Modelling vegetation responses under different scenarios of climate change

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Introduction

- Increased temperature and changes in seasonal precipitation patterns are predicted in southern Europe (IPCC, 2014) → changes in river discharge are also expected: general reduction of mean river flows, increase of high flows and decrease of low flows (Dankers and Feyen, 2008; Lehner et al. 2006; van Vliet et al., 2013).

- River discharge is an important control on both channel morphodynamics and riparian vegetation → hydrological changes will lead to changes in river morphology and riparian vegetation

- The consequences of climate change have been widely studied in relation to macroinvertebrates and fish communities, **but the effect of climate change on riparian vegetation remains more site-specific and complex to predict**.
- Advances in modelling techniques that predict successional life stages of riparian forests in the context of hydromorphodynamic processes allows to go a step forward.

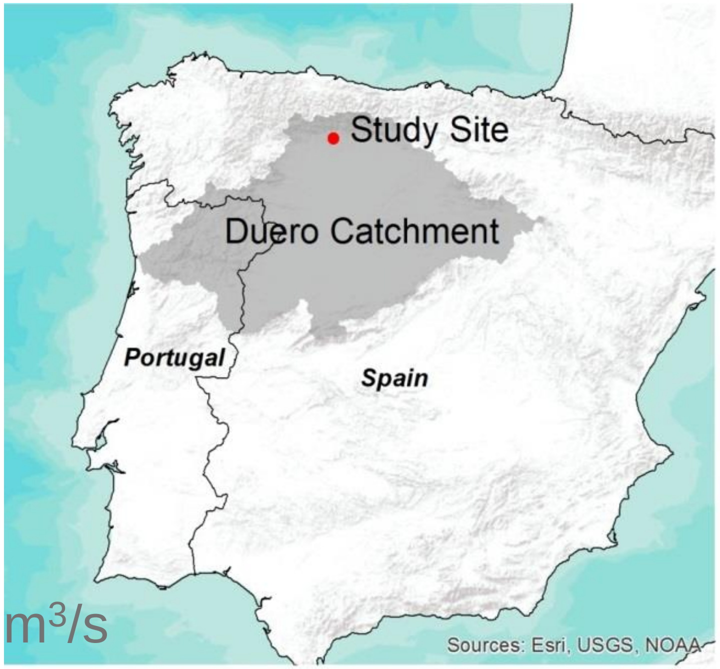
Introduction

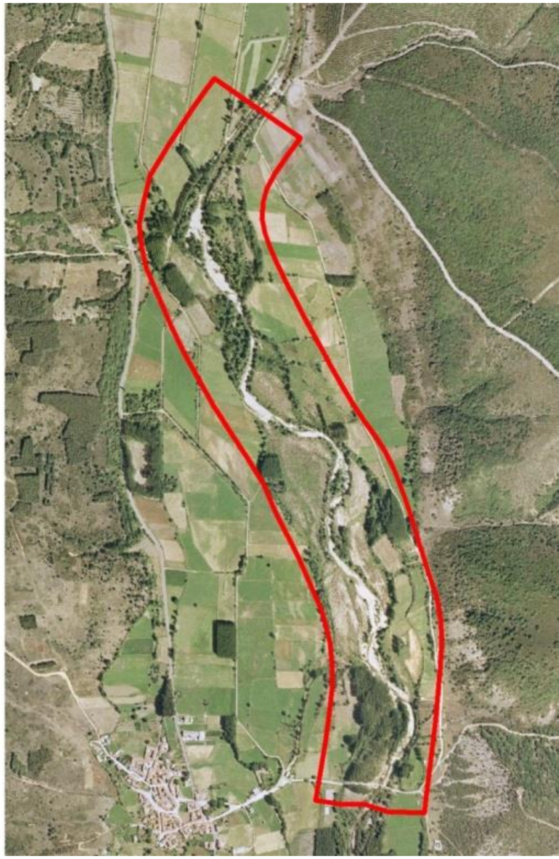
✓ **This research aims to explore the potential evolution of riparian corridors under different hydrological scenarios which are likely to occur in Mediterranean regions (*)**

1. Innovative model containing the coupling between advanced morphodynamics and dynamic vegetation (Van Oorschot et al., 2016) to explicitly take the interactions between vegetation and morphodynamics into account.
2. Climate change scenarios proposal according to bibliography

(*) Martínez-Fernández, V., Van Oorschot, M., De Smit, J., González del Tánago, M., & Buijse, A. D. (2018). **Modelling feedbacks between geomorphological and riparian vegetation responses under climate change in a Mediterranean context**. *Earth Surface Processes and Landforms*, *43*(9), 1825-1835.

