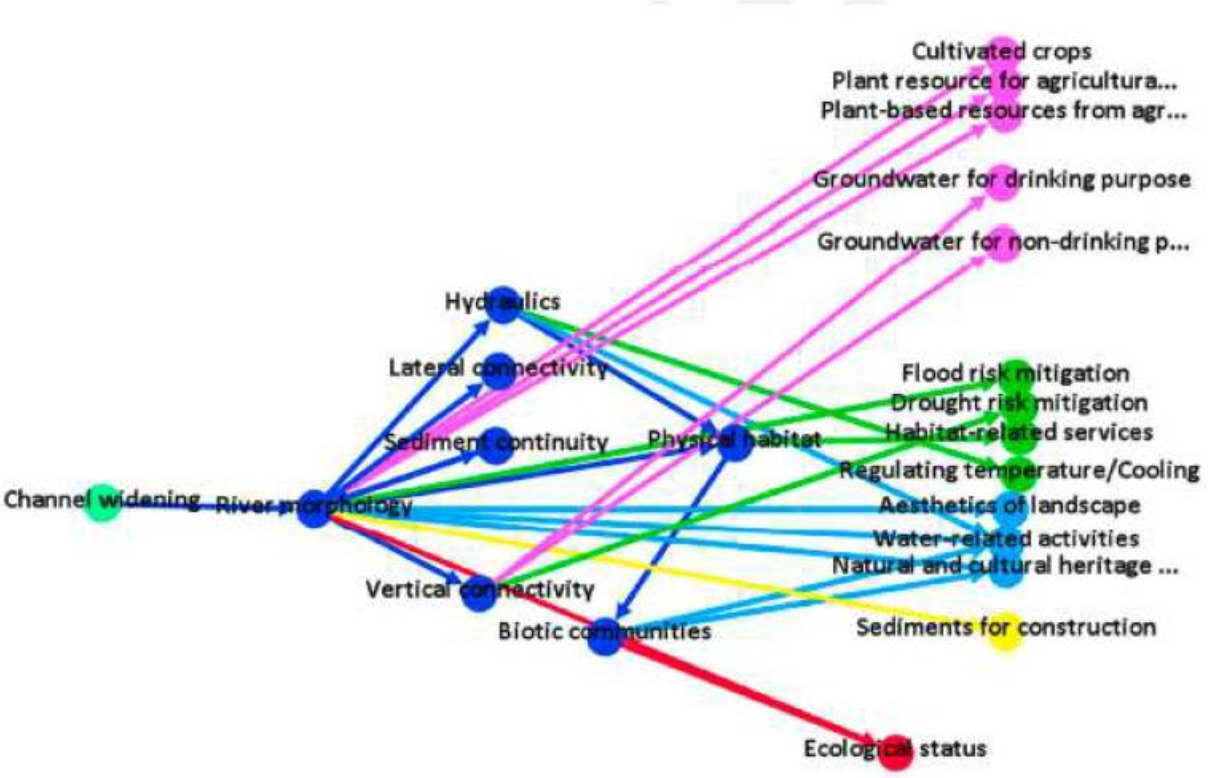

Figure 13 *Hydromorphological processes and ES for "channel widening" restoration action.*

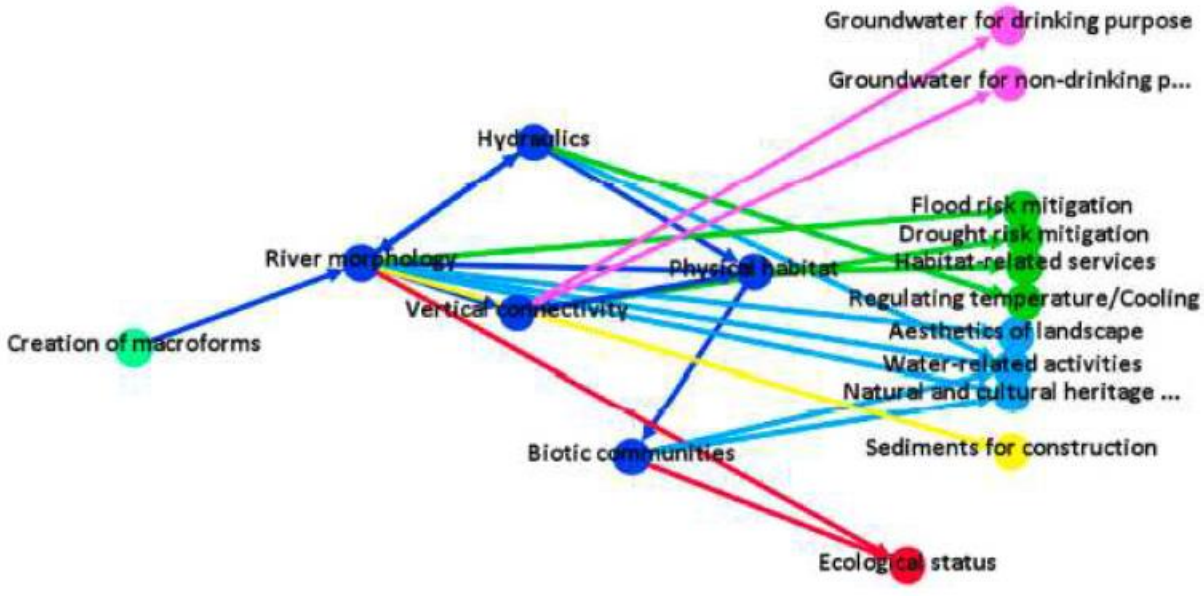

Figure 14 *Hydromorphological processes and ES for "creation of macroforms" restoration action.*

2 ES selection

2.1 Isarco River

Following the HyMoCARES framework, the ES affected by the restoration actions were selected according to its relevance for the specific site. The parameters used to describe the interaction between ES and functions were also selected according to its relevance for the site and the restoration action.

Table 4 *River ecosystem services suggested in deliverable D.T1.2.1 (2nd column), highlighted as relevant for the case studies (3rd column) and final selection by in.ge.na. of ES to evaluate (4th column).*

Ecosystem Service	Emerged from D.T1.2.1	Relevant for the case study ISARCO, selected by experts among HyMoCARES partners	Relevant ES for case study ISARCO, selected by ingena
Cultivated crops	x		
Plant resources for agricultural use - Pasture	x		
Surface water for drinking purpose	x	x	
Groundwater for drinking purpose	x	x	
Surface water for non-drinking purposes in industry and agriculture	x	x	
Ground water for non-drinking purposes in industry and agriculture	x	x	
Plant-based resources from agriculture, short rotation coppice, forestry	x		
Retention of nutrients	x		
Reduction of greenhouse gas emission / carbon sequestration	x	x	
Flood risk mitigation	x	x	x
Drought risk mitigation	x	x	
Soil formation in floodplains			
Regulating temperature/Cooling (water bodies and ground)	x	x	
Habitat-related services	x	x	x
Aesthetics of landscape	x	x	x
Natural and cultural heritage	x	x	x
Education, Science			

Water-related activities	x	x	x
Hydropower			
Navigation			
Sediments for construction	x		
Ecological status	x	x	x

2.2 Talvera River

Following the HyMoCARES framework, the ES affected by the restoration actions were selected according to its relevance for the specific site. The parameters used to describe the interaction between ES and functions were also selected according to its relevance for the site and the restoration action.

Table 5 *River ecosystem services suggested in deliverable D.T1.2.1 (2nd column), highlighted as relevant for the case studies (3rd column) and final selection by in.ge.na. of ES to evaluate (4th column).*

Ecosystem Service	**Emerged from D.T1.2.1**	**Relevant for the case study TALVERA, selected by experts among HyMoCARES partners**	**Relevant ES for case study TALVERA, selected by ingena**
Cultivated crops	x		
Plant resources for agricultural use - Pasture	x	x	
Surface water for drinking purpose	x	x	
Groundwater for drinking purpose	x	x	
Surface water for non-drinking purposes in industry and agriculture	x	x	
Ground water for non-drinking purposes in industry and agriculture	x	x	
Plant-based resources from agriculture, short rotation coppice, forestry	x		
Retention of nutrients	x		
Reduction of greenhouse gas emission / carbon sequestration	x		
Flood risk mitigation	x	x	x
Drought risk mitigation	x	x	
Soil formation in floodplains			
Regulating temperature/Cooling (water	x	x	

bodies and ground)			
Habitat-related services	x	x	x
Aesthetics of landscape	x	x	x
Natural and cultural heritage	x	x	x
Education, Science		x	x
Water-related activities	x	x	x
Hydropower			x
Navigation			
Sediments for construction	x		
Ecological status	x	x	x

2.3 Adige River

Following the HyMoCARES framework, the ES affected by the restoration actions were selected according to its relevance for the specific site. The parameters used to describe the interaction between ES and functions were also selected according to its relevance for the site and the restoration action.

Table 6 *River ecosystem services suggested in deliverable D.T1.2.1 (2nd column), highlighted as relevant for the case studies (3rd column) and final selection by in.ge.na. of ES to evaluate (4th column).*

Ecosystem Service	**Emerged from D.T1.2.1**	**Relevant for the case study ADIGE, selected by experts among HyMoCARES partners**	**Relevant ES for case study ADIGE, selected by ingena**
Cultivated crops	x		
Plant resources for agricultural use - Pasture	x		
Surface water for drinking purpose	x	x	
Groundwater for drinking purpose	x	x	
Surface water for non-drinking purposes in industry and agriculture	x	x	
Ground water for non-drinking purposes in industry and agriculture	x	x	
Plant-based resources from agriculture, short rotation coppice, forestry	x	x	
Retention of nutrients	x		
Reduction of greenhouse gas emission	x		

/ carbon sequestration			
Flood risk mitigation	x	x	x
Drought risk mitigation	x	x	
Soil formation in floodplains		x	
Regulating temperature/Cooling (water bodies and ground)	x	x	
Habitat-related services	x	x	x
Aesthetics of landscape	x	x	x
Natural and cultural heritage	x	x	x
Education, Science			x
Water-related activities	x	x	x
Hydropower		x	
Navigation			
Sediments for construction	x		
Ecological status	x	x	x

3 ES analysis

3.1 Isarco River

An analysis based on a before-after design was carried out in order to evaluate the difference between the ES on the river before and after the restoration. In the following table (Table 7) there is the list of indicators and data used to calculate the ES.

Table 7 *Selected ES for the Isarco case study, indicators and parameters.*

ES	**Indicators according to D.T1.3.1**	**Indicators according to in.ge.na**	**Data**
Aesthetics of the landscape	MQI	Naturalness and specificity scaled with disturbing factors	MQI, foto-documentation, survey
Habitat related ES		Biological water quality change in populations characteristics of aquatic communities	(N)ISECI, STAR.ICM, ICMi, raw data on diatoms, macrozoobenthos and fishes
Flood risk mitigation		Hazard risk maps	Hazard risk maps
Natural and cultural heritage	Presence of rare species (target species)	Fish population structure, typical morphological river structures	(N)ISECI, raw data on fish community
Ecological status	WFD		MQI, (N)ISECI, STAR_ICMi, ICMi, raw data on diatoms, macrozoobenthos and fishes
Water-related activities	WFD	Accessibility of the river	(N)ISECI, MQI, disturbing factors

3.1.1 Aesthetics of landscape

Table 8 *Evaluation of the Indicators chosen to calculate the ES aesthetics of the landscape.*

Naturalness		
Sub-unit	**Pre**	**Post**
T1	MQI 0,4 Natural elements 0,6 Protection status 0,5 TOT: 0,5	MQI 0,4 Natural elements 0,6 Protection status 0,5 TOT: 0,5
T2	MQI 0,4 Natural elements 0,4 Protection status 0,5 TOT: 0,4	MQI 0,6 Natural elements 0,4 Protection status 0,5 TOT: 0,5
Specificity		
Sub-unit	**Pre**	**Post**
T1	0,25	0,25
T2	0,25	0,25
Downscaling due to disturbing elements		
Sub-unit	**Pre**	**Post**
T1	- 2 steps	- 2 steps
T2	- 2 steps	- 2 steps

Table 9 *Calculation of the ES aesthetics of the landscape.*

Aesthetics of landscape				
Sub-unit	**Pre**	**Downscaling due to disturbing elements**	**Post**	**Downscaling due to disturbing elements**
T1	0,1[1]	-2 steps	0,1	-2 steps
T2	0,1	-2 steps	0,1	-2 steps
Difference between pre and post restoration				
T1	0			
T2	0			

[1] Downscaled result. Not downscaled results: T1 pre= 0,35; T1 post= 0,35; T2 pre= 0,35; T2 post= 0,4.

3.1.2 Habitat related ES

Table 10 *Evaluation of the Indicators chosen to calculate the ES habitat related ES.*

ICMi		
Sub-unit	**Pre**	**Post**
T1	NoData	NoData
T2	1	0,8
STAR-ICMi		
Sub-unit	**Pre**	**Post**
T1	NoData	NoData
T2	1	1
(N)ISECI		
Sub-unit	**Pre**	**Post**
T1	0,8	0,8
T2	0,8	0,8
Biological water quality		
Sub-unit	**Pre**	**Post**
T1	NoData	NoData
T2	0,8	0,8
Population structure of taxa		
Diatoms		
Sub-unit	**Pre**	**Post**
T1	0 [2]	0,5
T2	0	0,5
Macrozoobenthos		
Sub-unit	**Pre**	**Post**
T1	0	0,5
T2	0	0,5

[2] 0 not because the population structure is bad, but because the difference between pre and post restoration should be respectively 0,5, 0,5 and 0,7.

