KNOWLEDGE CONVERSION FOR ENHANCING MANAGEMENT OF EUROPEAN RIPARIAN ECOSYSTEM AND SERVICES

CONVERGES
European Riparian Ecosystems

COST ACTION **CONVERGES**

DELIVERABLE 1.3.: GRAPHIC DESCRIPTION OF RELATIONSHIPS BETWEEN PRESSURES AND STATUS

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CONTENT:

1. INTRODUCTION AND OBJECTIVES

The articulation of CONVERGES Action Working Groups has been conceived following the PSR Framework: Pressures/states and responses. To achieve this framework, a deep knowledge of causality relationships between pressures and states, in our case related to riparian vegetation, results fundamental to design efficient and sustainable responses.

This document collects the main results of the causality study carried on within the Working Group 1 of CONVERGES, based on a systematic literature review between pressures and the status of riparian vegetation. Its content corresponds to the Deliverable 1.3 entitled “Graphic description of relationships between pressures and status”.

1.1. Role of causality conceptual models and diagrams in knowledge transfer across scientific community and social agents

Simplified conceptual models explaining relationships between drivers, pressures and status of ecosystems may be very useful for environmental management purposes (Elliot, 2002; Smith et al., 2016). They state the current level of knowledge connecting human activities with their effects to ecosystems and may offer valuable insights to design proper restoration activities. At the same time, simplified conceptual models represent graphical tools easily understood by the stakeholders, and may act as very appropriate instruments for communication and dissemination among the public.

Counting with these types of conceptual models requires an important effort of scientists, aimed at creating consistent and research-based synthesis of existing literature informing evidence of causal effects between drivers/pressures and ecosystem impact/status. The resulting graphical representations of causal effect relationships likely help managers to better select the optimum programmes of measures, which should be the most directly addressed to mitigate or remove the main mechanisms of degradation. These graphical representations of causality may also assist managers in communicating with stakeholders and receiving their needed support for implementing the restoration measures. Additionally, the graphical information likely contributes to enhance the science-based environmental perception by the public, and may act as a useful instrument to be used in citizen-science development.

In the case of riparian vegetation, although there is a wide recognition of its important environmental services (Riss et al., 2020) and a significant awareness about the magnitude of problems and threats that face riparian corridors, no unified criteria have been developed or proposed to protect and enhance riparian vegetation. By the contrary, countermeasures for its conservation (e.g., vegetation thinning or removal) are frequently encouraged to apparently cope with flood risk management. Instead of fostering to leave room for riparian vegetation growth and succession aligned with natural fluvial processes and disturbance regime, and prevent human floodplain occupations like farming or urbanization, riparian vegetation clearance is very frequently promoted. This misalignment between theoretical interest in riparian vegetation and practical management measures may be explained by an incomplete understanding of riparian vegetation requirements, and how they are strongly altered by the existing multiple pressures.

The more recent approaches of living with rivers and bringing nature to our lives (e.g., EU Biodiversity Strategy for 2030) are demanding precise knowledge of causality of riparian corridors degradation, to achieve their proposed targets which are to increase natural forest and free-flowing river restoration. In this sense, a process-based framework linking existing pressures with altered fluvial variables and riparian vegetation habitat requirements is strongly needed, to understand the status of riparian vegetation and predict its expected future trajectories under different potential scenarios of restoration activities and climate change (González del Tánago et al., 2021).

1.2. Objectives of the Deliverable

This document addresses the reported major issue of pressures/status relationships of riparian vegetation, and has been designed to achieve three general objectives, 1) to create simplified graphical diagrams of process-based conceptual models linking pressures with riparian vegetation status; 2) to explore scientific evidences of vegetation responses to pressures and asses their causality; and 3) to identify gaps and limitations within the existing literature reporting process-based evidences of causal effects.

As it has been mentioned above, the content corresponds to the Deliverable D1.3 of the Cost Action CONVERGES (Knowledge Conversion for Enhancing management of European Riparian Ecosystems and Services), which aimed at providing graphic description of relationships between pressures and status concerning riparian vegetation.

2. METHODOLOGY

In this study we have followed a causal criteria analysis approach and followed some methodological aspects proposed by different authors (Downes *et al*., 2002; Nichols *et al*, 2011; Norris *et al*., 2012; Martin *et al*., 2021) for analysing causal effects in environmental assessments. We have applied the Eco-evidence framework to weight the emerged evidence from the literature (Nichols *et al.,* 2011), and finally design simplified causal diagrams according to the results (Figure 1).

First, we have selected the main pressures related to human actions that are most frequently associated to riparian vegetation changes, based on the review of Poff et al. (2011). The selected pressures, cited according to the amount of revised research, have been: Flow regulation by dams and reservoirs, Agriculture and Urbanization as main floodplain and riparian land occupations; and Grazing and Mining as main floodplain and riparian land uses.

For the literature review we used only peer-reviewed articles explored through Web of Science and Scopus, considering that the search was completed when both databases were reviewed. We applied this search in the title, keywords and abstract of the articles. To homogenise the search, we used the same sentence for all types of studied pressures, as: TS/T-A-K*= (("riparian vegetation") AND (response OR effect OR change) AND (river OR riparian OR floodplain OR stream) NOT (coast* OR estuar* OR mangrove OR tidal), followed by the type of disturbance as: AND (regulation OR flow alteration)); AND (agriculture) AND (nutrients OR pesticides OR fertilizers OR "suspended solids" OR channel OR "groundwater abstraction" OR irrigation); AND (agriculture OR agricultural) AND (abandonment OR abandoned); AND (grazing OR livestock); AND (channelization OR alignment OR embankment OR dredging OR gravel mining); AND (afforestation OR reforestation OR forest plantations). We searched for studies published since 1970 that directly examined cause-effect relationships between pressures and riparian vegetation responses. Reviews, models, and experimental assays were excluded.

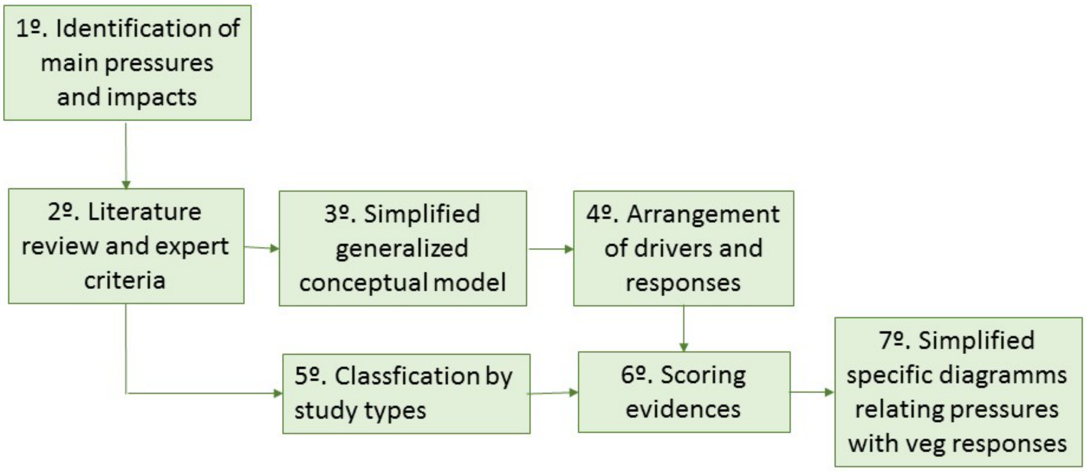

Figure 1. - Methodological stages based on literature review and causal criteria analysis to create diagrams relating pressures with riparian vegetation status.