Study site





- **Curueño River**
- Mean discharge: 4.5 m^3/s
- Gravel bed River
- Reach: 2 km long
- Vegetation composition
  - Pioneer species at lower elevationos: *Salix fragilis*, *Populus nigra, S. atrocinerea*, *S. purpurea, S. eleagnos* and *S. cantabrica*.
  - Hardwood species at higher positions: *Crataegus monogyna*, *Fraxinus angustifolia*, *F. excelsior* or *Prunus avium* .

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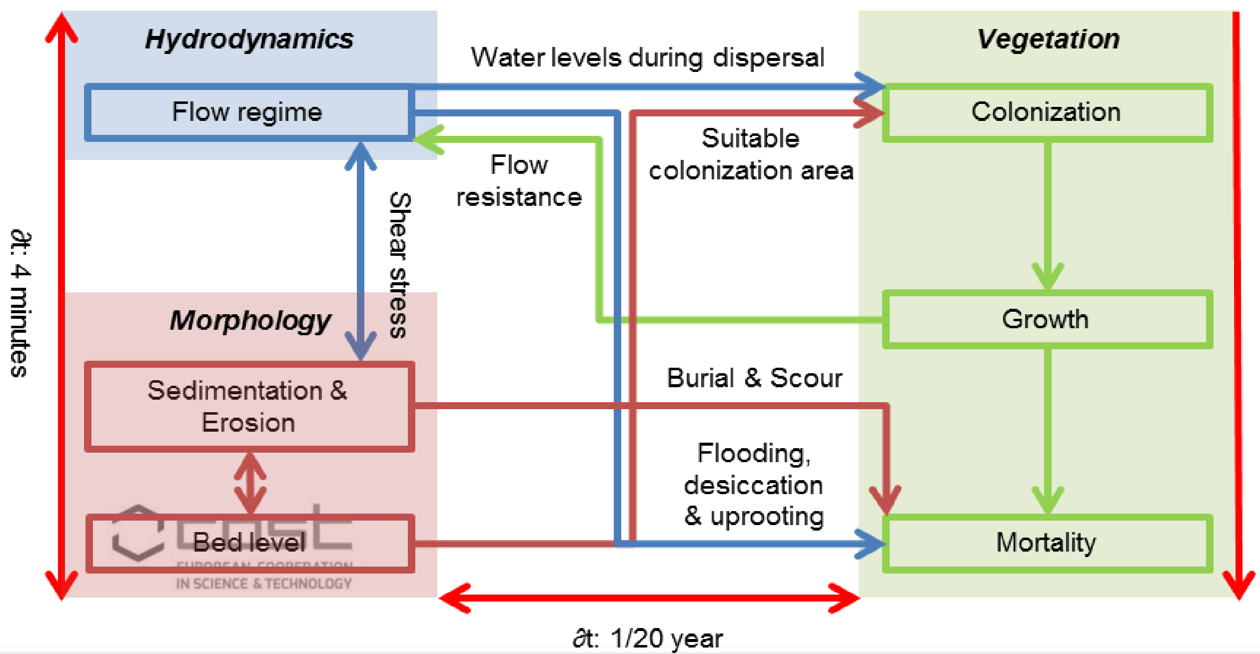
Methodology

- **1. Vegetation Model** (Van Oorchot et al., 2016)
- The morphodynamic model was constructed in Delft3D. Initial bed level conditions: DEM (5-m spatial resolution,www.ign.es, from 2010)
- The vegetation model was used as described in Van Oorschot et al. (2016):

1. Vegetation colonization: May and June
2. Growth and interaction **with morphodynamics** through flow resistance.
3. Mortality: **burial, scour, uprooting, flooding or desiccation.**