Fishes		
Sub-unit	**Pre**	**Post**
T1	0	0,75
T2	0	0,75

Table 11 *Calculation of the ES habitat related ES.*

Habitat related ES		
Sub-unit	**Pre**	**Post**
T1	NoData	NoData
T2	0,4	0,7
Sub-unit	**Difference between pre and post restoration**	
T1	-	
T2	+ 0,3	

3.1.3 Flood risk mitigation

Table 12 *Calculation of the ES flood risk mitigation.*

Flood risk mitigation		
Sub-unit	**Pre**	**Post**
T1	1	1
T2	0,5	0,5
Difference between pre and post restoration		
T1	0	
T2	0	

3.1.4 Natural and cultural heritage

Table 13 *Calculation of the ES natural and cultural heritage.*

Natural and cultural heritage		
Sub-unit	**Pre**	**Post**
T1	(0,8+0,5) /2=0,7	(0,8+0,75) /2=0,8
T2	(0,8+0,25) /2=0,5	(0,8+0,5) /2=0,7
Difference between pre and post restoration		
T1	+0,1	
T2	+0,2	

3.1.5 Ecological status

Table 14 *Evaluation of the Indicators chosen to calculate the ES ecological status.*

MQI		
Sub-unit	**Pre**	**Post**
T1	0,4	0,4
T2	0,4	0,6
Biological water quality		
Sub-unit	**Pre**	**Post**
T1	NoData	NoData
T2	0,8	0,8
Population structure		
T1	0 [3]	0,6
T2	0	0,6

[3] 0 not because the population structure is bad, but because the difference between pre and post restoration should be 0,6.

Table 15 *Calculation of the ES ecological status.*

Ecological status		
Sub-unit	**Pre**	**Post**
T1	NoData	NoData
T2	0,4	0,6
Difference between pre and post restoration		
T1	-	
T2	+0,2	

3.1.6 Water related activitites

Table 16 *Evaluation of the Indicators chosen to calculate the ES Water related activities.*

MQI		
Sub-unit	**Pre**	**Post**
T1	0,4	0,4
T2	0,4	0,6
(N)ISECI		
Sub-unit	**Pre**	**Post**
T1	(N)ISECI 0,8 Population structure 0 TOT 0,4	(N)ISECI 0,8 Population structure 0,75 TOT 0,8
T2	(N)ISECI 0,8 Population structure 0 TOT 0,4	(N)ISECI 0,8 Population structure 0,75 TOT 0,8
Recreational use		
Sub-unit	**Pre**	**Post**
T1	0,5	1
T2	0,5	1
Downscaling due to disturbing elements		
Sub-unit	**Pre**	**Post**
T1	-1	-1
T2	-1	-1

Table 17 *Calculation of the ES water related activities.*

Water related activities				
Sub-unit	**Pre**	**Downscaling due to disturbing elements**	**Post**	**Downscaling due to disturbing elements**
T1	0,2[4]	- 1 Stufe	0,5	- 1 Stufe
T2	0,2	- 1 Stufe	0,6	- 1 Stufe
Difference between pre and post restoration				
T1	+0,2			
T2	+0,2			

[4] Downscaled result. Not downscaled results: T1 pre= 0,4; T1 post= 0,4; T2 pre= 0,85; T2 post= 1,1.

Table 18 *Summary of ES values in subunit T1 before and after the restoration.*

ES	Pre	Post
AES	0,1	0,1
HS	NoData	NoData
FP	1	1
NCH	0,7	0,8
EST	NoData	NoData
WA	0,2	0,5

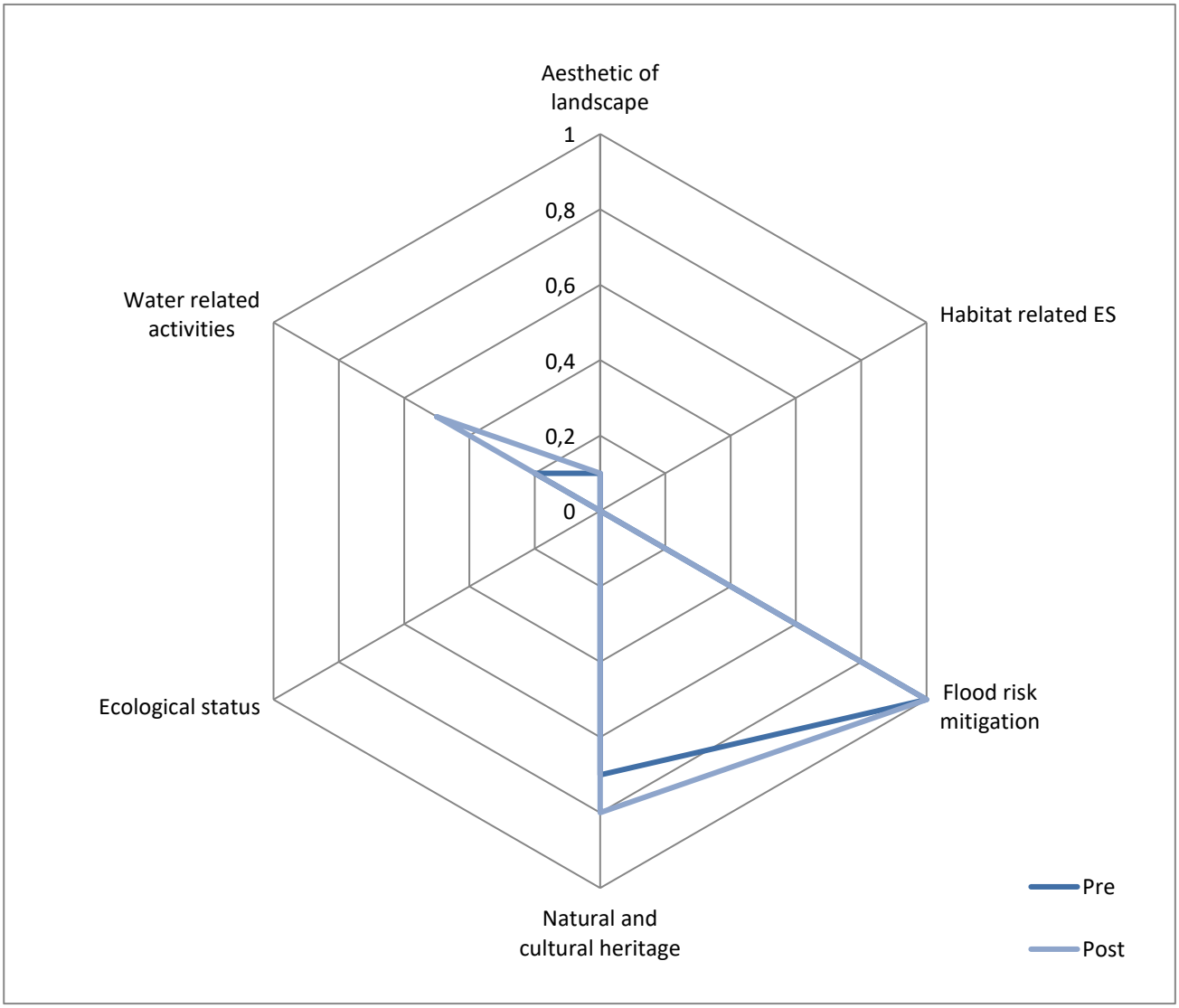

Figure 15 *Graphical summary of ES values in subunit T1 before and after the restoration.*

Table 19 *summary of ES values in subunit T2 before and after the restoration.*

ES	Pre	Post
AES	0,25	0,25
HS	0,4	0,7
FP	0,5	0,5
NCH	0,5	0,7
EST	0,4	0,7
WA	0,2	0,6

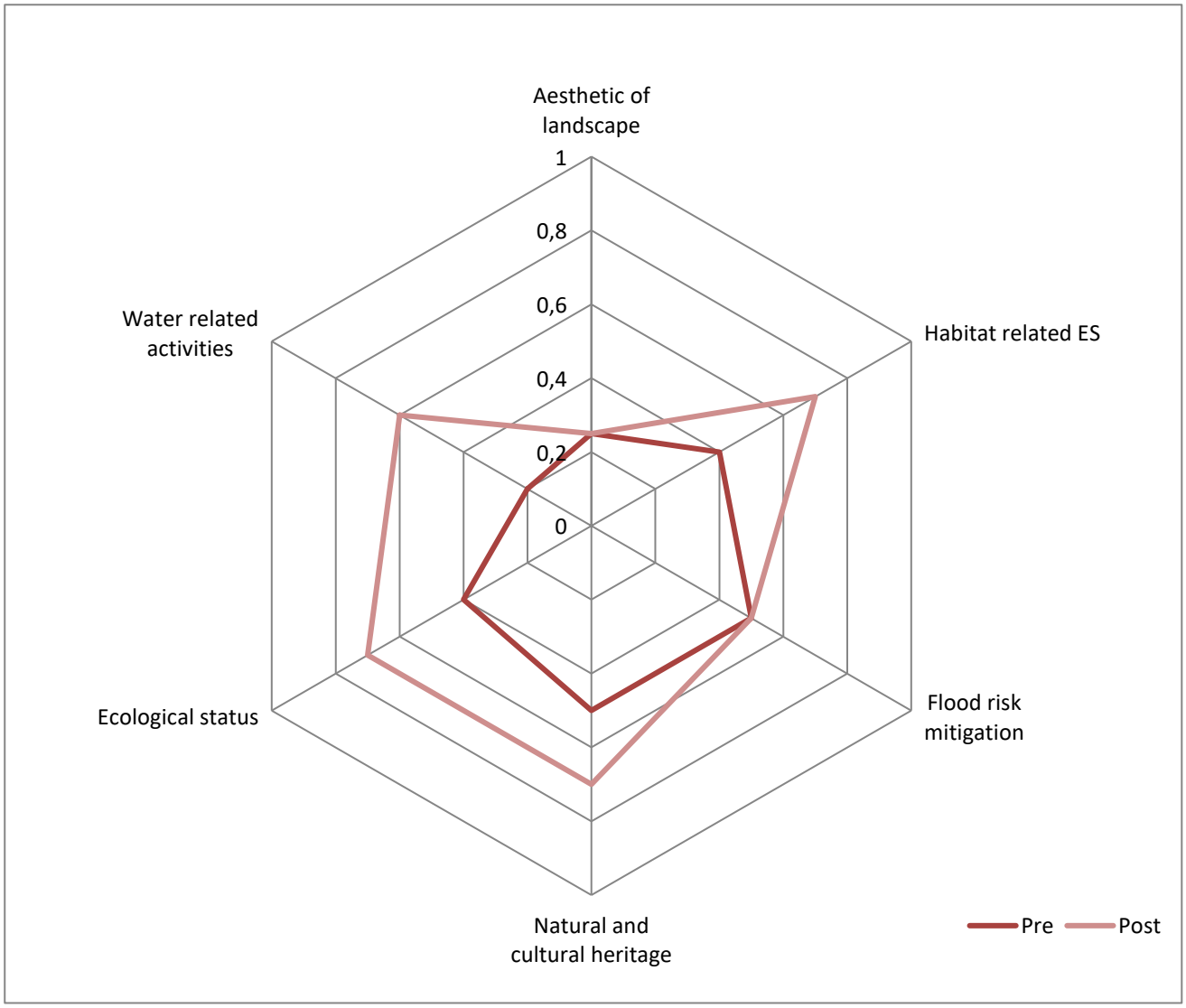

Figure 16 *Graphical summary of ES values in subunit T2 before and after the restoration.*

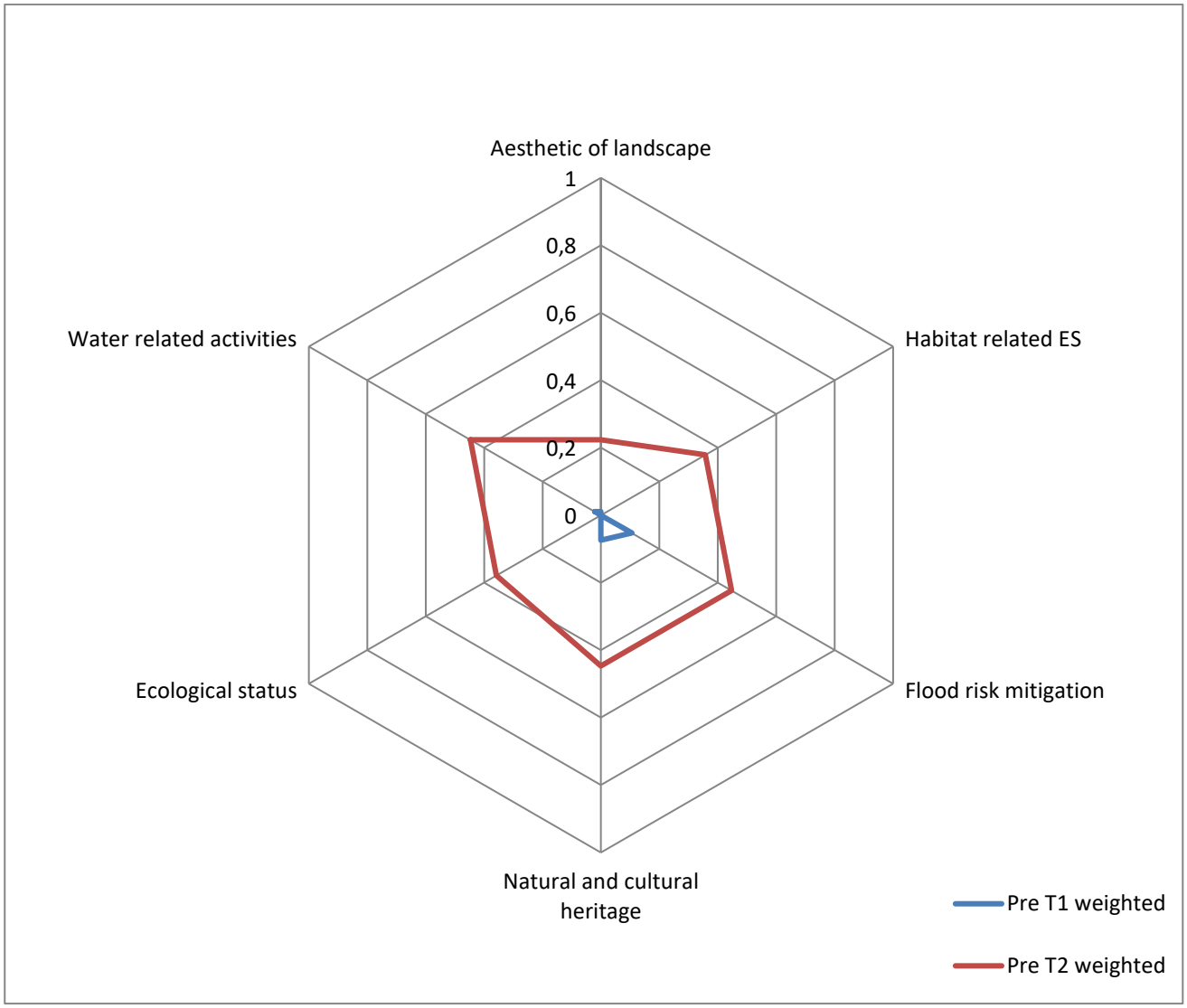

Figure 17 *Summary of weighted ES values of both subunits before the restoration*