From the selected articles we extracted the more relevant information on the studied variables altered by the respective pressure (i.e., physical drivers), and the type of observed changes in the studied riparian vegetation characteristics (i.e., vegetation responses). Related to vegetation we distinguished effects reported in life-stages processes (i.e., dynamic approach) from effects reported on the current state of vegetation (i.e., static approach) assessed in terms of taxonomical components, landscape attributes and functional attributes (González del Tánago *et al.* , 2022). With this information we were able to create a generalized conceptual model linking pressures with their potential influence altering the habitat requirements of vegetation (Gurnell *et al.*, 2016) and their potential influence altering life-stages processes and characteristics of vegetation, following a cascade process-based framework of causality, hierarchically arranging drivers and responses (figure 2).

To assess the level of support of the revised literature, we documented the type of each study differentiating temporal approaches (e.g., before-after (BA), after impact (AI)), spatial approaches (e.g., control-impact (CI) or both (BA-CI, gradients) and also counted the number of impact and control sampling units in each article. Each reviewed study was scored according to the quality of the evidence it provided, based on the research design, number of independent sites or samplings used as control, and number of independent impacted sites (Nichols *et al.,* 2011). Finally, each relationship between altered variables and vegetation responses was weighted by summing up the score of all the studies supporting it. For assessing the quality of total evidence for or against a causal relationship, we used the Eco-Evidence threshold of 20; a summed value that equals 20 or more indicates a high level of support, whereas a value less than 20 indicates a low level of support (Nichols *et al.,* 2011; Norris *et al.,* 2012).

According to the resulting scored evidence, we finally prepared simplified diagrams for each pressure, stating the more reported changes in the related physical variables (e.g., increase or decrease) and their scored causal effects on the riparian vegetation attributes.

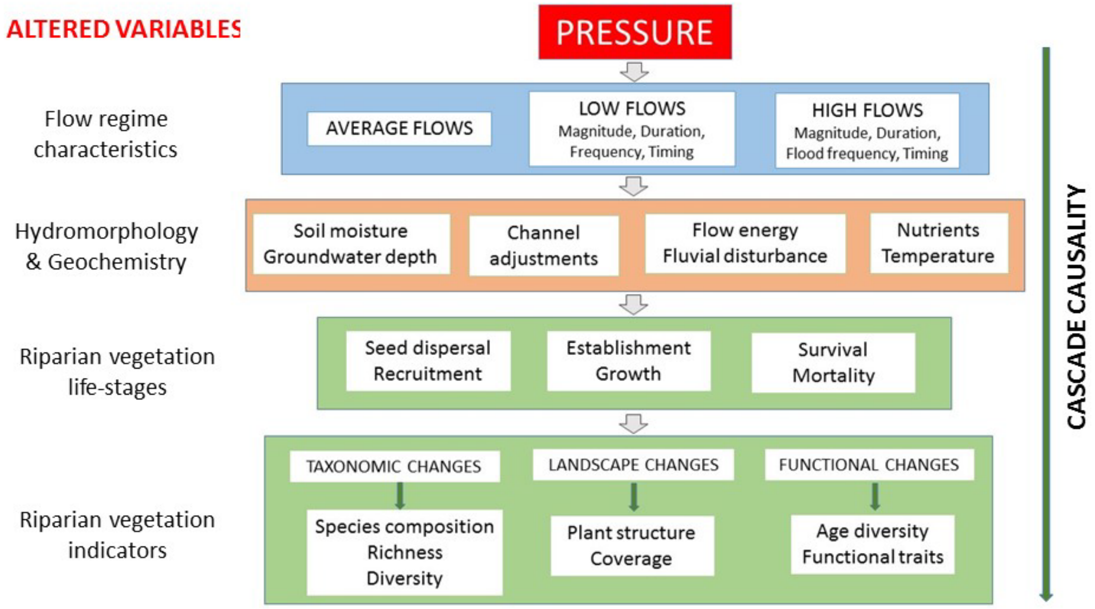

Figure 2.- Generalized conceptual model representing the hierarchical cascade of process-based effects of pressures altering hydro- morphological and geochemistry conditions, vegetation life-stages and characteristics of resulting riparian vegetation communities.

3. RESULTS

3.1.- General findings of the literature review

Table 1 shows the number of articles founded in our search related to pressure effects on riparian vegetation. From a total number of 856 articles only 177 articles could be used within the eco-evidence framework which are listed in the Annexe attached to this document.

Flow regulation by dams and reservoirs was the pressure most frequently studied relating flow alteration with vegetation changes. In this case, the most frequent study design was before and after dam operation (BA design), although comparisons between regulated and non-regulated reaches (i.e., control-impact approach) were also frequent. Grazing was the second pressure more studied, and in this case the study design was nearly always based on comparisons between grazed and non-grazed (fenced) area, clearly responding to a control-impact approach. Spatial gradient of pressure intensity was the less frequent study design, in the case of flow regulation responding to comparisons of the effects across increasing distances from the dam, whereas in the case of urbanization responding to comparisons along urban land increases in time.

Table 1.- Number of peer-reviewed articles and type of research design used to explore causality. (BA: Before-After; CI: Control-Impact; AI: After-Impact; BACI: Before-After-Control-Impact; SG: Spatial gradient)

PRESSURE	Total reviewed articles	Selected articles for Eco-evidence	Type of study design				
			BA	CI	AI	BACI	SG
FLOW REGULATION	304	88	36	28	7	10	7
AGRICULTURE	106	15	7	6	1	1	0
GRAZING	213	41	5	28	1	7	0
MINNING	52	7	2	3	0	1	1
URBANIZATION	181	26	6	6	1	0	13
TOTAL	**856**	**177**	**56**	**71**	**10**	**19**	**21**

In terms of year of publication, grazing effects on riparian corridors started to be very frequently studied since the 70´s, whereas agriculture or urbanization effects were much more recently reported in the revised literature (figure 3). In the case of flow regulation, although the effects of river damming on fluvial morphology and aquatic communities started to be an important focus of research at international scale since the 70´s (e.g., Ward & Stanford, 1979), the study of its effects on riparian vegetation communities was delayed until the 90´s (e.g., Johnson, 1997). In the case of grazing, there is a wide documentation on its effects on riparian zones and ecosystems since the 70´s (e.g., USDA, 1978; Warner & Hendrix, 1984), but the first peer-reviewed articles found in our search do not appear until the 90´s (e.g., Sedgwick & Knopf, 1991).