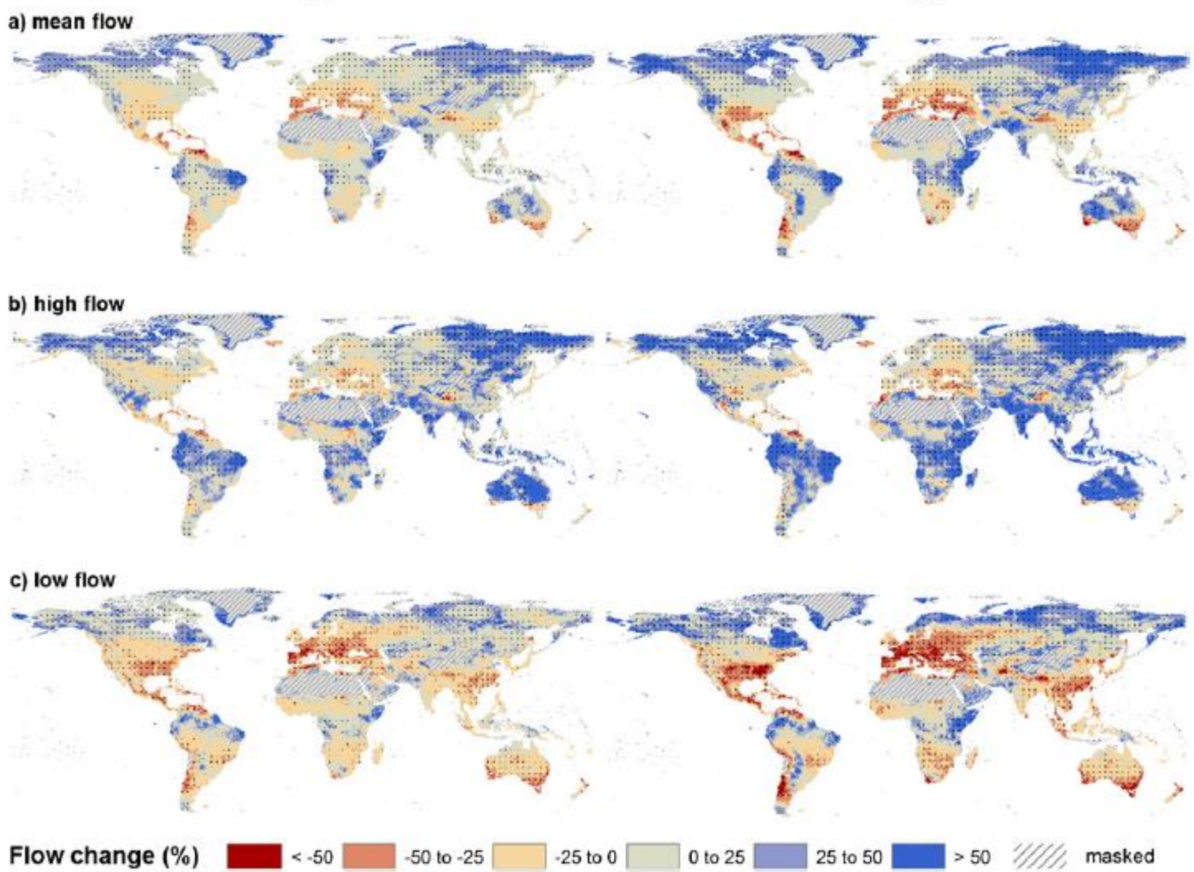
- Potential colonization
- Seedling establishment

Coupling structure between the morphodynamic model (Delft3D version 4.01.00) and vegetation model (van Oorschot, 2016).

Methodology

2. Climate change scenarios proposal (Van Vliet et al., 2013; Lehner et al., 2006)

- **Baseline scenarios:** Period from 1961 to 1990 commonly used by the World Meteorological Organization (WMO) and widely used in previous studies . The baseline discharge period is replicated from 1990 until 2100 .



van Vliet et al., 2013

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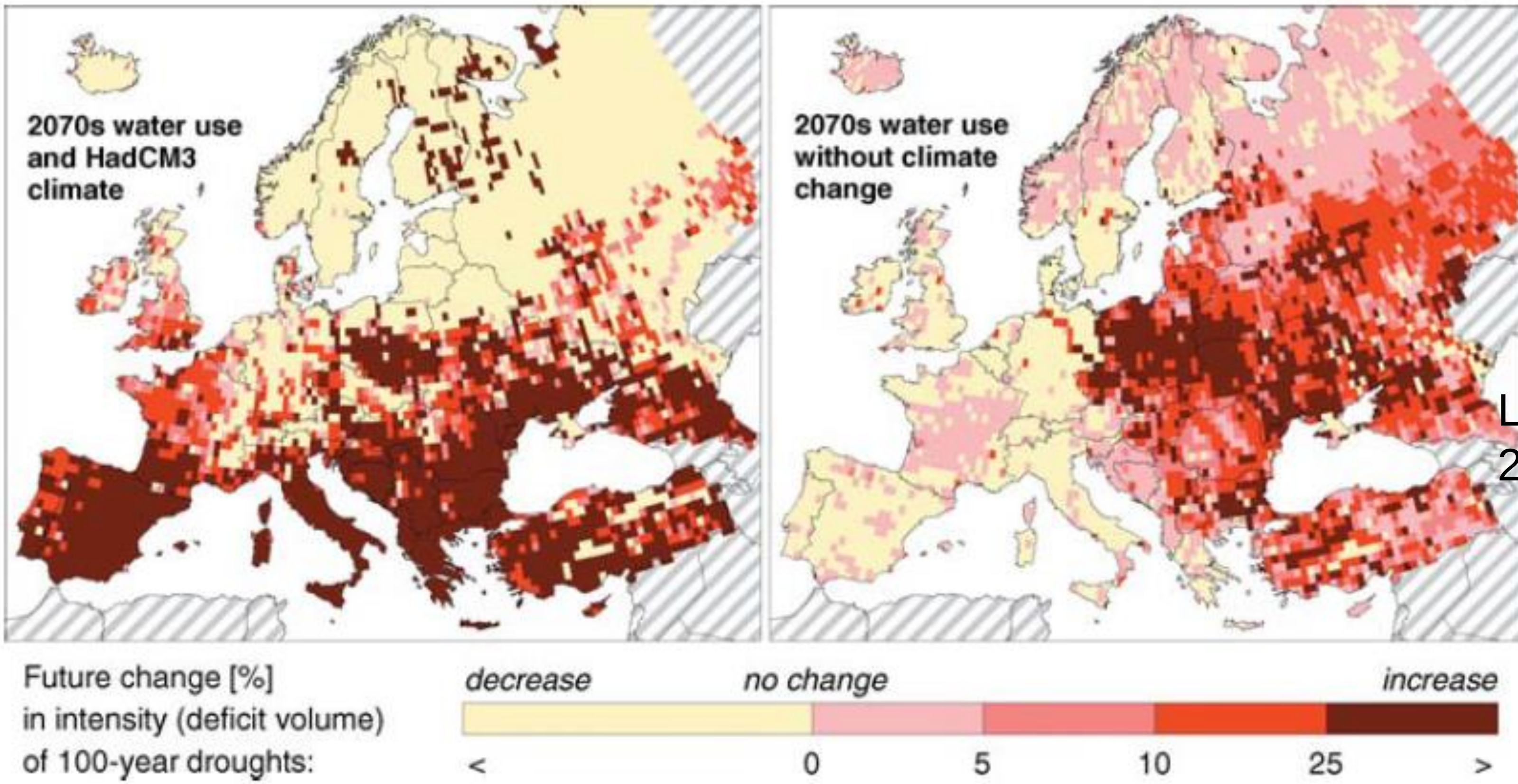