Table 20 *Summary of unweigthed and weighted ES values on subunit T1 and T2 before restoration.*

ES	Pre T1	Pre T1 weighted	Pre T2	Pre T2 weighted
Aesthetics of landscape	0,1	0,011	0,25	0,22
Habitat related ES	NoData	NoData	0,4	0,36
Flood risk mitigation	1	0,11	0,5	0,45
Natural and cultural heritage	0,7	0,07	0,5	0,45
Ecological status	NoData	NoData	0,4	0,36
Water related ES	0,2	0,02	0,5	0,5

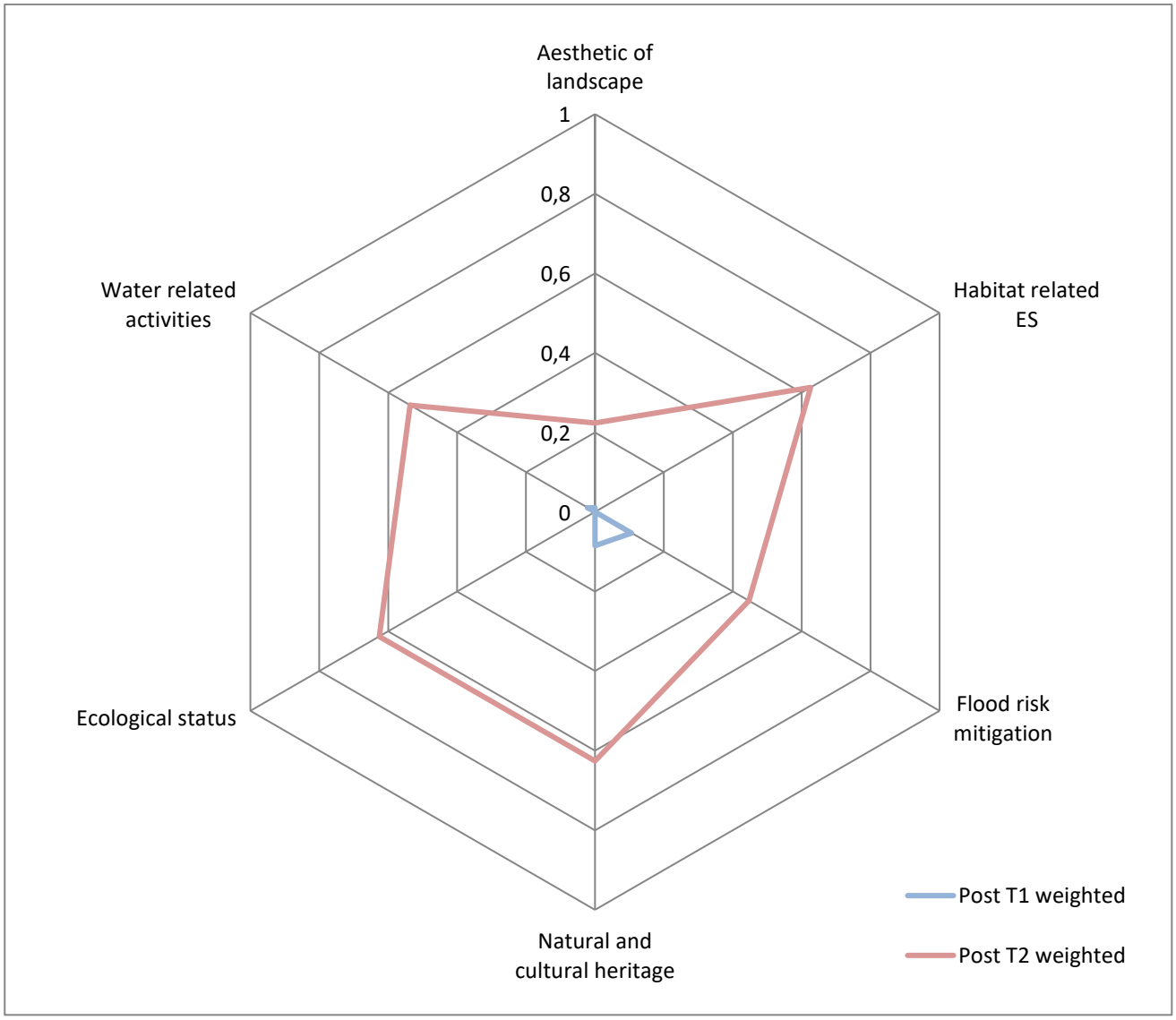

Figure 18 *Summary of weighted ES values of both subunits after the restoration.*

Table 21 *Summary of unweigthed and weighted ES values on subunit T1 and T2 after restoration.*

ES	Post	Post T1 weighted	Post	Post T2 weighted
Aesthetic of landscape	0,1	0,011	0,25	0,22
Habitat related ES	NoData	NoData	0,7	0,63
Flood risk mitigation	1	0,106	0,5	0,447
Natural and cultural heritage	0,8	0,09	0,7	0,63
Ecological status	NoData	NoData	0,6	0,54
Water related ES	0,2	0,0212	0,6	0,5364

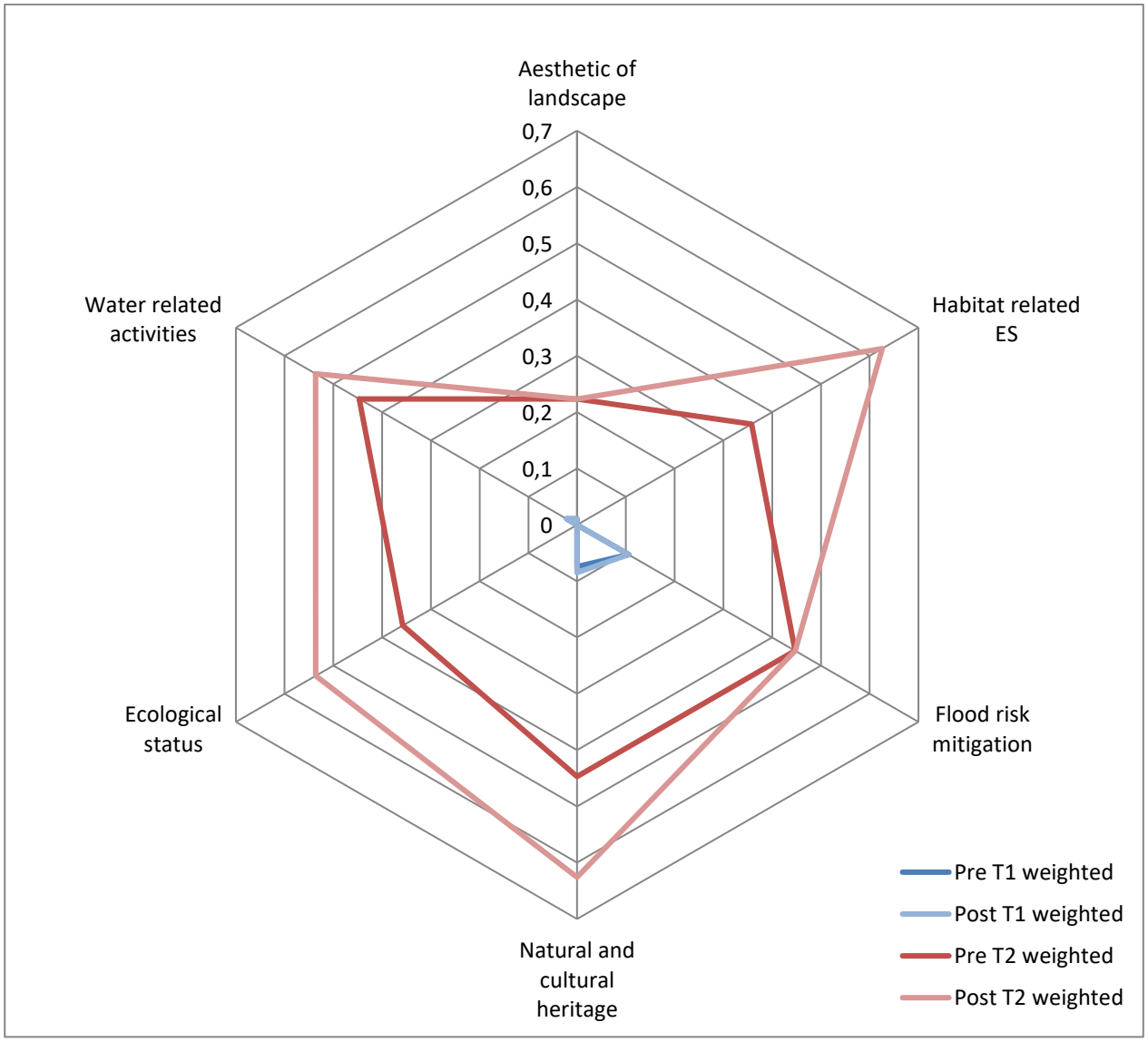

Figure 19 Summary of weighted ES values on subunits T1 and T2 before and after the restoration.

3.2 Talvera River

A before-after analysis was carried out in order to evaluate the difference between the ES on the river before and after the restoration. In the following table (Table 22) there is the list of indicators and data used to calculate the ES.

Table 22 *Selected ES for the Talvera case study, indicators and parameters.*

ES	Indicators according to D.T1.3.1	Indicators according to in.ge.na	Data
Aesthetics of the landscape	MQI	Naturalness and specificity scaled with disturbing factors	MQI, foto-documentation, survey
Education and science		Number of sampling sites and sampling dates	Number of sampling sites and sampling dates
Habitat related ES		Biological water quality, populations structure of aquatic communities	(N)ISECI, STAR.ICM, ICMi, raw data on diatoms, macrozoobenthos and fishes
Flood risk mitigation		Hazard risk maps	Hazard risk maps
Hydropower	Hydropower production (Hydropower/year)		
Natural and cultural heritage	Presence of rare species (target species)	Fish population structure, typical morphological river structures	(N)ISECI, raw data on fish community
Ecological status	WRR		MQI, (N)ISECI, STAR_ICMi, ICMi, raw data on diatoms, macrozoobenthos and fishes
Water-related activities	WRR	Accessibility of the river	(N)ISECI, MQI, disturbing factors

3.2.1 Aestethics of landscape

Table 23 *Evaluation of the Indicators chosen to calculate the ES aesthetics of landscape.*

Naturalness		
Sub-unit	**Pre**	**Post**
T1	MQI 0,2 Natural elementes 0,2 Protection status 0,4 TOT 0,3	MQI 0,8 Natural elements 0,6 Protection status 0,4 TOT 0,6
T2	MQI 0,6 Natural elements 0,2 Protection status 0,4 TOT 0,4	MQI 0,4 Natural elements 0,6 Protection status 0,4 TOT 0,5
T3	MQI 0,6 Natural elements 0,2 Protection status 0,4 TOT 0,4	MQI 0,6 Natural elements 0,6 Protection status 0,4 TOT 0,5
T4	MQI 0,4 Natural elements 0,2 Protection status 0,4 TOT 0,3	MQI 0,6 Natural elements 0,6 Protection status 0,4 TOT 0,5
Specificity		
Sub-unit	**Pre**	**Post**
T1	0,2	0,2
T2	0,2	0,2
T3	0,2	0,2
T4	0,2	0,2
Downscaling due to disturbing elements		
T1	-1 step	-1 step
T2	-1 step	-1 step
T3	-1 step	-1 step
T4	-1 step	-1 step

Table 24 *Calculation of the ES aesthetics of landscape.*

Aesthetics of landscape				
Sub-unit	**Pre**	**Downscaling due to disturbing factors**	**Post**	**Downscaling due to disturbing factors**
T1	0,1[5]	-1 step	0,2	-1 step
T2	0,1	-1 step	0,2	-1 step
T3	0,2	-1 step	0,2	-1 step
T4	0,1	-1 step	0,2	-1 step
Difference between pre and post restoration				
T1	+0,1			
T2	+0,1			
T3	0			
T4	+0,1			

3.2.2 Education and science

Table 25 *Evaluation of the indicators chosen to calculate the ES education and science.*

Number of sampling sites		
Sub-unit	**Pre**	**Post**
T1	0,2	0,2
T2	0,2	0,2
T3	0,2	0,2
T4	0,6	0,6
Number of sampling dates		
Sub-unit	**Pre**	**Post**
T1	0,2	0,2
T2	0,2	0,2
T3	0,2	0,2
T4	0,6	0,6

[5] Downscaled result. Not downscaled results: T1 pre = 0,2; T1 post = 0,45; T2 pre = 0,3; T2 post = 0,35; T3 pre = 0,3; T3 post = 0,4; T4 pre = 0,25; T4 post = 0,4.