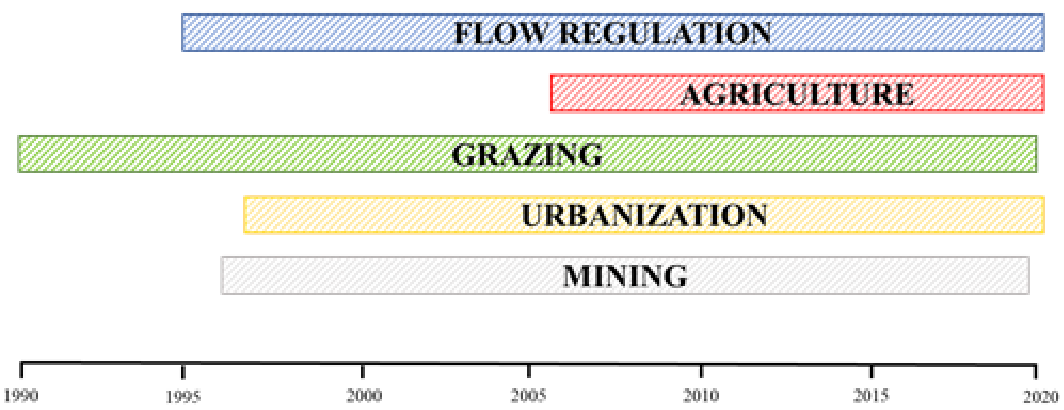

Figure 3.- Year of publication of the peer-reviewed articles considered in this research.

In general, most of research dealing with effects of pressures focused the study on changes in species composition, which implies field work, or on changes in vegetation coverage when the study was based on air-photographs reconnaissance (figure 4). Much less work has been done assessing changes in life-cycle stages (e.g., recruitment, growth, mortality) or functional aspects, which would result in great interest as the former may give a dynamic perspective of vegetation succession, whereas the second allows to compare vegetation communities across different regions (i.g., vicariant species) or different fluvial functioning (e.g., vegetation guilds).

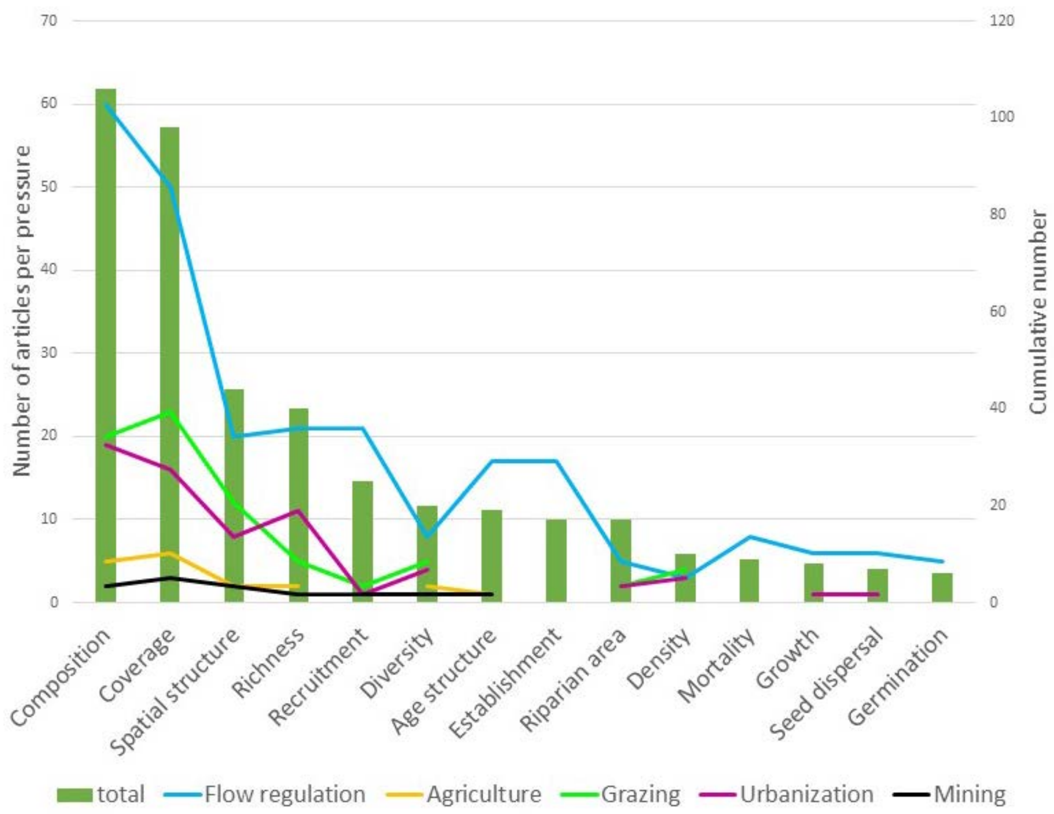

Figure 4.- Frequency of riparian vegetation variables considered in the peer-reviewed articles assessing pressure effects.

In terms of the physical habitat conditions of riparian vegetation altered by the studied pressures (e.g., fluvial disturbance, soil moisture, nutrients), the most frequently studied variables were the indicators of hydrological alteration, mostly related to changes in high flows, flood magnitude and frequency, low flows, etc. These indicators were associated to changes in soil moisture, groundwater depth, sediment supply, nutrients or considered drivers of channel adjustments as narrowing, incision, accretion, etc. (Table 2). For the rest of the pressures, the most frequently reported variable was the land under the respective pressure (e.g., agricultural land, grazing land, urban land), with in general very little detail on other physical conditions or processes derived from it which potentially could interfere riparian vegetation requirements.

Finally, it´s worthy to mention the variety of naming of the variables found in the literature reporting pressures and riparian vegetation effects, which have hindered the synthesis needed for our research. In relation to flow regulation, some articles only report the existence of the dam and the year of the starting of operation, without any further information about the hydrological variables altered by the dam. In many cases there was a great variety of ways to express the effects of flow regulation, like decreasing high flows, peak flows, flood magnitude, flood frequency, flooding; or increasing low flows, base flows, minimum flows, etc. This mentioned diversity of information has been necessarily simplified by clustering in groups, in this case in two types of hydrological alterations, high-flows decrease, and low-flows increase, respectively, to gain evidence of the results.

Table 2.- Frequency of physical variables considered in the peer-reviewed articles assessing pressure effects on riparian vegetation characteristics.

PRESSURE	VARIABLE	Nº ARTICLES	%
FLOW REGULATION	High flows	38	43
	Low flows	25	28
	Average flows	24	27
	Flood frequency	18	20
	Sediment supply	18	20
	Flood magnitude	13	13
	Timing	11	13
AGRICULTURE	Agricultural area	15	100
	Suspended solids	6	40
	Nutrients	5	33
	Channel narrowing	3	20
	Average flow	2	13
GRAZING	Grazing land	41	100
	Soil nutrients	4	10
	Soil moisture	2	5
URBANIZATION	Urban land	26	100
	Impervious área	8	31
	Soil moisture	2	8
MINING	Mining area	6	86
	Pollutants	2	29
	Channel incision	2	29

3.2. Flow regulation effects

The effects of flow regulation on riparian vegetation status have been extensively studied worldwide. Figure 5 shows the country of the publications considered in our research, with a great majority coming from United States, Canada and European countries, and the Iberian Peninsula (Spain and Portugal) offering the highest number of publications among the European regions.

Table 3 shows the number of articles reporting changes (e.g., increase, decrease) in the hydrological variables that were related to observed vegetation changes. High-flows decrease was the more frequently studied hydrological alteration, followed by low-flows increase which in many cases occurred simultaneously to high-flows decrease.