Lehner et al., 2006

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Scenarios	Changes in flow by 2100 (%)		
	Mean flows	High flows (Q>Q95)	Low flows (Q<Q10)
Reference	0	0	0
1	**-25**	**0**	**-25**
2	**-37.5**	**-12.5**	**-37.5**
3	**-50**	**-25**	**-50**
4	0	+10	-25
5	-25	+10	-25

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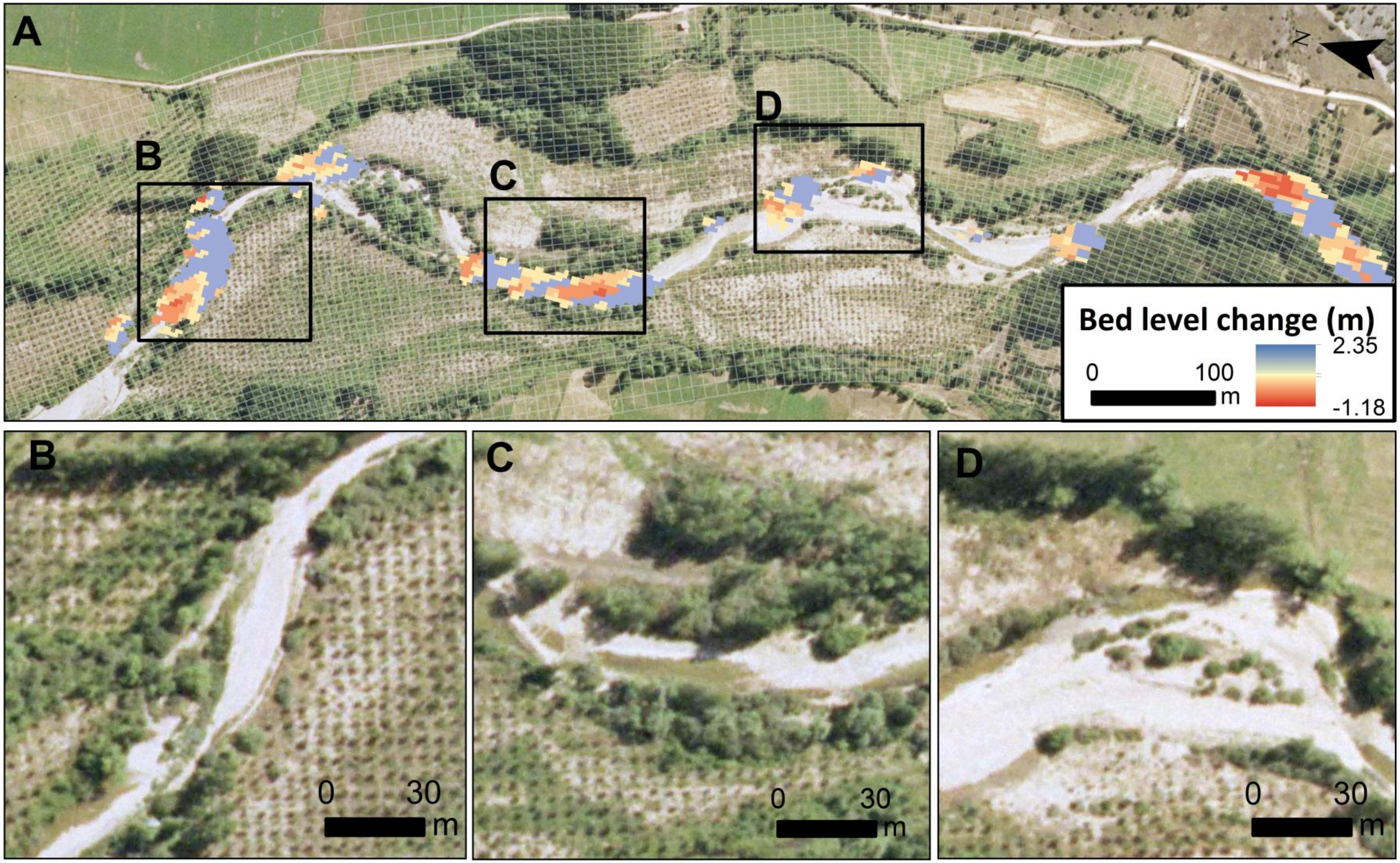
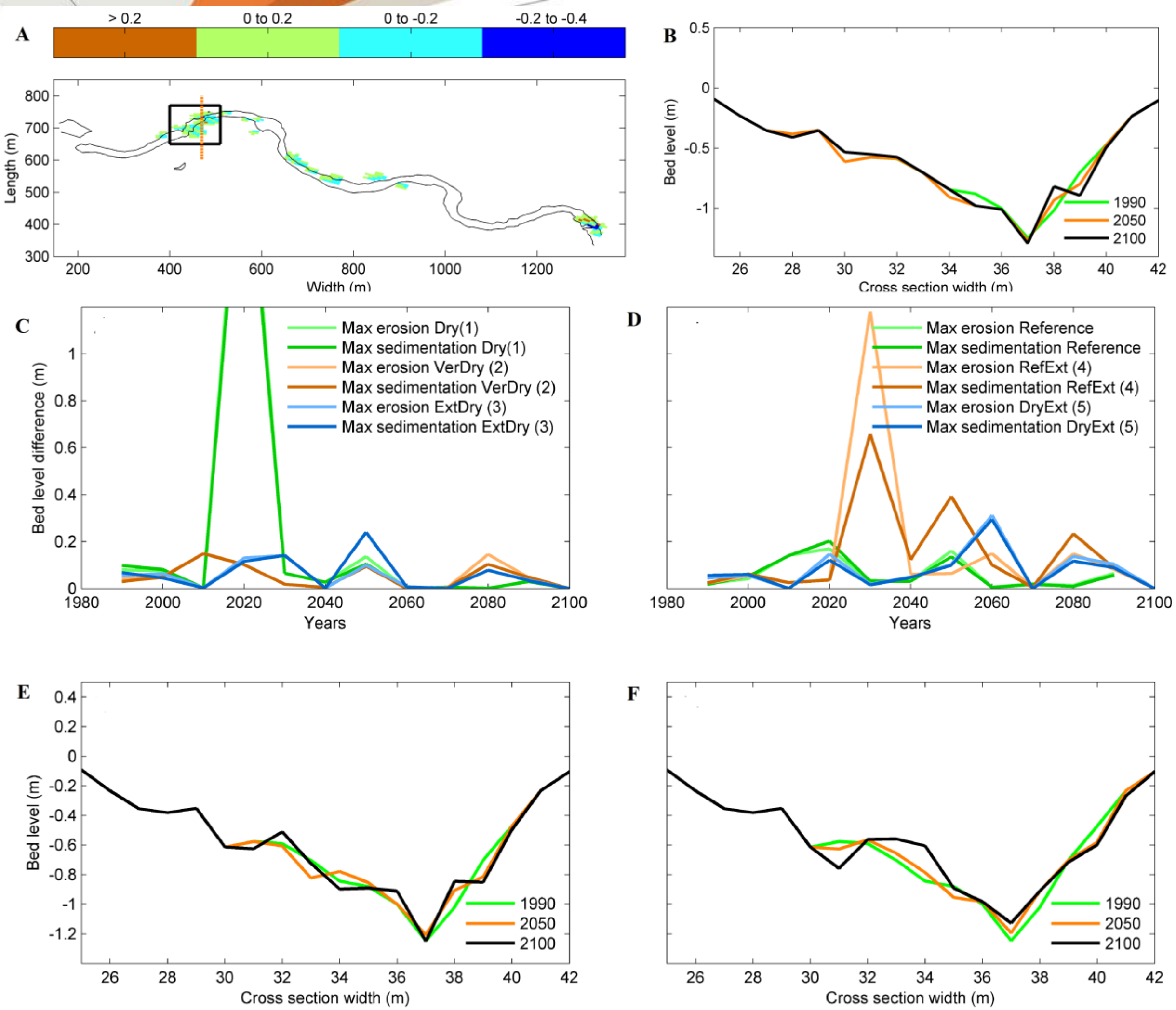
Results



Results



The Reference and ExtDry scenarios show the smaller bed level differences, the highest are found in *RefExt* and *Dry* scenarios.