Number of information signs		
Sub-unit	**Pre**	**Post**
T1	0,2	0,2
T2	0,2	0,2
T3	0,2	0,2
T4	0,2	0,2
Education and science		
Sub-unit	**Pre**	**Post**
T1	0,2	0,2
T2	0,2	0,2
T3	0,2	0,2
T4	0,5	0,5
Difference between pre and post restoration		
T1	NoData	
T2	NoData	
T3	NoData	
T4	NoData	

3.2.3 Habitat related ES

Table 26 *Evaluation of the Indicators chosen to calculate the ES habitat related ES.*

ICMi		
Sub-unit	**Pre**	**Post**
T1	NoData	NoData
T2	NoData	NoData
T3	NoData	NoData
T4	1	1
STAR-ICMi		
Sub-unit	**Pre**	**Post**
T1	NoData	NoData
T2	NoData	NoData
T3	NoData	NoData
T4	1	0,8

(N)ISECI		
Sub-unit	**Pre**	**Post**
T1	NoData	NoData
T2	NoData	NoData
T3	NoData	NoData
T4	0,8	0,8
Biological water quality		
Sub-unit	**Pre**	**Post**
T1	NoData	NoData
T2	NoData	NoData
T3	NoData	NoData
T4	0,8	0,8
Population structure		
Diatoms		
Sub-unit	**Pre**	**Post**
T1	0	0,6
T2	0	0,6
T3	0	0,6
T4	0	0,6
Macrozoobenthos		
Sub-unit	**Pre**	**Post**
T1	0	0,6
T2	0	0,6
T3	0	0,6
T4	0	0,6
Fishes		
Sub-unit	**Pre**	**Post**
T1	0	0,75
T2	0	0,75
T3	0	0,75
T4	0	0,75

Table 27 *Calculation of the ES habitat related ES.*

Habitat related ES		
Sub-unit	**Pre**	**Post**
T1	NoData	NoData
T2	NoData	NoData
T3	NoData	NoData
T4	0,4	(0,7+0,7+0,8)/3= 0,7
Difference between pre and post restoration		
T1	-	
T2	-	
T3	-	
T4	+0,3	

3.2.4 Flood risk mitigation

Table 28 *Evaluation of the indicators chosen to calculate the ES flood risk mitigation.*

Flood risk mitigation		
Sub-unit	**Pre**	**Post**
T1	0,25	0,25
T2	0,25	0,25
T3	0,5	0,5
T4	0,5	0,5
Difference between pre and post restoration		
T1	0	
T2	0	
T3	0	
T4	0	

3.2.5 Hydropower

This ES cannot yet be evaluated, because the restoration action has not yet been completed. At the time of writing, the new plant is not yet fully functional.

3.2.6 Natural and cultural heritage

Table 29 *Calculation of the ES natural and cultural heritage.*

Natural and cultural heritage		
Sub-unit	**Pre**	**Post**
T1	NoData	NoData
T2	NoData	NoData
T3	NoData	NoData
T4	(0,8+0,4)/2= 0,6	(0,8+0,6)/2= 0,7
Difference between pre and post restoration		
T1	-	
T2	-	
T3	-	
T4	+ 0,1	

3.2.7 Ecological status

Table 30 *Evaluation of the Indicators chosen to calculate the ES ecological status.*

MQI		
Sub-unit	**Pre**	**Post**
T1	0,2	0,8
T2	0,6	0,4
T3	0,6	0,6
T4	0,4	0,6
Biological water quality		
Sub-unit	**Pre**	**Post**
T1	NoData	NoData
T2	NoData	NoData
T3	NoData	NoData
T4	0,8	0,8

Population structure		
T1	0	0,7
T2	0	0,7
T3	0	0,7
T4	0	0,7

Table 31 *Calculation of the ES ecological status.*

Ecological status		
Sub-unit	**Pre**	**Post**
T1	NoData	NoData
T2	NoData	NoData
T3	NoData	NoData
T4	0,4	0,7
Difference between pre and post restoration		
T1	-	
T2	-	
T3	-	
T4	+0,3	

3.2.8 Water related activities

Table 32 *Evaluation of the Indicators chosen to calculate the ES water related activities.*

MQI		
Sub-unit	**Pre**	**Post**
T1	0,2	0,8
T2	0,6	0,4
T3	0,6	0,6
T4	0,4	0,6
(N)ISECI		
Sub-unit	**Pre**	**Post**
T1	(N)ISECI NoData Population structure 0 TOT NoData	(N)ISECI NoData Population structure 0,7 TOT NoData

T2	(N)ISECI NoData Population structure 0 TOT NoData	(N)ISECI NoData Population structure 0,7 TOT NoData
T3	(N)ISECI NoData Population structure 0 TOT 0	(N)ISECI NoData Population structure 0,7 TOT NoData
T4	(N)ISECI 0,8 Population structure 0 TOT 0,4	(N)ISECI 0,8 Population structure 0,7 TOT 0,8
Recreational use		
Sub-unit	**Pre**	**Post**
T1	0,25	0,5
T2	0,25	0,5
T3	0,25	0,5
T4	0,25	0,5
Downscaling due to disturbing factors		
Sub-unit	**Pre**	**Post**
T1	-1 step	-1 step
T2	-1 step	-1 step
T3	-1 step	-1 step
T4	-1 step	-1 step

Table 33 *Calculation of the ES water related activities.*

Water-related activities				
Sub-unit	**Pre**	**Downscaling due to disturbing factors**	**Post**	**Downscaling due to disturbing factors**
T1	NoData		NoData	
T2	NoData		NoData	
T3	NoData		NoData	
T4	0,1[6]	-1 step	0,4	-1 step

[6] Downscaled result. Not downscaled results T4 pre = 0,3 und T4 post = 0,6.

Difference between pre and post restoration	
T1	-
T2	-
T3	-
T4	0,3

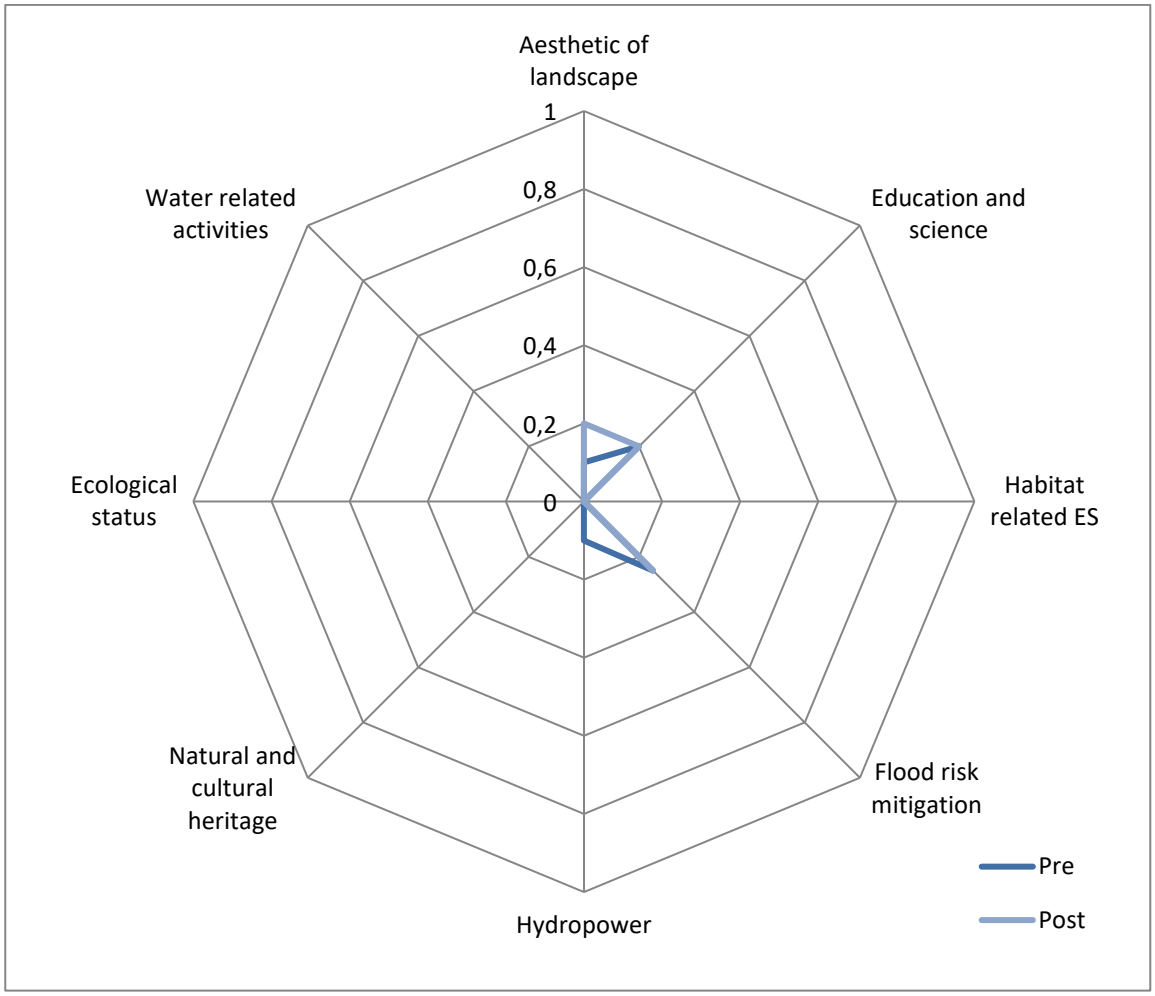

Figure 20 *Graphical summary of ES values in subunit T1 before and after the restoration.*

Table 34 *Summary of ES values in subunit T1 before and after the restoration.*

ES	Pre	Post
AES	0,1	0,2
EDU	0,2	0,2
HAB	NoData	NoData
FRM	0,25	0,25
HYP	0,1	NoData
HER	NoData	NoData
ECO	NoData	NoData

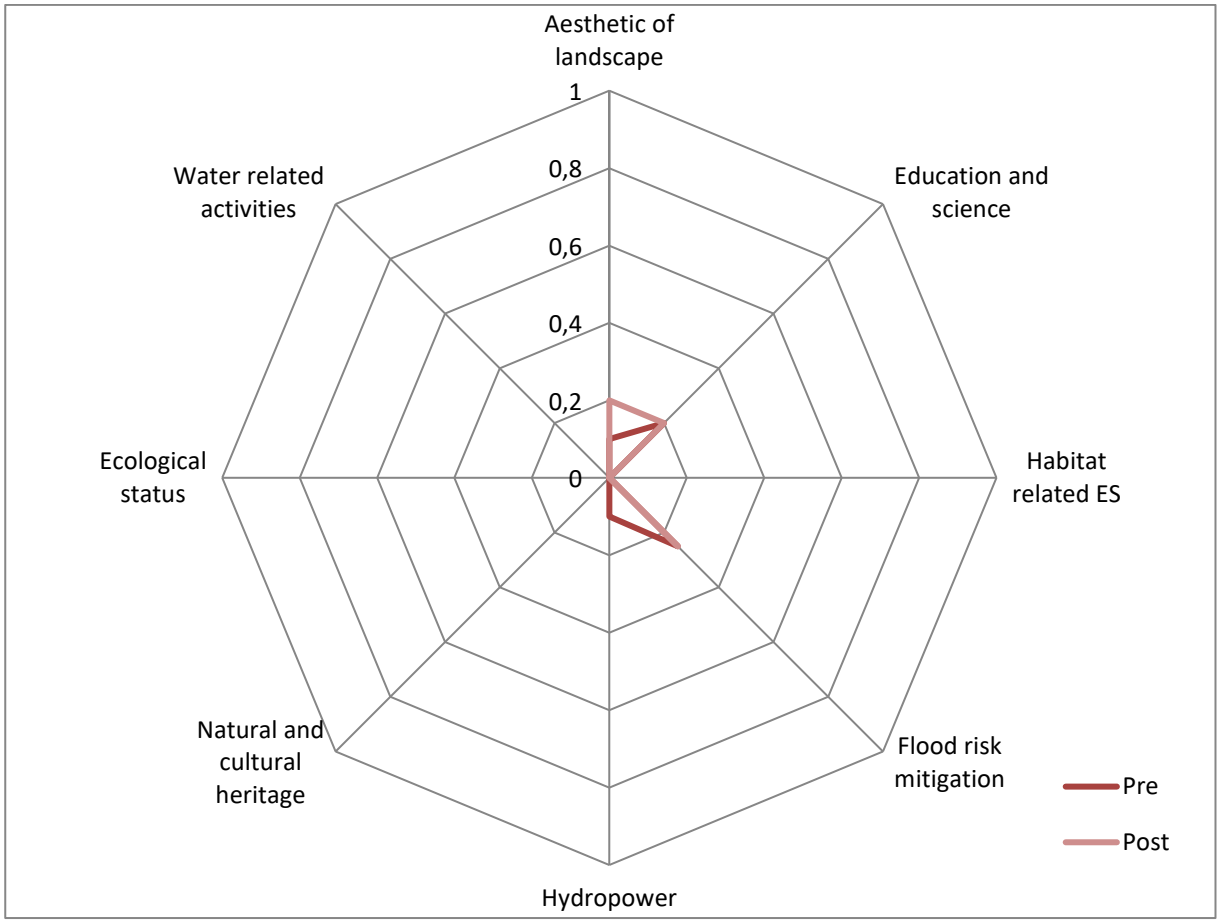

Figure 21 *Graphical summary of ES values in subunit T2 before and after the restoration.*

Table 35 *Summary of ES values in subunit T2 before and after the restoration.*

ES	Pre	Post
AES	0,1	0,2
EDU	0,2	0,2
HAB	NoData	NoData
FRM	0,25	0,25
HYP	0,1	NoData
HER	NoData	NoData
ECO	NoData	NoData
AES	NoData	NoData