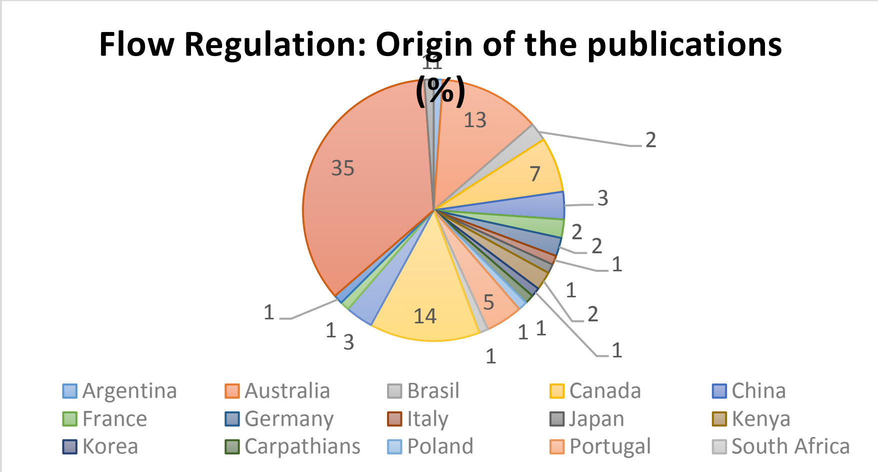

Figure 5. - % of peer-reviewed articles per country, dealing with flow regulation effects on riparian vegetation (Total number of articles = 88).

Table 3.- Number of peer-reviewed articles reporting changes in hydrological variables or processes due to flow regulation, which were associated to observed riparian vegetation changes (Total number of articles = 88).

FLOW REGULATION			
ALTERED HYDROLOGICAL VARIABLE/PROCESS	**REPORTED CHANGE**	**Nº ARTICLES**	**%**
High Flows	Decreases	38	43
Low Flows	Increases	25	28
Average Flow	Decreases	24	27
Flood Frequency	Decreases	18	20
Sediment Supply	Decreases	18	20
Flood Magnitude	Decreases	13	15
Timming	Altered	11	13
Soil Moisture	Decreases	8	9
Flow Regulation	_	8	9
Channel Incision	Increases	6	7
Sediment accumulation	Increases	7	8
Flood Duration	Decreases	5	6
Floods	Decreases	4	5
Flow Magnitude	Decreases	4	5
Water Table Depth	Increases	4	5
Channel Width	Increases/Decreases	4	5
Flood Disturbance	Decreases	3	3
Summer Flow	Increases/Decreases	3	3
Baseflow	Continous	2	2
Channel Accretion	Increases/Decreases	2	2
Flow Augmentation	_	1	1
Flow Variability	Altered	1	1

Nival Flood	Decreases	1	1
Nutrient availability	Decreases	1	1
Shear stress	Decreases	1	1

In relation to vegetation changes, the more frequently assessed responses were changes in species composition and richness (i.e., alteration of taxonomic attributes) and changes in cover and spatial structure (i.e., changes in landscape features) (Table 4).

Table 4.- Number of peer-reviewed articles reporting changes in riparian vegetation variables likely associated to flow regulation. (Total number of articles = 88)

FLOW REGULATION				
VEGETATION VARIABLE		**RESPONSE**	**Nº ARTICLES**	**%**
Taxonomic Changes	Composition	Altered	60	68
	Diversity	Increases/Decreases	8	9
	Richness	Increases/Decreases	21	24
Landscape Changes	Coverage	Increases/Decreases	50	57
	Riparian Area	Decreases	5	6
	Spatial Structure	Altered	20	23
	Age Structure	Altered	17	19
	Density	Increases/Decreases	3	3
Functional Changes	Establishment	Increases/Decreases	17	19
	Recruitment	Increases/Decreases	21	24
	Growth	Increases/Decreases	6	7
	Germination	Increases/Decreases	5	6
	Regeneration	Decreases	1	1
	Flowering	Increases	1	1
	Seed Dispersal	Increases/Decreases	6	7
	Seed Production	Decreases	1	1
	Survival	Decreases	1	1
	Mortality	Increases	8	9
	Ecological quality	Decreases	1	1
		Decreases	1	1
	Functional richness	Decreases	1	1
	Functional redundancy	Decreases	2	2

Following the eco-evidence approach to weight the evidence of causality offered by the revised articles, we summed up the scores obtained by each vegetation response and summarized the results (Tables 5). According to our findings, we can conclude that the available literature highly supports the hypothesis that flow regulation alters species composition, spatial structure, and age mosaics, increases mortality and decreases the extension of the riparian zone. The revised literature also offers high evidence that flow regulation influences many other characteristics of riparian vegetation, but the type of change may be variable towards increasing or decreasing.

This is the case of many vegetation life-stages like recruitment, establishment, seed dispersal, germination, or growth. Also, other taxonomic attributes like richness and diversity showed high evidence of being altered by flow regulation but with variable trend.

A more detailed analysis of the observed vegetation responses to the increase or decrease in high-flows and low-flows, respectively, has been graphically represented in figures 6a and 7a where the scored evidence is reported. These figures remark the high support for the hypothesis that flow regulation is directly related to certain vegetation changes. To give insights in the mechanisms involved, we tried to adapt the process-based conceptual model of figure 2 to the altered hydrological variables, resulting in the diagrams represented in figures 6b and 7b. These diagrams suggest the agents that are promoting the observed vegetation responses and facilitate a better understanding of the involved processes.

In relation to high-flows decrease, the process-based effects are relatively well documented, with an expected soil moisture decrease and groundwater depth increase, and with high support of channel narrowing, incision and sediment accumulation. These physical processes surely interfere with recruitment and establishment and come up with very likely changes in species composition and age structure, together with the increasing vegetation coverage frequently reported as encroachment. In relation to low-flows increase, which frequently occurred simultaneously with high-flows decrease, the mechanisms involved are not so clear, and the literature only support the hypothesis that the increasing of low flows negatively affects the recruitment and establishment of vegetation, presumably of the pioneer species, and results also in vegetation encroachment likely associated to the frequently simultaneous high-flows decrease.

Table 5.- Assessment of the evidence supported by the revised literature in relation to causal effects of flow regulation on riparian vegetation characteristics.

FLOW REGULATION CAUSALITY				
VEGETATION VARIABLE	**RESPONSE TO FLOW REGULATION**	**TOTAL SCORE**	**TOTAL SCORE**	**EVIDENCE ASSESSMENT**
Composition	Altered	366	>20	High
Coverage	Increases/Decreases	287	>20	High
Recruitment	Increases/Decreases	144	>20	High
Richness	Increases/Decreases	141	>20	High
Spatial Structure	Altered	121	>20	High
Age Structure	Altered	107	>20	High
Establishment	Increases/Decreases	100	>20	High
Diversity	Increases/Decreases	50	>20	High
Mortality	Increases	49	>20	High
Seed Dispersal	Increases/Decreases	45	>20	High
Germination	Increases/Decreases	36	>20	High
Growth	Increases/Decreases	33	>20	High
Riparian Area	Decreases	32	>20	High
Functional redundancy	Decreases	16	20_10	Moderate
Density	Increases/Decreases	12	20_10	Moderate
Flowering	Increases	8	<10	Low
Seed Production	Decreases	8	<10	Low
Functional richness	Decreases	8	<10	Low
Survival	Decreases	5	<10	Low
Helthy	Decreases	5	<10	Low
Regeneration	Decreases	4	<10	Low
Ecologycal quality	Decreases	4	<10	Low