B. Temporal evolution of a particular cross-section: the river narrows in the deeper parts.

These morphological changes lead to different local conditions for seedling colonization and survival.

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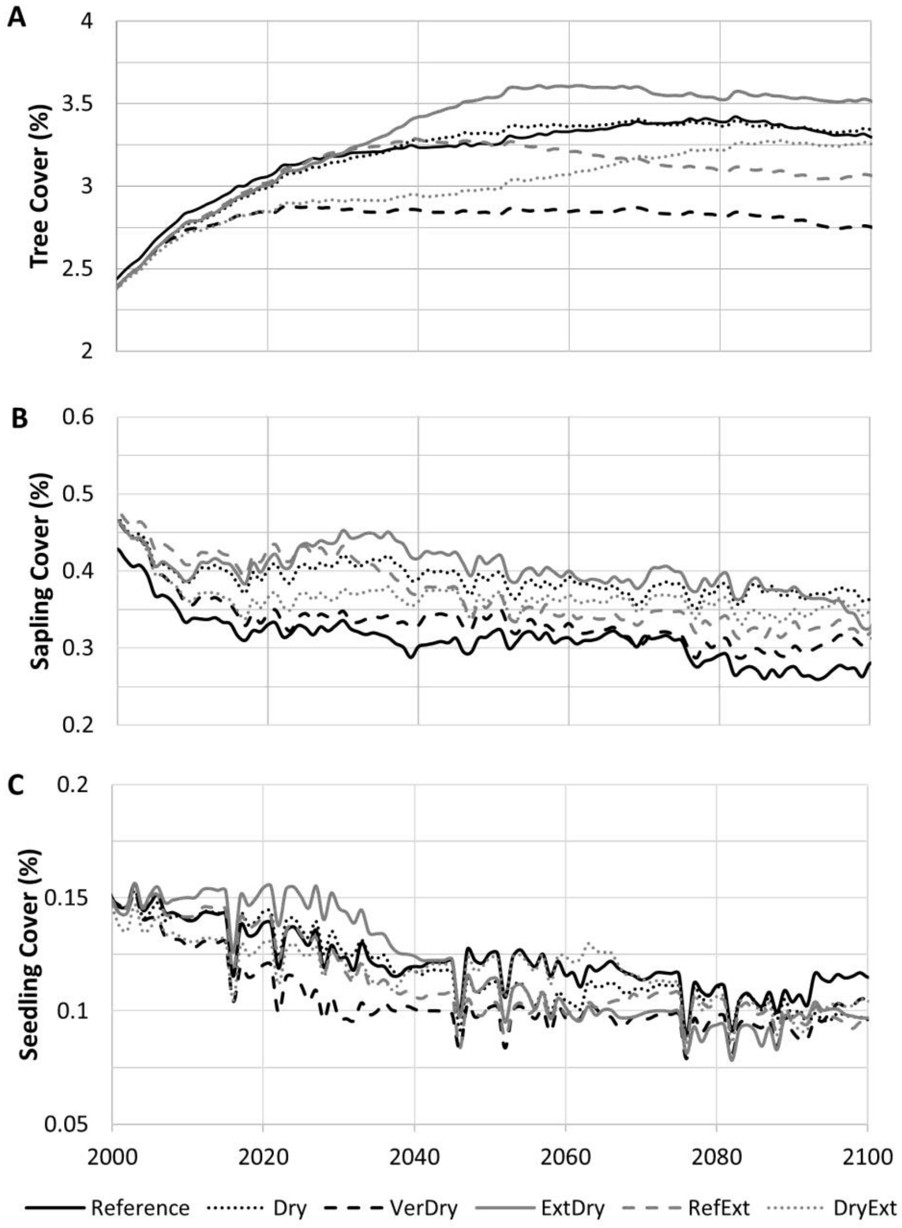
Results