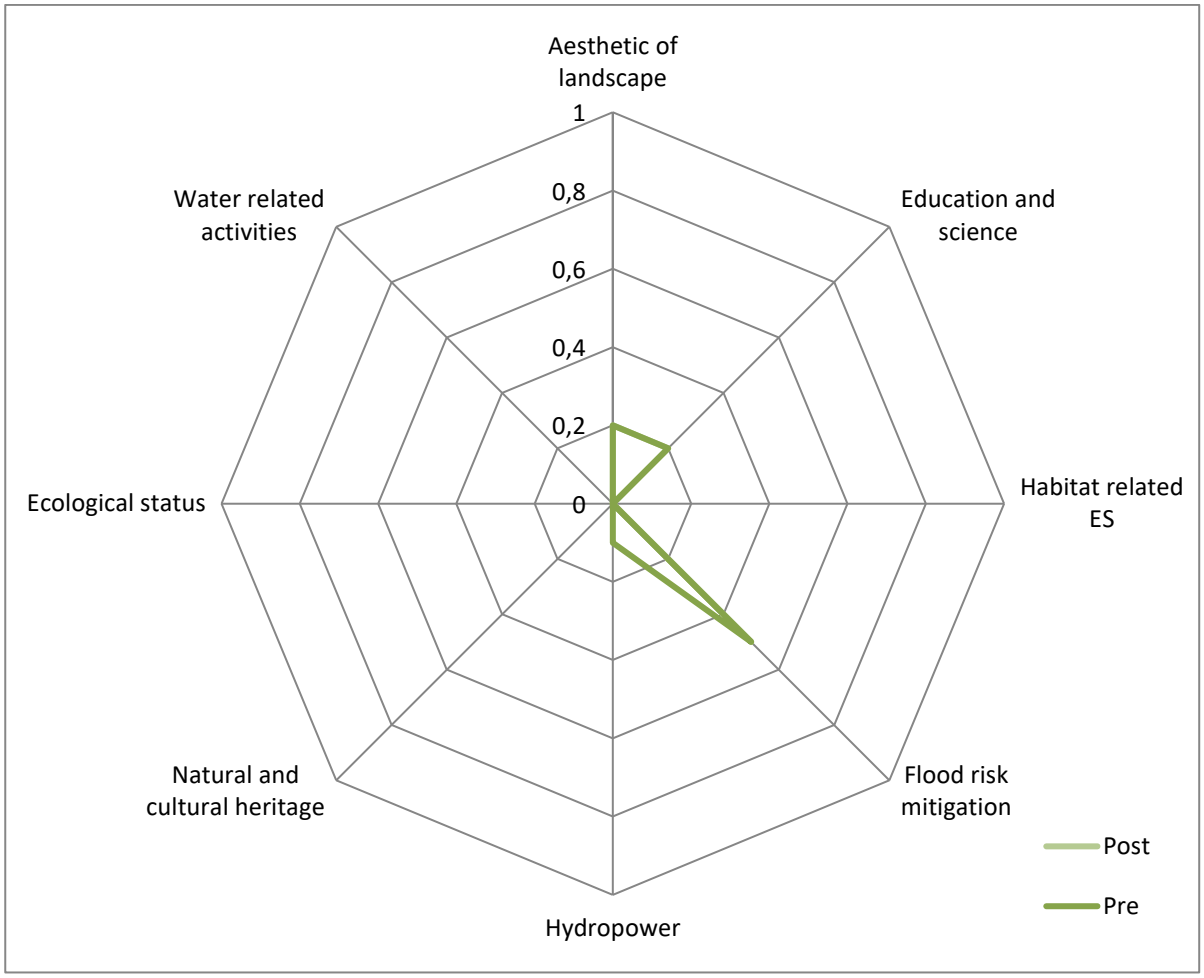

Figure 22 *Graphical summary of ES values in subunit T3 before and after the restoration.*

Table 36 *Summary of ES values in subunit T3 before and after the restoration.*

ES	Pre	Post
AES	0,2	0,2
EDU	0,2	0,2
HAB	NoData	NoData
FRM	0,5	0,5
HYP	0,1	NoData
HER	NoData	NoData
ECO	NoData	NoData
AES	NoData	NoData

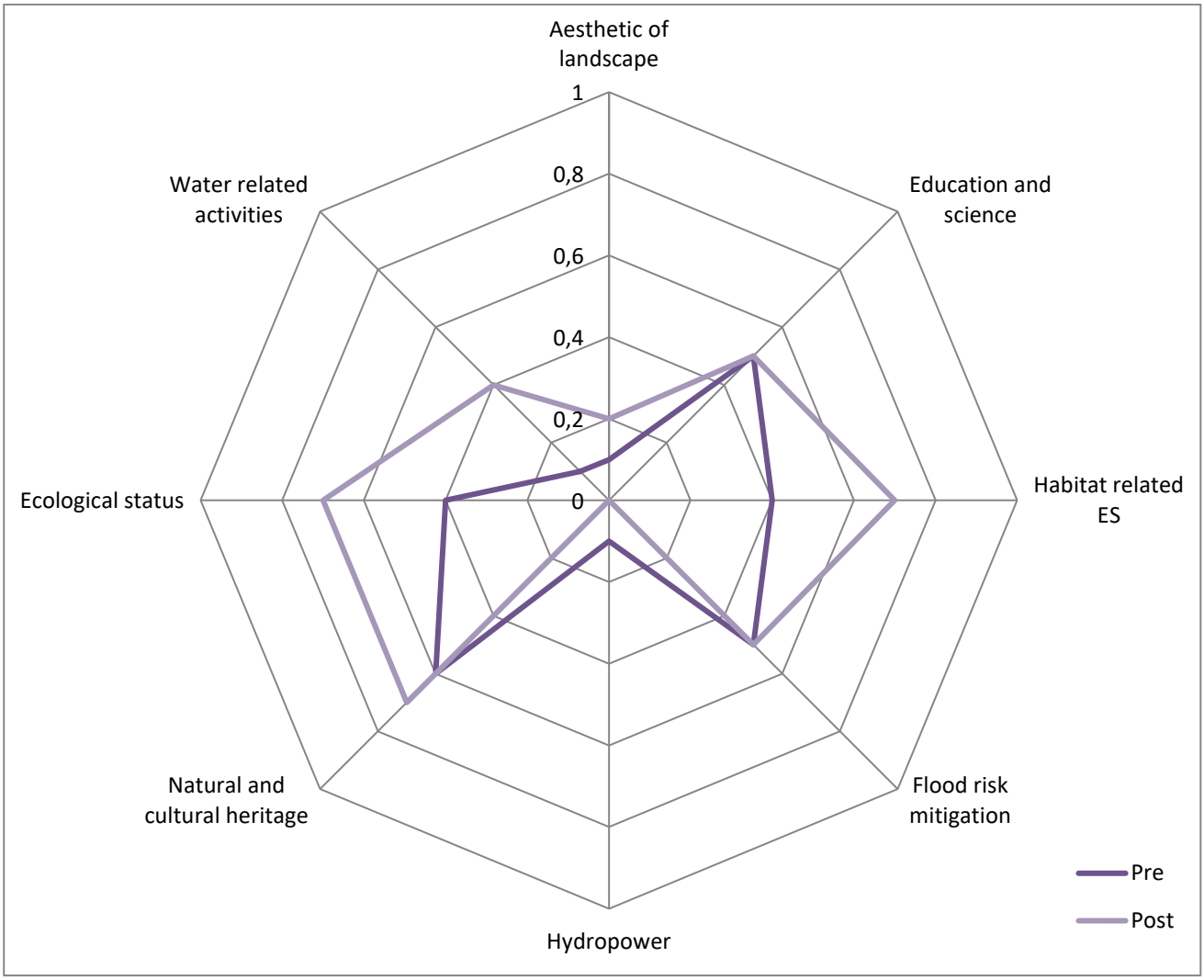

Figure 23 *Graphical summary of ES values in subunit T4 before and after the restoration.*

Table 37 *Summary of ES values in subunit T4 before and after the restoration.*

ES	Pre	Post
AES	0,1	0,2
EDU	0,5	0,5
HAB	0,4	0,7
FRM	0,5	0,5
HYP	0,1	NoData
HER	0,6	0,7
ECO	0,4	0,7
AES	0,1	0,4

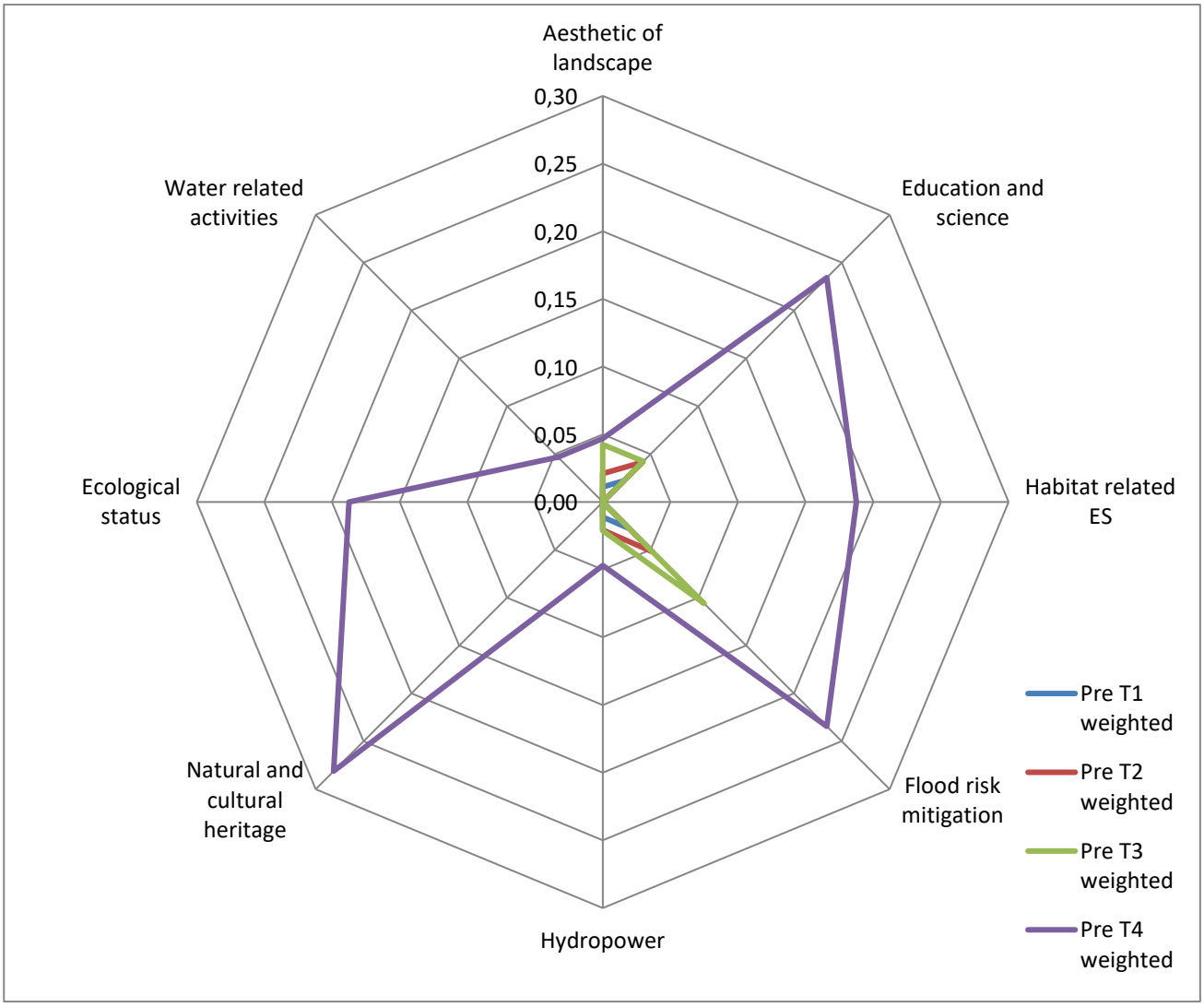

Figure 24 *Summary of weighted ES values of all subunits before the restoration.*

Table 38 *Summary of unweigthed and weighted ES values on subunit T1 and T2 before restoration.*

ES	Pre T1	Pre T1 weighted	Pre T2	Pre T2 weighted	Pre T3	Pre T3 weighted	Pre T4	Pre T4 weighted
AES	0,1	0,01	0,1	0,02	0,2	0,04	0,1	0,05
EDS	0,2	0,02	0,2	0,04	0,2	0,04	0,5	0,23
HS	NoData	NoData	NoData	NoData	NoData	NoData	0,4	0,19
FP	0,25	0,03	0,25	0,05	0,5	0,11	0,5	0,23
HP	0,1	0,01	0,1	0,02	0,1	0,02	0,1	0,05
NCH	NoData	NoData	NoData	NoData	NoData	NoData	0,6	0,28
EST	NoData	NoData	NoData	NoData	NoData	NoData	0,4	0,19
WA	NoData	NoData	NoData	NoData	NoData	NoData	0,1	0,05

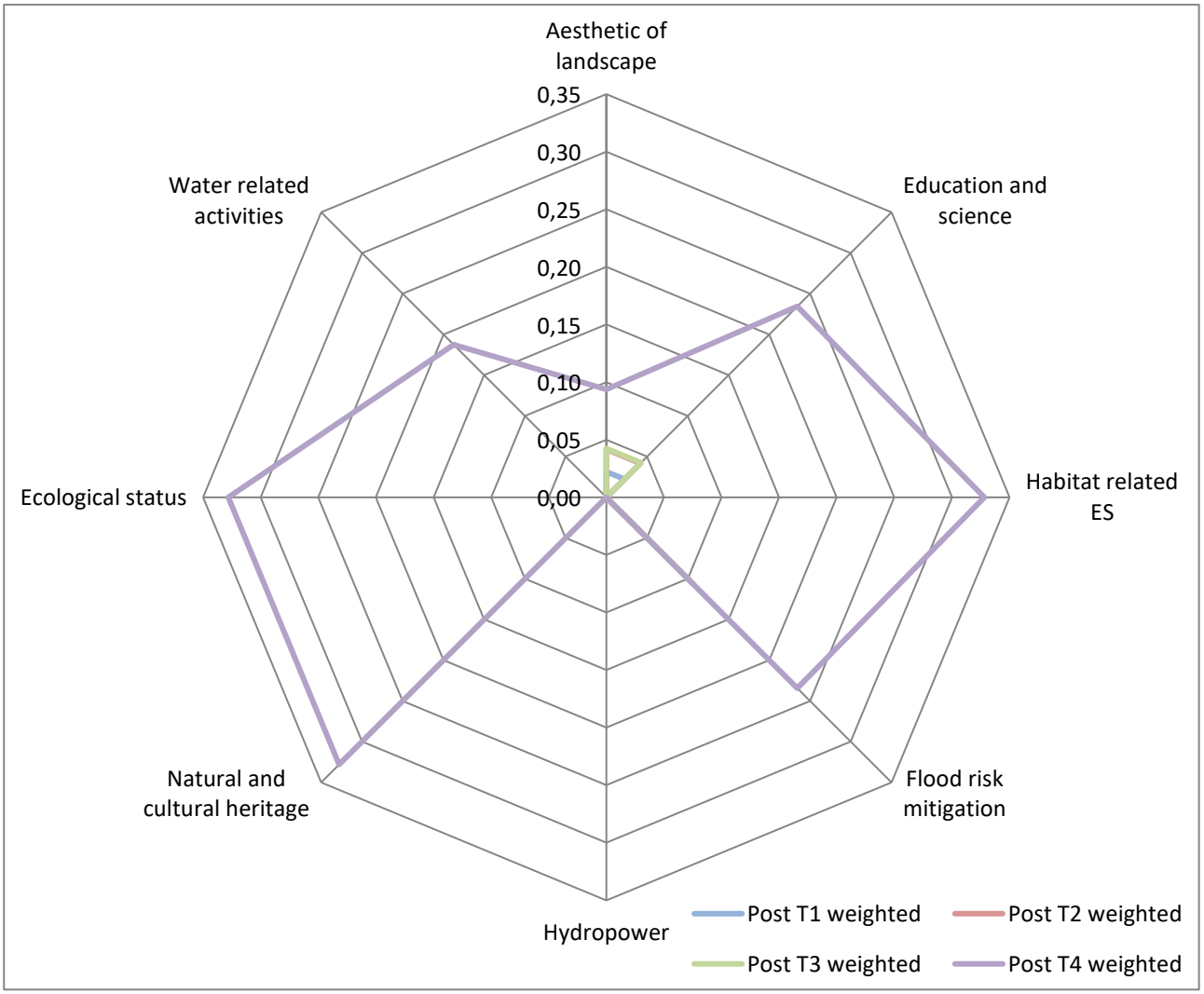

Figure 25 *Summary of weighted ES values of all subunits after the restoration.*

Table 39 *Summary of unweigthed and weighted ES values on subunit T1 and T2 after restoration.*