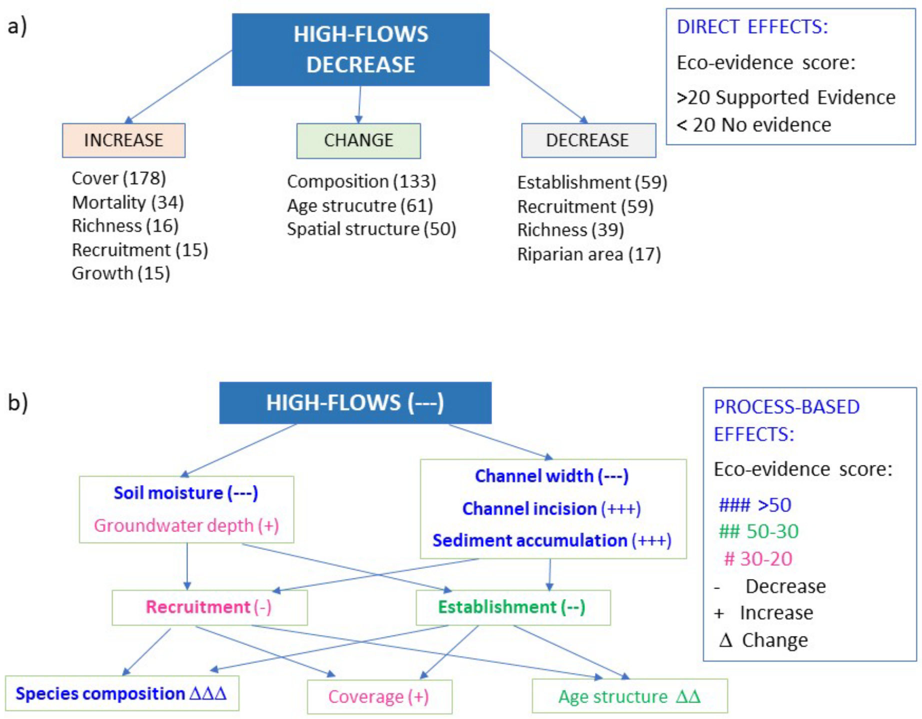

Figure 6.- Scored evidence of flow regulation effects on riparian vegetation supported by the reviewed literature. a) Evidence of direct effects in riparian vegetation characteristics related to high-flows decrease. B) Evidence of cascading effects in fluvial processes and conditions that affect vegetation life-stages and resulting vegetation characteristics.

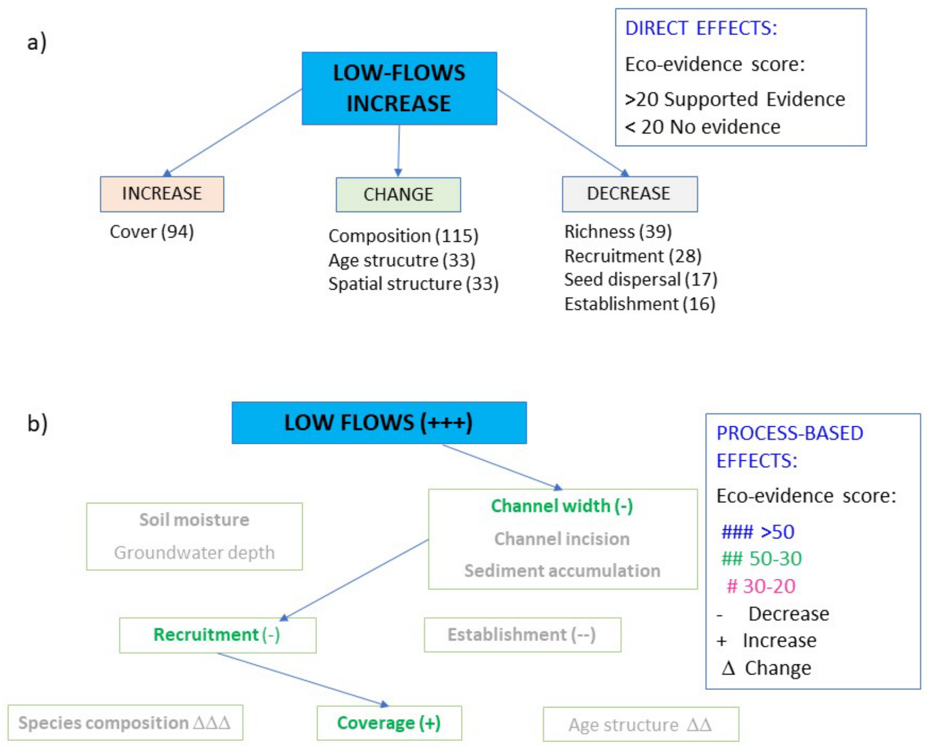

Figura 7.- Scored evidence of flow regulation effects on riparian vegetation supported by the reviewed literature. a) Evidence of direct effects in riparian vegetation characteristics related to low-flows increase. b) Evidence of cascading effects in fluvial processes and conditions that affect vegetation life-stages and resulting vegetation characteristics. Variables in grey colour mean evidence < 20.

3.3. Floodplain and riparian land occupation effects

After flow regulation, riparian vegetation is frequently impaired by the physical occupation of floodplains and riparian zones by agriculture and urban expansion which directly affect the establishment and growth of vegetation communities.

3.3.1. Agricultural land

Table 6 shows the number of articles dealing with changes in physical variables or processes related to agricultural practices which have been reported to promote changes in riparian vegetation characteristics (Table 7).

Table 6.- Number of peer-reviewed articles reporting changes in hydro-morphological variables or processes associated to agricultural practices, related to observed riparian vegetation changes (Total number of articles = 15).

AGRICULTURAL LAND INCREASE			
ALTERED PHYSICAL VARIABLE/PROCESS	**CHANGE**	**Nº ARTICLES**	**%**
Agriculture Land	Increases	15	100
Suspended solids	Increases	6	40
Nutrients	Increases	5	33
Channel Narrowing	Increases	3	20
Average Flow	Decreases/Increases	2	13
Salinity	Increases	1	7
Peak Flows	Decreases	1	7
Runoff	Increases	1	7
Floods	Decreases	1	7
Base Flows	Increases	1	7
Channel Accretion	Increases	1	7
Channel incision	Increases	1	7
Groundwater levels	Increases	1	7

Table 7.- Number of peer-reviewed articles reporting changes in riparian vegetation variables associated to agricultural practices. (Total number of articles = 15)

AGRICULTURAL LAND INCREASE				
VEGETATION VARIABLE		**RESPONSE**	**Nº ARTICLES**	**%**
Taxonomic Changes	Composition	Altered	5	33
	Diversity	Decreases	2	13
	Richness	Decreases	2	13
Landscape Changes	Coverage	Increases/Decreases	6	40
	Riparian Area	Decreases	7	47
	Spatial Structure	Altered	2	13
	Age Structure	Altered	1	7
Functional Changes	Mortality	Increases	1	7
	Riparian Condition	Altered	1	7

Summing up the scored evidence of the revised articles, we can conclude that the literature highly support the hypothesis that agricultural land increase promotes changes in the species composition of riparian communities and decreases the area and cover of riparian corridors (Table 8, Figure 8a).