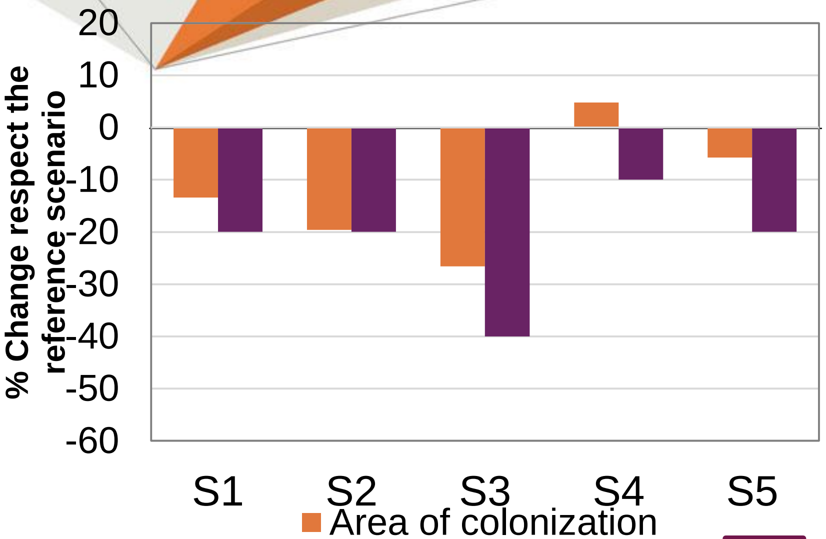
Classification of model output:

1. Seedlings: < 3 years
2. Saplings: between 3 and 10 years
3. Trees: > 10 years

Total vegetation cover in 2100 ranging from 3.2 % in scenario 2 to 3.94 in scenario 3.

- ✓ Seedling and sapling cover present a decreasing trend.
- ✓ Seedling cover under climate change is generally lower.
- ✓ Sapling cover is higher.
- ✓ Tree cover present an increasing trend that stabilizes in 2050

Results



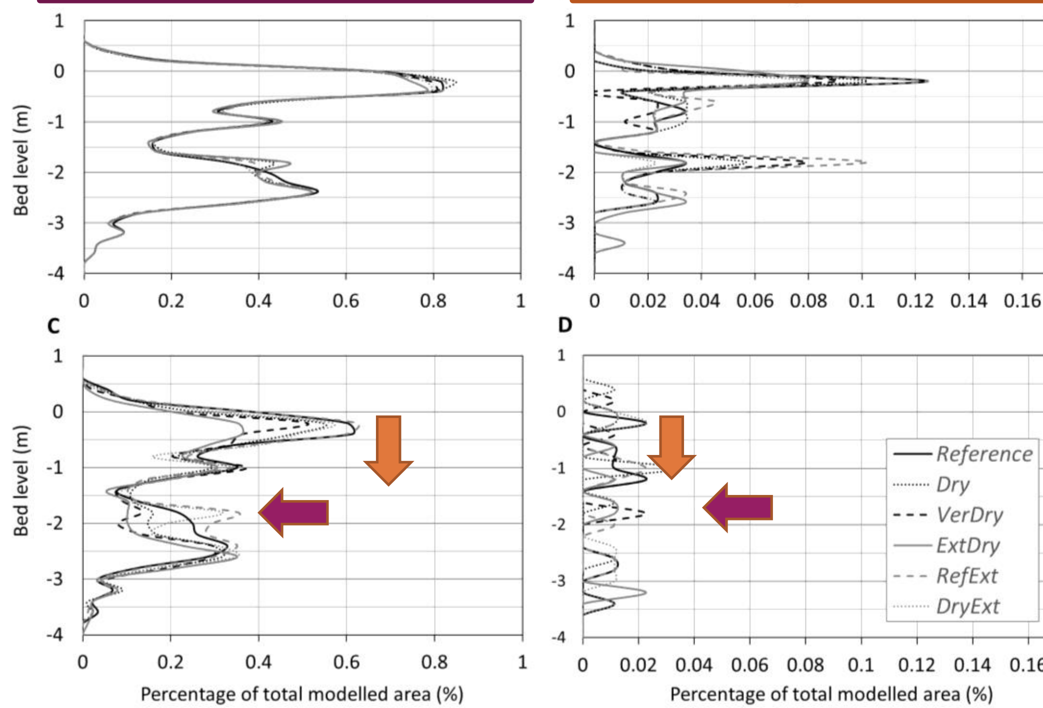
- The colonization area would decrease by the year 2100, **being more intense the decline with driest conditions** (S3)
- Spatial distribution: Lower positions (the lowest for the driest scenario)