ES	Post T1	Post T1 weighted	Post T2	Post T2 weighted	Post T3	Post T3 weighted	Post T4	Post T4 weighted
AES	0,2	0,02	0,2	0,04	0,2	0,04	0,2	0,09
EDS	0,2	0,02	0,2	0,04	0,2	0,04	0,5	0,23
HS	NoData	NoData	NoData	NoData	NoData	NoData	0,7	0,33
FP	0,25	0,03	0,25	0,05	0,50	0,11	0,50	0,23
HP	0,1	0	0,1	0,02	0,1	0,02	0,1	0,05
NCH	NoData	NoData	NoData	NoData	NoData	NoData	0,7	0,33
EST	NoData	NoData	NoData	NoData	NoData	NoData	0,7	0,33
WA	NoData	NoData	NoData	NoData	NoData	NoData	0,40	0,19

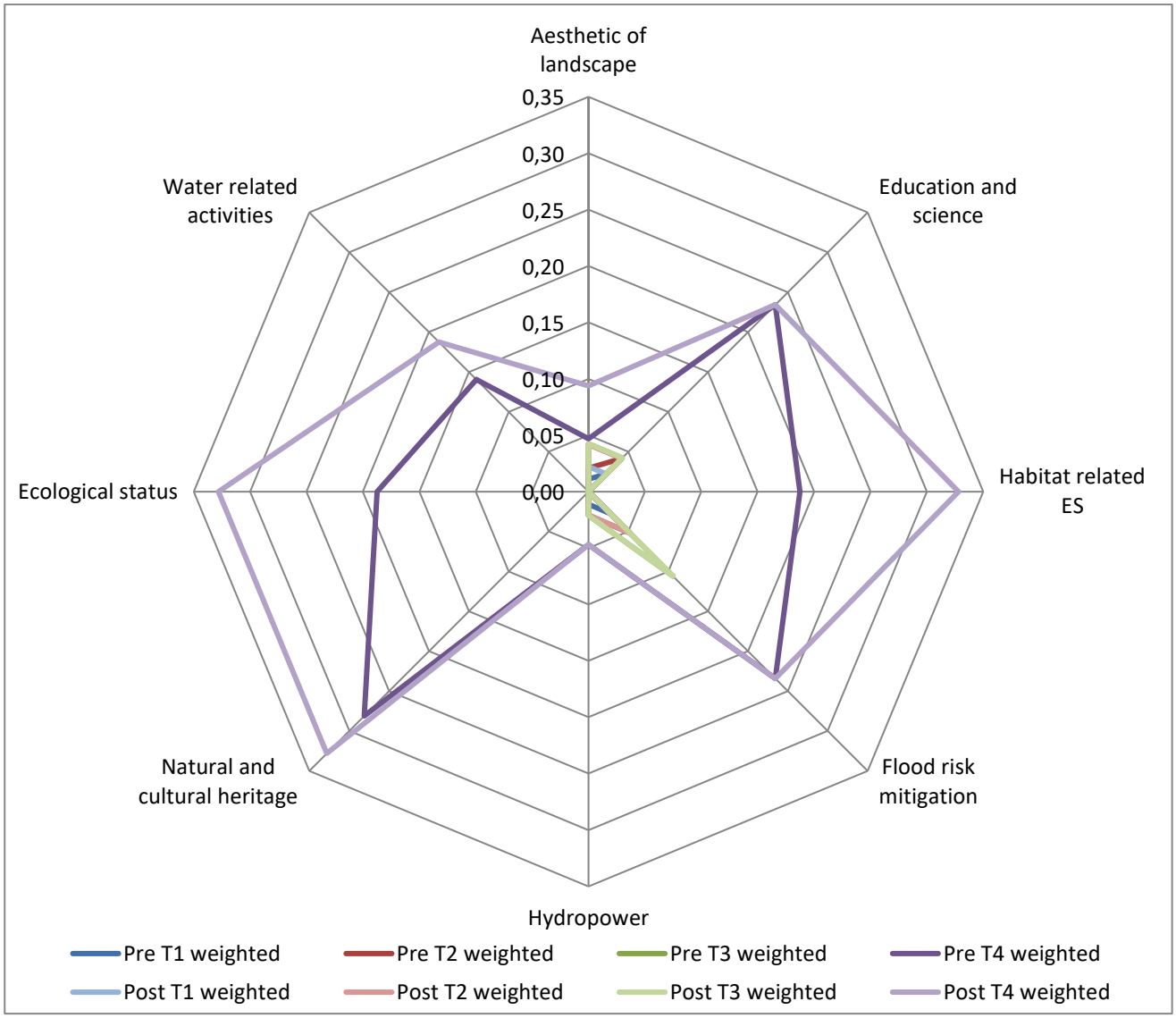

Figure 26 *Summary of weighted ES values on subunits all subunits before and after the restoration.*

3.3 Adige River

A before-after analysis was carried out in order to evaluate the difference between the ES on the river before and after the restoration. In the following table (Table 22) there is the list of indicators and data used to calculate the ES.

Table 40 *Selected ES for the Adige case study, indicators and parameters.*

ES	Indicators according to D.T1.3.1	Indicators according to in.ge.na	Data
Aesthetics of the landscape	MQI	Naturalness and specificity scaled with disturbing factors	MQI, foto-documentation, survey
Education and science		Number of sampling sites and sampling dates	Number of sampling sites and sampling dates
Habitat related ES		Biological water quality, populations structure of aquatic communities	(N)ISECI, STAR.ICM, ICMi, raw data on diatoms, macrozoobenthos and fishes
Flood risk mitigation		Hazard risk maps	Hazard risk maps
Natural and cultural heritage	Presence of rare species (target species)	Fish population structure, typical morphological river structures	(N)ISECI, raw data on fish community
Ecological status	WRR		MQI, (N)ISECI, STAR_ICMi, ICMi, raw data on diatoms, macrozoobenthos and fishes
Water-related activities	WRR	Accessibility of the river	(N)ISECI, MQI, disturbing factors

3.3.1 Aesthetics of the landscape

Table 41 *Evaluation of the Indicators chosen to calculate the ES aesthetics of landscape.*

Naturalness		
Sub-unit	**Pre**	**Post**
T1	MQI NoData [7] Natural elements 0,2 Protection elements 0,4 TOT 0	MQI 0,2 Natural elements 0,7 Protection elements 0,6 TOT 0,5
T2	MQI NoData Natural elements 0,2 Protection elements 0,4 TOT 0	MQI 0,6 Natural elements 0,7 Protection elements 0,6 TOT 0,6
Specificity		
Sub-unit	**Pre**	**Post**
T1	0,2	0,2
T2	0,2	0,2
Downscaling due to disturbing factors		
Sub-unit	**Pre**	**Post**
T1	-2	-2
T2	-2	-2

Table 42 *Calculation of the ES aesthetics of landscape.*

Aesthetics of landscape				
Sub-unit	**Pre**	**Downscaling due to disturbing factors**	**Post**	**Downscaling due to disturbing factors**
T1	NoData	-2	0,1[8]	-2
T2	NoData	-2	0,1	-2

[7] There is no MQI for this subunit.

[8] Downscaled result. Not downscaled results: T1 post = 0,2 und T2 post = 0,4.

Difference between pre and post restoration	
T1	-
T2	-

3.3.2 Education and science

Table 43 *Evaluation of the Indicators chosen to calculate the ES education and science.*

Number of sampling sites		
Sub-unit	**Pre**	**Post**
T1	0,6	0,6
T2	0,6	0,6
Number of sampling dates		
Sub-unit	**Pre**	**Post**
T1	0,6	0,6
T2	1	1
Number of information signs		
Sub-unit	**Pre**	**Post**
T1	0,2	0,6
T2	0,2	0,6
Education and science		
Sub-unit	**Pre**	**Post**
T1	0,5	0,5
T2	0,6	0,7
Difference between pre and post restoration		
T1	0	
T2	+0,1	

3.3.3 Habitat related ES

Table 44 *Evaluation of the Indicators chosen to calculate the ES habitat related ES.*

ICMi		
Sub-unit	**Pre**	**Post**
T1	0,7	NoData
T2	1	0,8
STAR-ICMi		
Sub-unit	**Pre**	**Post**
T1	1	0,8
T2	1	0,8
(N)ISECI		
Sub-unit	**Pre**	**Post**
T1	0,8	0,8
T2	0,8	0,8
Biological water quality		
Sub-unit	**Pre**	**Post**
T1	0,8	NoData
T2	0,8	0,8
Population structure		
Diatoms		
Sub-unit	**Pre**	**Post**
T1	0	0
T2	0	0,5
Macrozoobenthos		
Sub-unit	**Pre**	**Post**
T1	0	0,5
T2	0	0,5
Fishes		
Sub-unit	**Pre**	**Post**
T1	0	0,75
T2	0	0,75

Table 45 *Calculation of the ES habitat related ES.*

Habitat related ES		
Sub-unit	**Pre**	**Post**
T1	NoData	NoData
T2	0,4	(0,7+0,7+0,8) /3= 0,7

Difference between pre and post restoration	
T1	-
T2	-
T3	-
T4	+0,3

3.3.4 Flood risk mitigation

Table 46 *Evaluation of the Indicators chosen to calculate the ES flood risk mitigation.*

Flood risk mitigation		
Sub-unit	**Pre**	**Post**
T1	0,25	0,25
T2	0,25	0,25
Difference between pre and post restoration		
T1	0	
T2	0	

3.3.5 Natural and cultural heritage

Table 47 Calculation of the ES natural and cultural heritage.

Natural and cultural heritage		
Sub-unit	**Pre**	**Post**
T1	(0,8+0,2) /2=0,5	(0,8+0,2) /2= 0,5
T2	(0,8+0,25) /2=0,5	(0,6+0,8) /2= 0,7
Difference between pre and post restoration		
T1	0	
T2	+ 0,2	

3.3.6 Ecological status

Table 48 *Evaluation of the Indicators chosen to calculate the ES Ecological status.*

MQI		
Sub-unit	**Pre**	**Post**
T1	NoData	0,2
T2	NoData	0,6
Biological water quality		
Sub-unit	**Pre**	**Post**
T1	0,8	NoData
T2	0,8	0,8
Population structure		
Sub-unit	**Pre**	**Post**
T1	0	0,6
T2	0	0,6

Table 49 *Calculation of the ES ecological status.*

Ecological status		
Sub-unit	**Pre**	**Post**
T1	NoData	0
T2	NoData	0,7
Difference between pre and post restoration		
T1	-	
T2	+ 0,7	

3.3.7 Water related activities

Table 50 *Evaluation of the Indicators chosen to calculate the ES water related activities.*

MQI		
Sub-unit	**Pre**	**Post**
T1	NoData	0,2
T2	NoData	0,6
(N)ISECI		
Sub-unit	**Pre**	**Post**
T1	(N)ISECI 0,8 Population structure 0 TOT 0,4	(N)ISECI 0,8 Population structure 0,75 TOT 0,8
T2	(N)ISECI 0,8 Population structure 0 TOT 0,4	(N)ISECI 0,8 Population structure 0,75 TOT 0,8
Recreational use		
Sub-unit	**Pre**	**Post**
T1	0,5	1
T2	0,25	1
Downscaling due to disturbing factors		
Sub-unit	**Pre**	**Post**
T1	-1 step	-1 step
T2	-1 step	-1 step

Table 51 *Calculation of the ES water related activities.*

Water related activities				
Sub-unit	**Pre**	**Downscaling due to disturbing factors**	**Post**	**Downscaling due to disturbing factors**
T1	NoData		0,5[9]	- 1 step
T2	NoData		0,6	- 1 step

[9] Downscaled result. Not downscaled results: T1=0,7; T2= 0,8.