Table 8.- Assessment of evidence supported by the revised literature in relation to causal effects of agricultural practices on riparian vegetation characteristics.

AGRICULTURE CAUSALITY				
VEGETATION VARIABLE	**RESPONSE**	**TOTAL SCORE**	**TOTAL SCORE**	**EVIDENCE ASSESSMENT**
Riparian area	Decrease	40	>20	High
Total Cover	Increase/Decrease	37	>20	High
Composition	Altered	25	>20	High
Richness	Decrease	16	20_10	Moderate
Diversity	Decrease	16	20_10	Moderate
Spatial Structure	Altered	13	20_10	Moderate
Riparian Condition	Altered	8	<10	Low
Age Structure	Altered	5	<10	Low
Mortality	Increase	5	<10	Low

Exploring the involved mechanisms, we could expect causality between agricultural practices and channel narrowing and sediment and nutrient delivery increases. These hypothesis were weakly supported by the revised literature. However, we found evidence of agriculture promoting changes in species composition and decreases in riparian area and coverage likely associated to those expected effects (figure 8b).

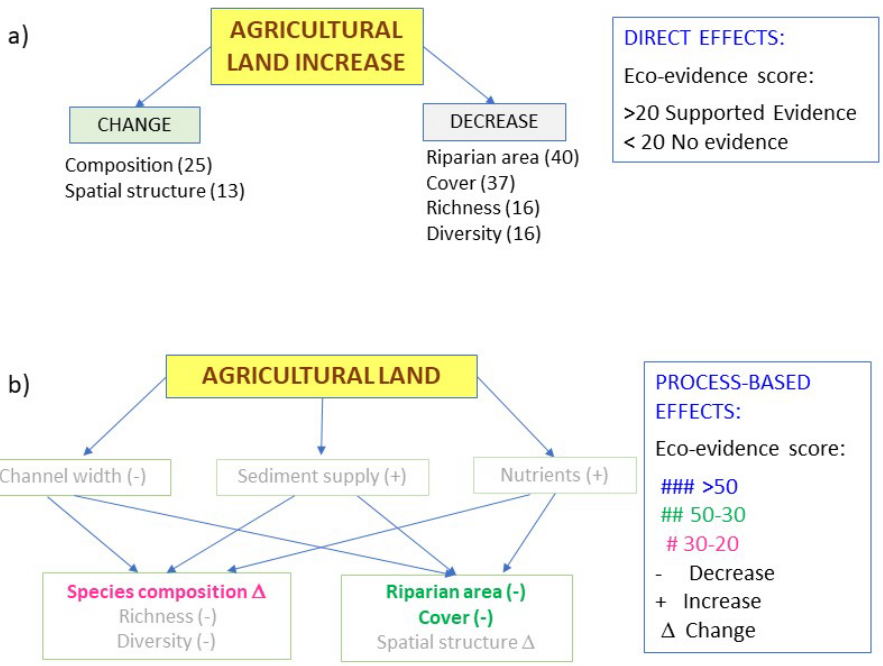

Figura 8.- Scored evidence of agricultural practices effects on riparian vegetation supported by the reviewed literature. a) Evidence of direct effects in riparian vegetation characteristics related to agricultural land increase. b) Evidence of cascading effects in fluvial processes and conditions that affect vegetation life-stages and resulting vegetation characteristics. Variables in grey colour mean evidence < 20

3.3.2. Urban land

Table 9 shows the number of articles dealing with changes in physical variables or processes related to urbanization that are associated with riparian vegetation changes, whereas Table 10 summarizes the number of articles stating the riparian vegetation changes.

Table 9.- Number of peer-reviewed articles reporting changes in hydro-morphological variables or processes associated to urbanization, related to observed riparian vegetation changes (Total number of articles = 26).

URBANIZATION EFFECTS			
ALTERED PHISICAL VARIABLE/PROCESS	**CHANGE**	**Nº ARTICLES**	**%**
Urban Land	Increases/Follow a gradient	26	100
Impervious Surface	Increases	8	31
Stream Flow	Increases	1	4
Soil Organic Matter	Increases	1	4
Soil Moisture	decreases	2	8
Soil compaction	Increases	1	4
Runoff	Increases	2	8
pH	Increases	1	4
Infiltration	Decreases	1	4
Flood Magnitude	Increases	1	4
Flood Intensity	Decreases	1	4
Channel Width	Increases	1	4
Soil Nutrients	Increases	1	4
Baseflow	Decreases	1	4
Annual Discharges	Increases	1	4

Table 10.- Number of peer-reviewed articles reporting changes in riparian vegetation variables associated to urbanization. (Total number of articles = 26)

URBANIZATION EFFECTS				
VEGETATION VARIABLE		**CHANGE**	**Nº ARTICLES**	**%**
Taxonomic Changes	Composition	Altered	19	73
	Diversity	Decreases	4	15
	Richness	Increases/Decreases	11	42
Landscape Changes	Coverage	Increases/Decreases	16	62
	Riparian Area	Decreases	2	8
	Density	Decreases	3	12
	Spatial Structure	Altered	8	31
	Structural complexity	Decreases	1	4
Functional Changes	Growth	Decreases	1	4
	Recruitment	Decreases	1	4
	Functional aspects	Altered	1	4
	Functional richness	Decreases	1	4
	Functional Traits	Altered	1	4
	Seed dispersal	Altered	1	4
	Succession	Altered	1	4

Table 11 shows the results of summing up the scored evidence of the revised articles dealing with urbanization effects. In this case we found high support for the hypothesis that increasing urban land altered species composition and spatial structure, decreases diversity and density and change cover and richness but resulting in increase or decrease according to the site.

Table 11.- Assessment of evidence supported by the revised literature in relation to causal effects of urbanization on riparian vegetation characteristics.

URBANIZATION CAUSALITY				
VEGETATION VARIABLE	**RESPONSE**	**TOTAL SCORE**	**TOTAL SCORE**	**EVIDENCE ASSESSMENT**
Composition	Altered	160	>20	High
Coverage	Increases/Decreases	130	>20	High
Richness	Increases/Decreases	103	>20	High
Spatial Structure	Altered	63	>20	High
Diversity	Decreases	36	>20	High
Density	Decreases	22	>20	High
Functional Traits	Altered	10	10	Moderate
Seed dispersal	Altered	10	10	Moderate
Structural complexity	Decreases	8	<10	Low
Growth	Decreases	8	<10	Low
Functional aspects	Altered	8	<10	Low
Functional richnes	Decreases	8	<10	Low
Riparian Area	Decreases	7	<10	Low
Recruitment	Decreases	6	<10	Low
Succession	Altered	6	<10	Low

Finally, figure 9 includes diagrams showing causal effects of urbanization. Direct effects resulting in change or decrease of several attributes exposed in table 10 are highly supported (figure 9a). Bly the contrary, the mechanisms involved in these changes are in general poorly supported (figure 9b). Obviously, increasing urbanization increases impervious land which reduces soil moisture, but the rest of mechanism likely responsible for the observed vegetation responses were very weakly reported.