Potential Colonization

Seedling stablishment

2000

2100

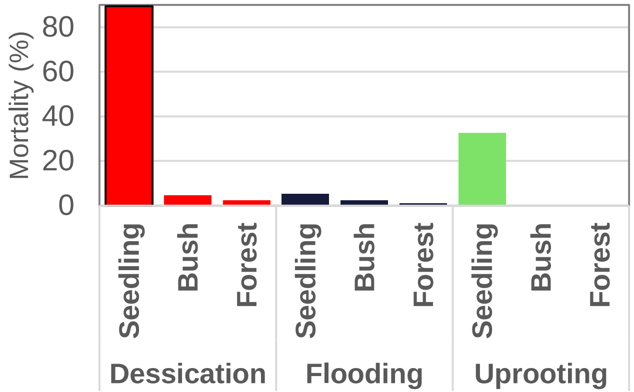


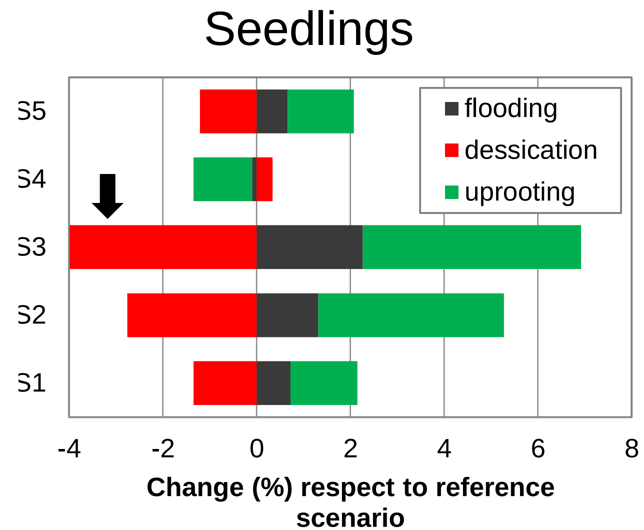
- Stablishment areas would also decrease by the year 2100.
- Spatial distribution: Lower positions (-0.2 m to -1 for Dry; -1.8 for VerDry, -3.2 for ExtDry)

Results

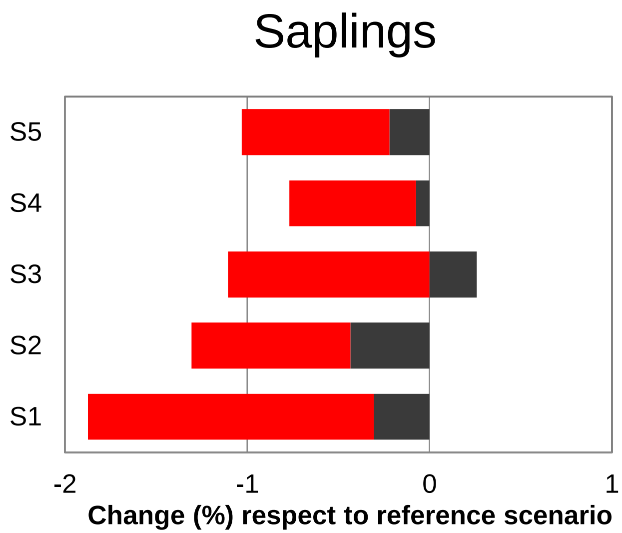
Mortality

- Total mortality rates are very high for seedlings, intermediate for saplings and very low for trees.





- Seedlings: less mortality due to desiccation.
- Saplings: less mortality due to **desiccation**, less mortality due to **flooding** (except driest S3)
- Trees: less mortality due to **desiccation** and **flooding** (except S3)



Discussion

Our results suggest…

✓ We forecast that drier conditions associated with climate change will lead to a decline in vegetation recruitment, a tendency for seedlings to occupy lower positions in the channel where they are more exposed to mortality by uprooting and flooding.

→General narrowing and ageing of riparian corridors.

✓ This temporal trajectory of riparian corridors is applicable to those areas where climate change predictions are related to a decrease in water availability: (Most southern European rivers)

Discussion

Similar biogeomorphic effects on rivers have been observed by other authors in response to other pressures acting at smaller scales (e.g. afforestation, damming), but synergistically with climate change.

Boix-Fayos *et al*. (2007): channel narrowing and vegetation encroachment with catchment-scale land-use changes (reduced sediment supply driven by afforestation and erosion control works).

Liebault & Piégay (2002): extensive channel narrowing with forest development on river margins and human abandonment of intensive floodplain land-uses at catchment scale.

Discussion

Pressures at river segment or reach scale, e.g. flow regulation, similar biogeomorphic responses on fluvial landscapes. Examples of channel narrowing and vegetation encroachment (Graf, 2006; Bejarano *et al*., 2011; González del Tánago *et al*., 2016; Martínez-Fernández *et al*., 2017) that could become reinforced by climate change.

River impacts should be assessed at multiple scales, and that persistent long-term and large-scale pressures like climate change must be taken into account when diagnosing problems induced by small-scale pressures, in order to strategically design realistic rehabilitation goals and sustainable mitigation or adaptation measures.

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