Difference between pre and post restoration	
T1	+0,5
T2	+0,6

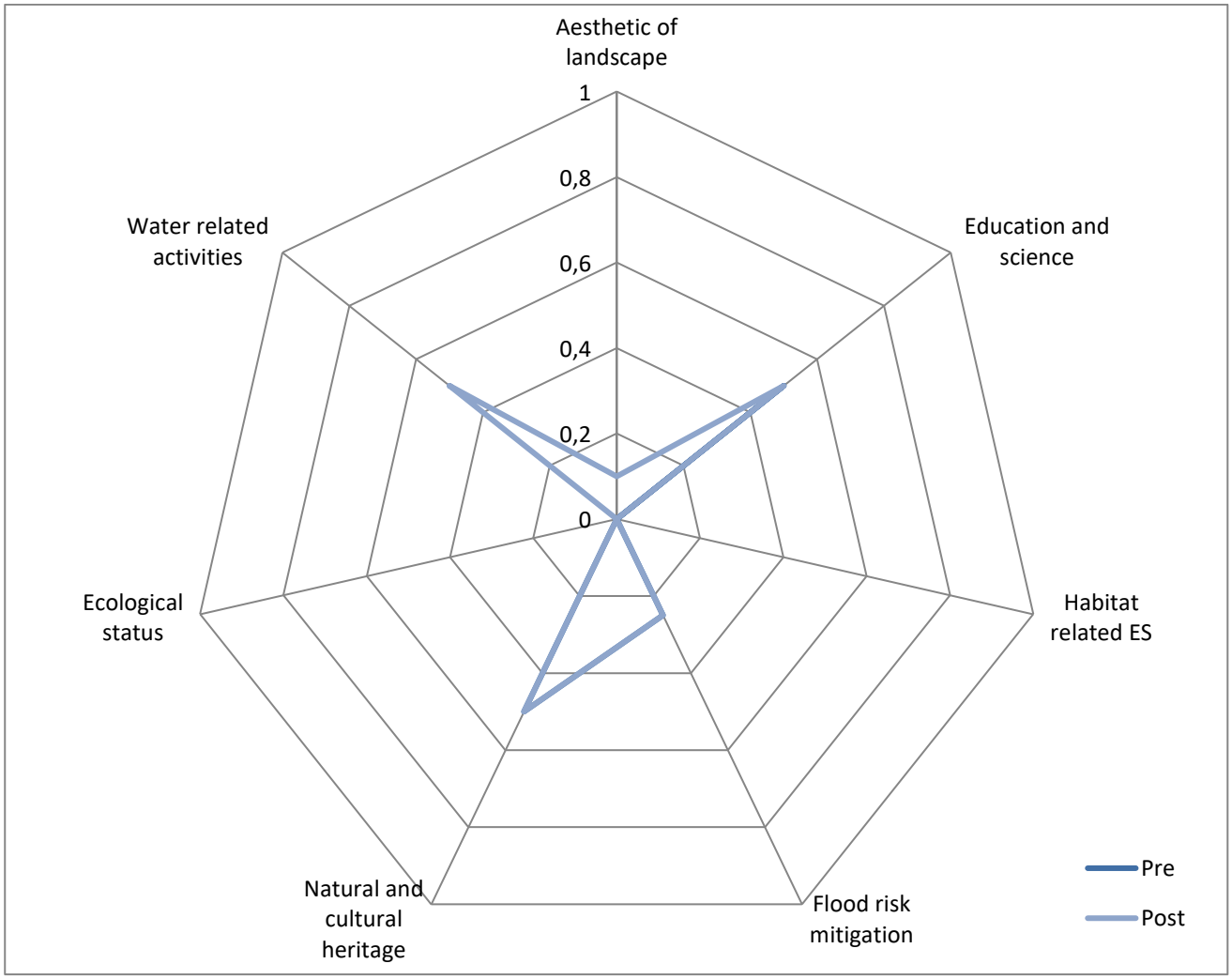

Figure 27 *Graphical summary of ES values in subunit T1 before and after the restoration.*

Table 52 *Summary of ES values in subunit T1 before and after the restoration.*

ES	Pre	Post
AES	NoData	0,1
EDS	0,5	0,5
HS	NoData	NoData
FP	0,25	0,25
HP	0,5	0,5
EST	NoData	NoData
WA	NoData	0,5

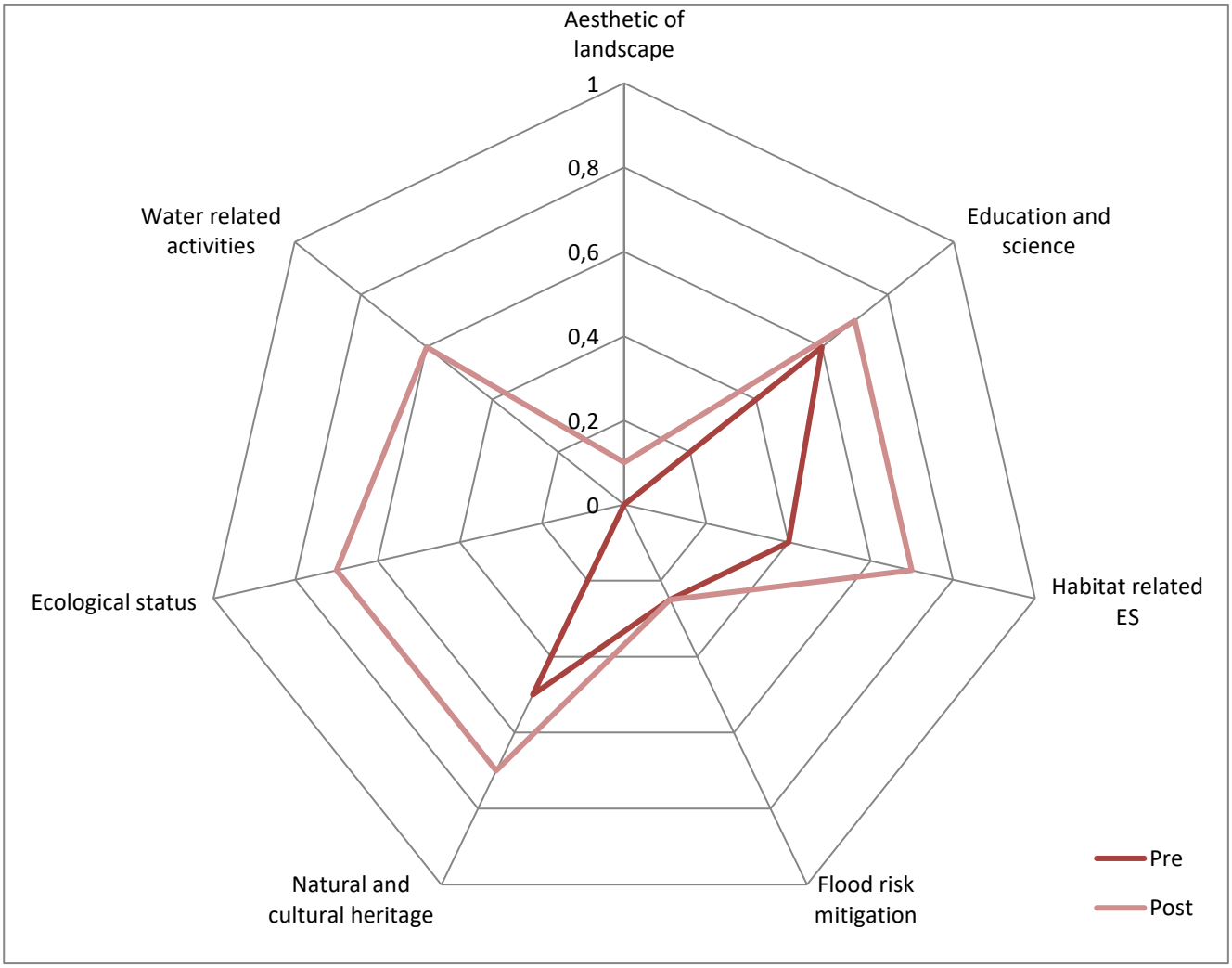

Figure 28 *Graphical summary of ES values in subunit T2 before and after the restoration.*

Table 53 *Summary of ES values in subunit T2 before and after the restoration.*

ES	Pre	Post
AES	NoData	0,1
EDS	0,6	0,7
HS	0,4	0,7
FP	0,25	0,25
HP	0,5	0,7
EST	NoData	0,7
WA	NoData	0,6

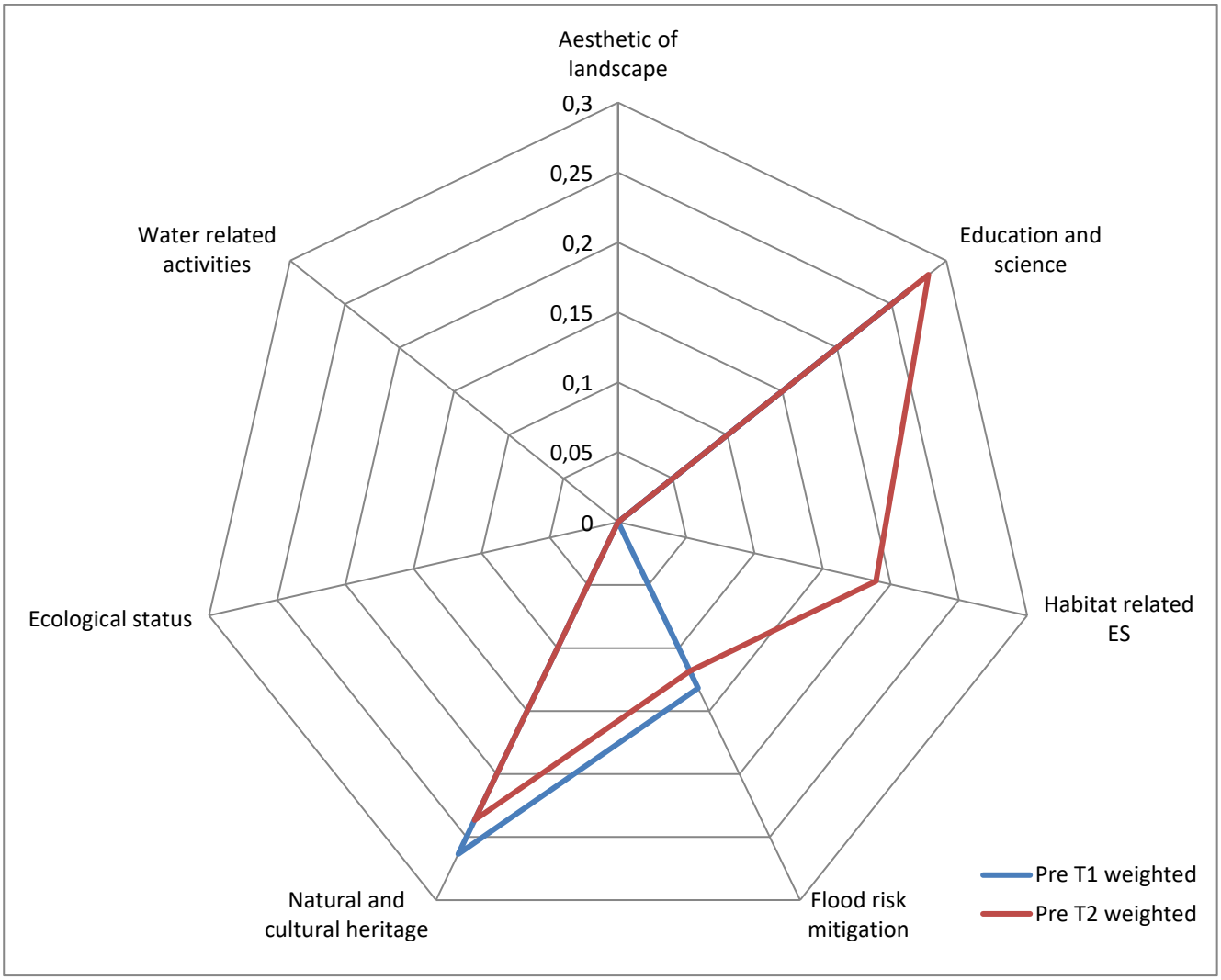

Figure 29 *Summary of weighted ES values of all subunits before the restoration.*

Table 54 *Summary of weighted and unweighted ES values of all subunits before and after the restoration.*

ES	Pre T1	Pre T1 weighted	Pre T2	Pre T2 weighted
Aesthetics of landscape	NoData	NoData	NoData	NoData
Education and science	0,5	0,26	0,6	0,28
Habitat related ES	NoData	NoData	0,4	0,19
Flood risk mitigation	0,25	0,13	0,25	0,12
Natural and cultural heritage	0,5	0,26	0,5	0,24
Ecological status	NoData	NoData	NoData	NoData
Water related activities	NoData	NoData	NoData	NoData

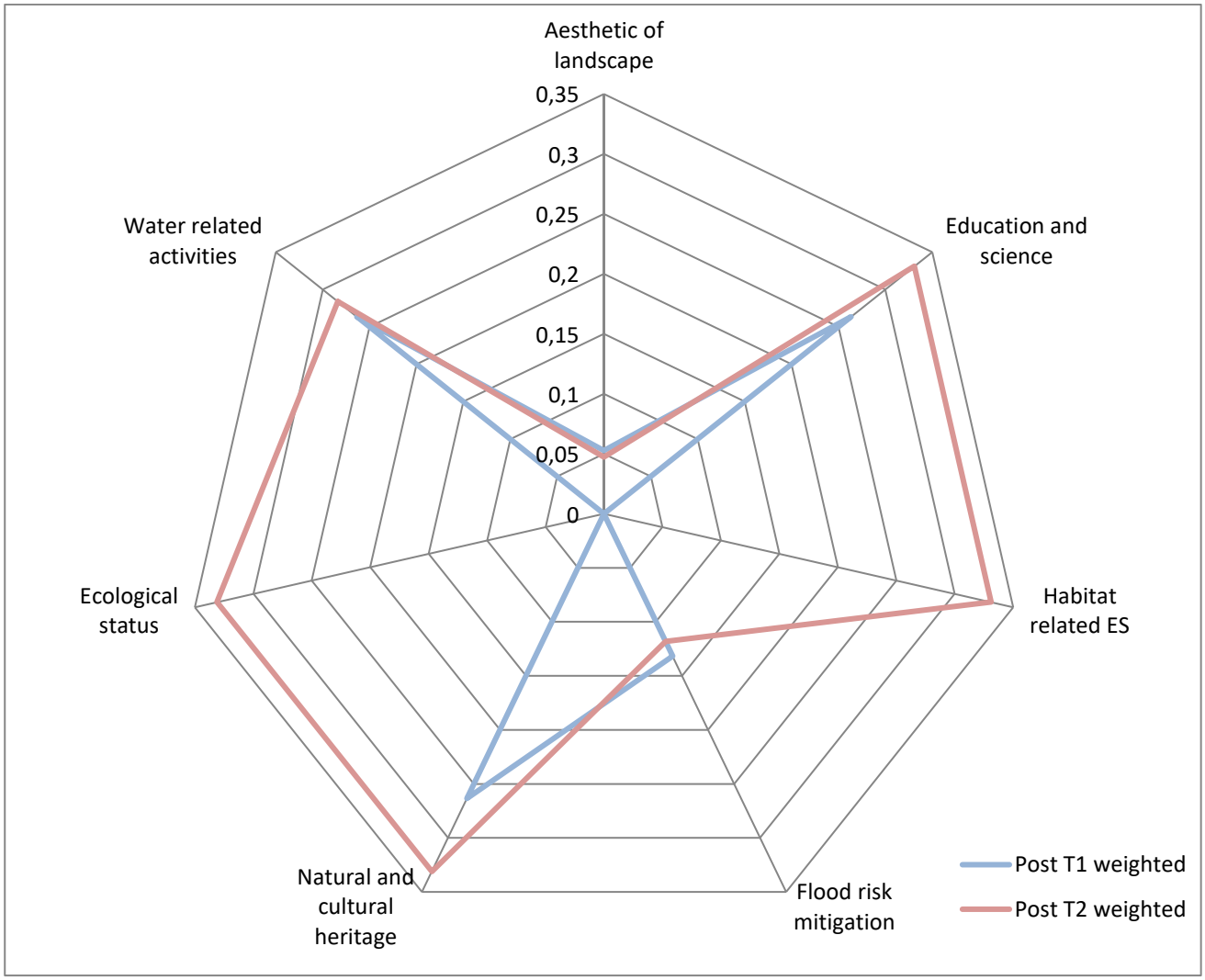

Figure 30 *Summary of weighted ES values of all subunits before the restoration.*