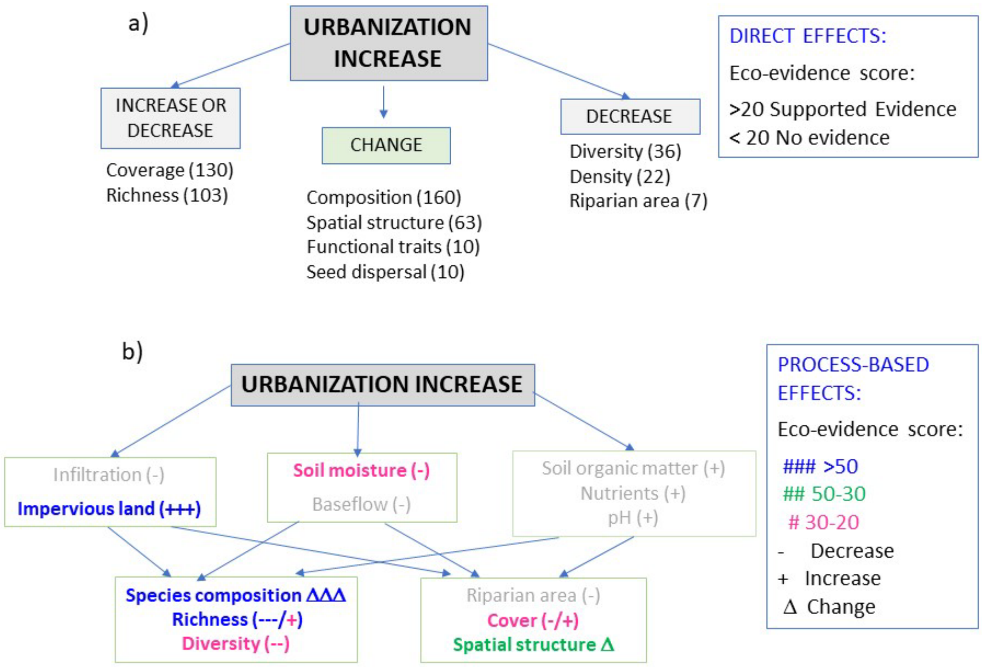

Figure 9.- Scored evidence of urbanization effects on riparian vegetation supported by the reviewed literature. a) Evidence of direct effects in riparian vegetation characteristics related to agricultural land increase. b) Evidence of cascading effects in fluvial processes and conditions that affect vegetation life-stages and resulting vegetation characteristics. Variables in grey colour mean evidence < 20

3.4. Floodplain and riparian land uses

Grazing and mining within the floodplains and riparian zones may be considered, after agriculture and urbanization, the main land uses likely associated to riparian vegetation impairment.

3.4.1. Grazing

Tables 12 a 13 shows the number of peer-reviewed articles found in our literature search dealing with grazing effects on riparian vegetation, stating the physical variables or processes altered by the livestock and the main studied vegetation variables, respectively.

Table 12.- Number of peer-reviewed articles reporting changes in hydro-morphological variables or processes associated to grazing, related to observed riparian vegetation changes (Total number of articles = 41).

GRAZING EFFECTS			
PHYSICAL ALTERED VARIABLE/PROCESS	**CHANGE**	**Nº ARTICLES**	**%**
Grazing Land	Current / Increase	41	100
Soil Nutrients	Increases/Decreases	4	10
Soil Moisture	Increases/Decreases	2	5
pH	Decreases	1	2
Bank erosion	Increases	1	2
Channel Width	Increases	1	2
Stream depth	Increases	1	2

Table 13.- Number of peer-reviewed articles reporting changes in riparian vegetation variables associated to grazing. (Total number of articles = 41)

GRAZING EFFECTS				
VEGETATION VARIABLE		**CHANGE**	**Nº ARTICLES**	**%**
Taxonomic Changes	Composition	Altered	20	49
	Diversity	Increases/Decreases	5	12
	Richness	Increases/Decreases	5	12
Landscape Changes	Coverage	Increases/Decreases	23	56
	Area	Decreases	2	5
	Density	Decreases	4	10
	Biomass	Increases/Decreases	3	7
	Spatial Structure	Altered	12	29
Functional Changes	Growth	Decreases	1	2
	Flowering	Altered	1	2
	Productivity	Decreases	3	7
	Recruitment	Decreases	2	5

Table 14 includes the results of summing up the scored evidence of the revised articles. As it is reflected in the table, causal effects of grazing altering species composition and spatial structure are highly supported by the literature, together with decreases in riparian vegetation density and productivity. Causal relationships of grazing with changes in coverage, diversity, richness and biomass were also evidenced by the revised literature, but with variable results towards increase or decrease according to the sites.

Table 14.- Assessment of evidence supported by the revised literature in relation to causal effects of grazing on riparian vegetation characteristics.

GRAZING CAUSALITY				
VEGETATION VARIABLE	**RESPONSE**	**TOTAL SCORE**	**TOTAL SCORE**	**EVIDENCE ASSESSMENT**
Composition	Altered	95	>20	High
Spatial Structure	Altered	90	>20	High
Coverage	Increases/Decreases	69	>20	High
Density	Decreases	34	>20	High
Diversity	Increases/Decreases	32	>20	High
Richness	Increases/Decreases	32	>20	High
Biomass	Increases/Decreases	24	>20	High
Productivity	Decreases	21	>20	High
Area	Decreases	18	18	Moderate
Recruitment	Decreases	13	13	Moderate
Growth	Decreases	8	<10	Low
Flowering	Altered	8	<10	Low

Figure 10 represents the diagrams related to grazing effects. As in the previous cases, high support is found for the hypothesis that grazing causes direct riparian vegetation changes (figure 10a) but the mechanisms involved are not so clear (figure 10b), and the existing literature do not evidence the mechanisms involved, resulting in this case much more variable and site-specific than in the previous reported pressures.

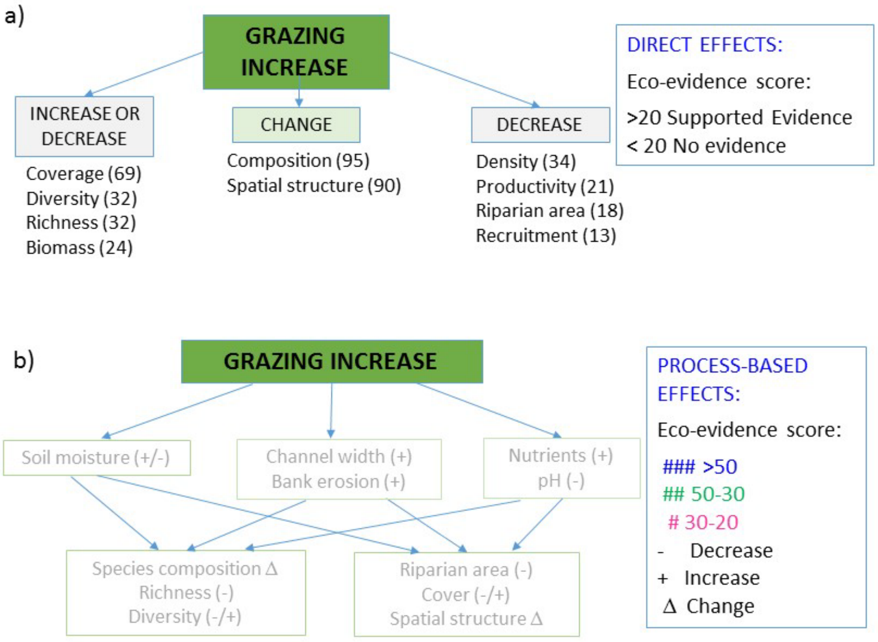

Figure 10.- Scored evidence of grazing effects on riparian vegetation supported by the reviewed literature. a) Evidence of direct effects in riparian vegetation characteristics related to agricultural land increase. b) Evidence of cascading effects in fluvial processes and conditions that affect vegetation life-stages and resulting vegetation characteristics. Variables in grey colour mean evidence < 20

3.4.2. Mining

Mining activity within the floodplain and riparian zones, implying dredging and gravel extraction, seriously impair riparian vegetation stands. The existing literature dealing with these effects is relatively scarce, producing the findings exposed in tables 15 to 17.