Table 55 *Summary of weighted and unweighted ES values of all subunits before and after the restoration.*

ES	Post T1	Post T1 weighted	Post T2	Post T2 weighted
Aesthetics of landscape	0,1	0,05	0,1	0,05
Education and science	0,5	0,26	0,7	0,33
Habitat related ES	NoData	NoData	0,7	0,33
Flood risk mitigation	0,25	0,13	0,25	0,12
Natural and cultural heritage	0,5	0,26	0,7	0,33
Ecological status	NoData	NoData	0,7	0,33
Water related activities	0,5	0,26	0,6	0,27

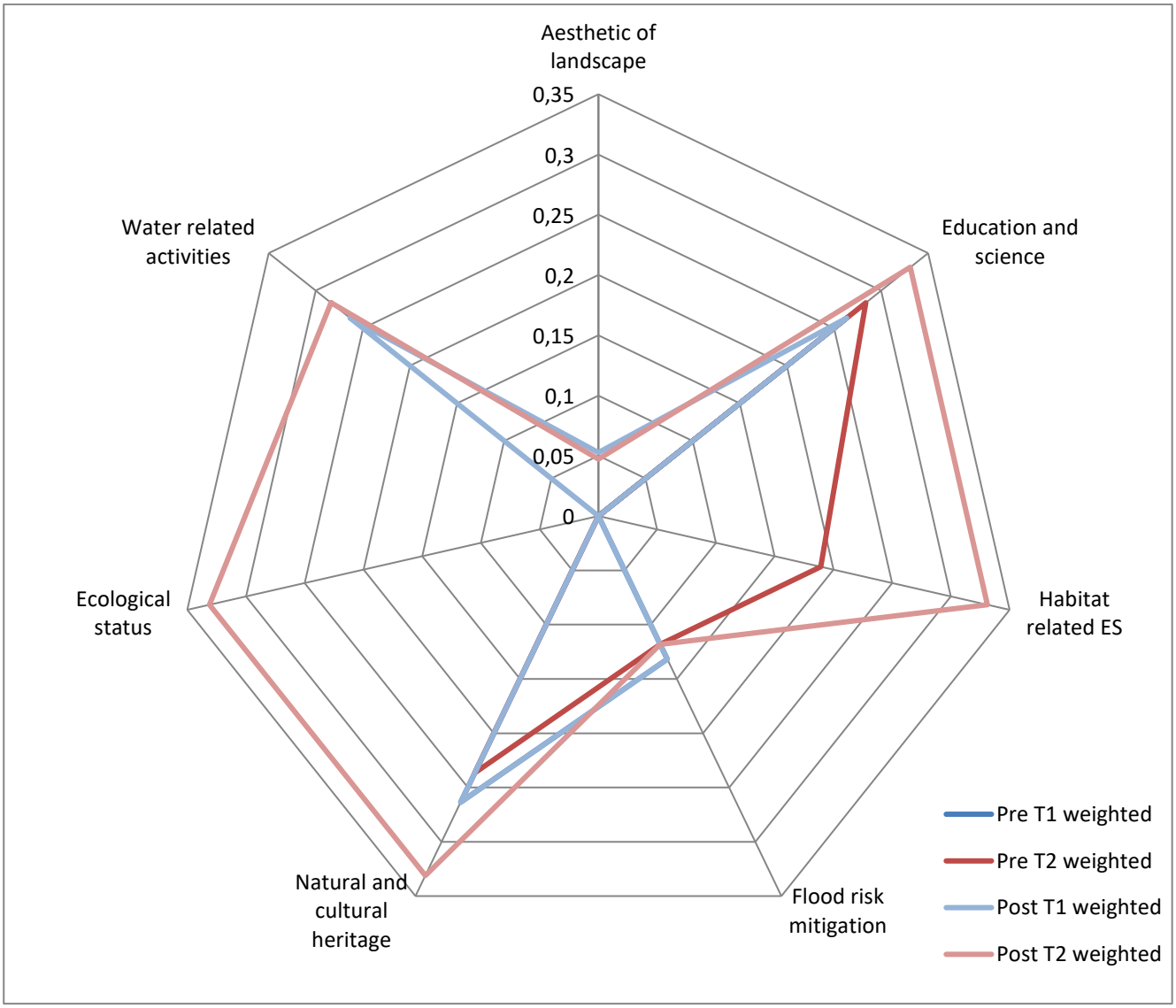

Figure 31 *Summary of weighted ES values on subunits all subunits before and after the restoration.*

4 Conclusions and perspectives

An improvement of the Ecosystem Services (ES) after the revitalisation of the river sections could be observed in all three case studies, even though different sections show different variations in ES values.

In particular, the natural and cultural heritage, the aesthetics of the landscape, the water related activities and the habitat related ES have been improved after revitalisation. This improvement is due to the small-scale identification of the typical morphological structures in the sections, which are characteristic for the specific (river) region, as well as for a particular cultural and landscape value. The visual mapping of these structures allows the use of a smaller scale to evaluate the ES, in contrast to the application of the MQI.

In the case of water related activities and habitat related ES, recreational use and improved population structure of fishes are the key elements contributing to the improvement of ES. The revitalisation measures on watercourses are directly related to these ES: the opening of the weirs on section T4 of the Talvera River, for example, has made it possible for fishes to get from the Isarco River to the Talvera, so that the population structure of fishes on this section has improved significantly. The situation is similar in the Isarco River, where the riverbed widening has led to an increase in the number of fishes, because the increased number of available habitats, especially for juveniles and larvae.

This can be stated looking at the distribution of change classes. Although the ES natural and cultural heritage ranks first among the ES that show improvements, although among these, it is the one which experiences the smaller changes after a restoration. It usually changes by 0,1 or 0,2 (just like the aesthetics of the landscape), i.e. by just one step, in contrast to the water related activities, which, on section T2 of the Isarco River, improves also by 0,4, i.e. by 2 steps. This could be due to the fact that the water related activities and habitat related ES are directly related to the aims of the revitalisation and the ES natural and cultural heritage or the aesthetics of the landscape have been collaterally improved.

The ES that could most often not be evaluated due to missing data is the ecological status, because the indices ICMi, STAR_ICMi and (N)ISECI were often not calculated for all sections. This problem occurs particularly on the Talvera and the Isarco, because on the examined river sections there is only one sampling site (on the Talvera this is in section T4 and on the Isarco in section T2), so that on these rivers there is only one subunit on which these indices have been calculated.

Flood risk mitigation is the ES, which most remains unchanged after revitalization. The hazard zone has not been changed after restoration measures, because the widths of the riverbed of these dammed watercourses have not changed, despite minimal changes in cross sections and hydraulic roughness, at the same flow rate.

The section of the Isarco River are the ones which show most improvements after revitalisation, specifically 50% of the ES improve after the restoration, only 16,7%, cannot be evaluated due to missing data, in contrast to 50% at the other sites, which indicates a low validity of these results. Approximately one-third (33,3% on the Isarco, 28,1% on the Talvera and 28,6% on the Adige) of the ES on the Isarco section, however, remain unchanged at all sites.

In the course of this study, we focused on developing a strongly analytical approach for the evaluation of ES. This is based on analysing each ES in order to be able to break it down into its building blocks, evaluate each aspect of the ES and, finally, the reproduce an overall picture that describes all these elements. This is very important because of the scale selected and with regard to the recording of small-scale changes, such as the revitalisation of parts of watercourses.

The main problem encountered when analysing the data was the fact that these were not collected specifically for the evaluation of the restoration measures. This means that the evaluation of the individual components of the ES was often hampered by external factors. In the following section, all ES are listed again with their weak points.

Aesthetics of the landscape: The indicators used to assess this ES are naturalness and specificity. The naturalness is also determined with the MQI, which was not collected before the restoration in the case studies Isarco and Adige. The first time this index was calculated was 2015, with the revitalisation measures being carried out in 2013 and 2008 respectively. The MQI value before the intervention is therefore missing for these sites.

Education and Science: The data for the evaluation of this ES show no deficiencies, as the number of sampling dates and sampling sites was provided by the Biological Laboratory in Laives and the presence of information signs was determined by photo documentation and surveys.

Habitat related ES: Data on aquatic organisms are the ones most associated with substantive difficulties. The first problem is the spatial resolution of the data: not all subunits have been sampled, or the official sampling sites do not correspond to the examined subunits. In addition, the effect of revitalization measures on macrozoobenthos and diatoms is not always detectable, because it depends on multiple factors. According to national legislation, macrozoobenthos are determined at family, genus or species group level at most, whereas the greatest effects can be observed at species level. The colonisation of revitalised subunits by macrozoobenthos depends, to a large extent, on the populations in the immediate vicinity, i.e. targeted sampling including reference or control sites would provide more robust results. A similar situation arises in the case of the fish population. The (N)ISECI index has, for example, a large-scale resolution, and does, therefore, not easily allow a transfer of its results to the small-scale habitats created by a revitalisation. By using these indices, it was hardly possible to detect any change or improvement after the revitalisation, on a purely quantitative level. Nevertheless, the (N)ISECI, as well as the ICMi and STAR_ICMi, according to the implementation of the Water Framework Directive in Italy, represent the official methods for recording the ecological status of aquatic communities and should therefore be used for this purpose. However, in our case there are problems with the spatial resolution of the data that we

have circumvented by using, in addition to the above-mentioned indices, raw data from sampling before and after the restoration measures. Where data were available, significant habitat improvements were observed, especially for fish communities (macrozoobenthos and diatoms are subject to the above-mentioned difficulties, which cannot be avoided by analysing the raw data). Ideally, fishing was carried out with a reference or control area close to the study site, so that clear improvements can be identified, which can be directly linked to the revitalisation.

Flood risk mitigation: After the revitalisation, the hazard zones were not changed nor were provided the corresponding simulation results. However, the changes of the cross-section or the hydraulic roughness, at the same flow rate, are not sufficient to change the hazard zones at the rivers. Thus, the same values were used for the revitalisation after the revitalisation as those before the revitalisation.

Hydropower: As the new plant on the Talvera is not yet fully operational at the time of writing, this ES cannot yet be evaluated. An important part of this plant, the underground retention basin, which is used to adjust the minimum flow, is not yet operational and two turbines have not yet been installed.

Natural and cultural heritage: To assess this ES, the (N)ISECI and the population structure of fish communities were used, which show the above-mentioned difficulties.

Ecological status: The indicators used to evaluate this ES have weaknesses reported in the section Habitat related ES. For example, the MQI was never calculated before the revitalisation and the indicators of the good ecological status lack of accuracy due to the spatial resolution.

Water related activities: The indicators used to determine the ES water related activities were the MQI, the (N)ISECI and recreational use, which is the only one which can be assessed without weaknesses, while the other two show the problems listed above.

In summary, an improvement in some ES can be observed on the revitalised sections of the three study sites, the lack of data availability and accuracy lead to substantial difficulties. A targeted data sampling plans for before and after the revitalisation can remedy these deficiencies.

Nevertheless, this study has enabled the development of an approach that can be used for the analysis of ES on revitalised river sections. This approach has proved to be appropriate and effective for the objectives of the contract, as the results of this study have identified and confirmed the aims for the revitalisation measures.

5 Highlights

The selection of the ES to evaluate in our case studies was based on the relevance of each ES to the site and the management action occurred. We chose to integrate the list of indicators for each ES proposed by the HyMoCARES framework, with indicators we consider describing better the ES for the aim of the study and which are able to detect the small scale changes in river hydromorphology due to restoration action occurred on our study sites, i.e. channel widening, check dam removal, creation of macroforms, ensuring ecological flow, sediment recharge and weir removal.

Following this rule, we found that the natural and cultural heritage, the aesthetics of the landscape, the water related activities and the habitat related ES were the ES which were mostly improved after the restoration of the river sections. The improvement of two of these ES, the water related activities and the habitat related ES was indeed in the targets of the restoration actions. For all these ES, the detection of the small scale ameliorations was decisive to assess the improvement, even though the target ES showed a greater scope of improvement than the ones which were not in the aim of the projects.

On the other hand we can state that the ES which did not change after the revitalisation and the ones which could not be evaluated due to missing data are also the ones which have to be described through large-scale indicators. For example the ecological status has to be described through indices of good ecological status of aquatic communities, which are calculated for big river portions, this means, on one hand, that the spatial resolution is not adequate to detect the positive effect of restoration actions and on the other that not all the subunits have been sampled. The problem of missing data arises throughout the analysis, also for ES which were improved after the revitalisation like the water related activities and the habitat related services: for these ES, data is not available in all the subunits. So for these ES we could state an improvement only where data were available. This fact points out to the need of a targeted data collection in vision of the specific restoration action, in order to be able to evaluate the improvement of ES on all river sections.

We can conclude that the effect of restoration actions in our case studies is positive on a small scale level, which is not detectable for all ES, for several reasons. The adequate spatial resolution is ensured only by a targeted data collection before and after the restoration action, or through the choice of suitable indicators, which refer to the specific interaction and are not affected by external factors.

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