Mining has been associated with the increase in pollutants and channel narrowing and incision (table 15) and changes in many characteristics of vegetation, with variable response in coverage (table 16).

According to the scored evidence of causality shown in table 17, we could conclude that the literature only supports the hypothesis that mining changes the vegetation cover, with variable results towards increasing or decreasing. For the rest of observed changes (e.g., alteration of species composition, spatial structure, o decrease in diversity, richness, riparian area, etc.) the causal links with mining were not enough evidence-based.

Table 15.- Number of peer-reviewed articles reporting changes in hydro-morphological variables or processes associated to mining, related to observed riparian vegetation changes (Total number of articles = 7).

MINING EFFECTS			
PHYSICAL ALTERED VARIABLE/PROCESS	**ALTERATION**	**Nº ARTICLES**	**%**
Mining area	Increases	6	86
Pollutants	Increases	2	29
Channel Incision	Increases	2	29
Channel Narrowing	Increases	1	14
Dredging area	Increases	1	14

Table 16.- Number of peer-reviewed articles reporting changes in riparian vegetation variables associated to mining. (Total number of articles = 7)

MINING EFFECTS				
VEGETATION VARIABLE		RESPONSE	Nº ARTICLES	%
Taxonomic Changes	Composition	Altered	2	29
	Diversity	Decreases	1	14
	Richness	Decreases	1	14
Landscape Changes	Coverage	Increases/Decreases	3	43
	Riparian Area	Decreases	1	14
	Biomass	Decreases	1	14
	Spatial Structure	Altered	2	29
	Age Structure	Altered	1	14
	Plant Structure	Altered	1	14
Functional Changes	Colonization	Increases	1	14
	Germination	Decreases	1	14
	Live form	Altered	1	14
	Survival	Decreases	1	14

Table 17.- Assessment of evidence supported by the revised literature in relation to causal effects of mining on riparian vegetation characteristics.

VEGETATION VARIABLE	RESPONSE	TOTAL SCORE	TOTAL SCORE	EVIDENCE ASSESSMENT
Coverage	Increases/Decreases	23	>20	High
Composition	Altered	16	20_10	Moderate
Diversity	Increases	9	<10	Low
Spatial Structure	Altered	9	<10	Low
Live form	Altered	9	<10	Low
Richness	Decreases	8	<10	Low
Biomass	Decreases	8	<10	Low
Plant Structure	Altered	6	<10	Low
Germination	Decreases	6	<10	Low
Survival	Decreases	6	<10	Low
Riparian Area	Decreases	5	<10	Low
Age Structure	Altered	5	<10	Low
Colonization	Increases	5	<10	Low

In the case of mining, the revised articles did not allow to produce diagrams stating causality, as they did not inform enough on the altered variables and the mechanisms involved, both because of the reduced number of publications and the absence of evidences.

4. GENERAL CONCLUSIONS

As preliminary conclusions of the results presented in this document, needing a deep discussion that is not included in this Deliverable, we could summarize the following:

1.- Causal criteria analysis and evidence-based review have been found to be well suited to establishing causal links between pressures and riparian vegetation status, identifying gaps and limitations of the existing knowledge.

2.- The use of weighted evidence from the reviewed literature has allowed the creation of simplified diagrams of causality, stating the level of support for the proposed hypothesis. This diagrams represent useful tools for transferring knowledge from scientific community to stakeholders.

3.- Most of the research that deals with effects of pressures on the status of riparian vegetation focuses on the direct effects on the characteristics of vegetation, but without evidencing the mechanisms or involved processes that could explain the observed responses and status.

4.- In relation to pressures, flow regulation by dams and reservoirs has been the most studied and best reported, both in terms of altered hydrological variables and responses of the vegetation.

5.- The decrease in high-flows, together with the increase in low flows, have been the most studied hydrological alterations with observed effects on riparian vegetation in the reviewed literature.

6.- In the case of the decrease of high-flows, the literature supports the hypothesis that it causes the decrease in riparian soil moisture and the increase in channel narrowing and incision, and also supports their causality of increase in vegetation cover (e.g., vegetation encroachment) and changes in species composition (e.g., decline of pioneers, terrestrialization) and age structure (e.g., aging).

7.- Concerning the increase of low flows, it frequently occurs simultaneously with the decrease of high-flows and the reported vegetation responses are in most of the cases assessed together, without clear understanding of its isolated effect.

8.- Regarding the other pressures studied, insufficient or inconsistent evidence of causality has often been found. Change in species composition is the most frequently reported effect, it occurs as a consequence of all the studied pressures, and increase or decrease in coverage and richness have been also frequently found according to the cases, under the same reported pressure.

9.- Multiple pressures acting at multiple scales wit cumulative spatio-temporal effects can make it difficult to understand the role of each pressure and its causal effects on the current vegetation status. By other side, similar responses of riparian vegetation to different pressures have been frequently found.

10.- The strong site-specificity of vegetation responses to pressures is recognized, taking into account the potential uniqueness of river reaches where different external agents may influence, exacerbate or mitigate the effects (e.g., hydromorphological context, valley type, soil texture, channel size, particle size, climatic conditions, etc.).

11.- The difficulty in achieving compliance with the causal criteria is recognized, given the great diversity of approaches and research designs, the variability of the altered variables reported and the responses of the vegetation, the different denomination of equal or equivalent variables, and the relative small number of sites reported as before-impact, control or spatial gradients.

12.- Our results reveal an important gap in the scientific evidence of causality between pressures and mechanisms involved in the observed vegetation changes, both in terms of alteration of the riparian vegetation requirements and alteration of vegetation life-stages. By other side, our results also reveal a relatively strong evidence of correlation between pressures and changes in certain vegetation characteristics.

13.- The exploration of causal links between pressures and habitat requirements of riparian vegetation should be a priority in research on pressures and vegetation status. From this research, a better understanding of the processes involved that are taking place in each case could be achieved, as a fundamental basis for defining guidelines and strategies for the sustainable management of riparian vegetation.

14.- More comprehensive process-based evidence of the causality between pressures, mechanisms involved and interactions with vegetation life-stages that ultimately determine the current characteristics and status of riparian vegetation seems necessary to adequately argue for the best management and restoration measures to be accepted by the stakeholders and the society.

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ANEXE

REVISED PEER-REVIEWED ARTICLES

1. FLOW REGULATION

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