# HyMoCARES Project
## WPT3. EFFECTS OF HYDROMORPHOLOGICAL MANAGEMENT AND RESTORATION MEASURES

# Report regarding the effects on ES of management/restoration works, applying the overall ES framework

## Case studies: Wertach River, Lech River

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# 1 Case studies

The case studies targeted for the analysis in the HyMoCARES project for Germany are the Wertach River and the Lech River.

## 1.1 Wertach River

The case study starts in Augsburg from the district Inningen and ends in the district Göggingen (Figure 1). The case studies are delimited by the area where restoration projects took place. Laterally, the study area has been delimited using historical floodplains data (WMS service http://www.lfu.bayern.de/gdi/wms/hwrk/historische_ereignisse?).

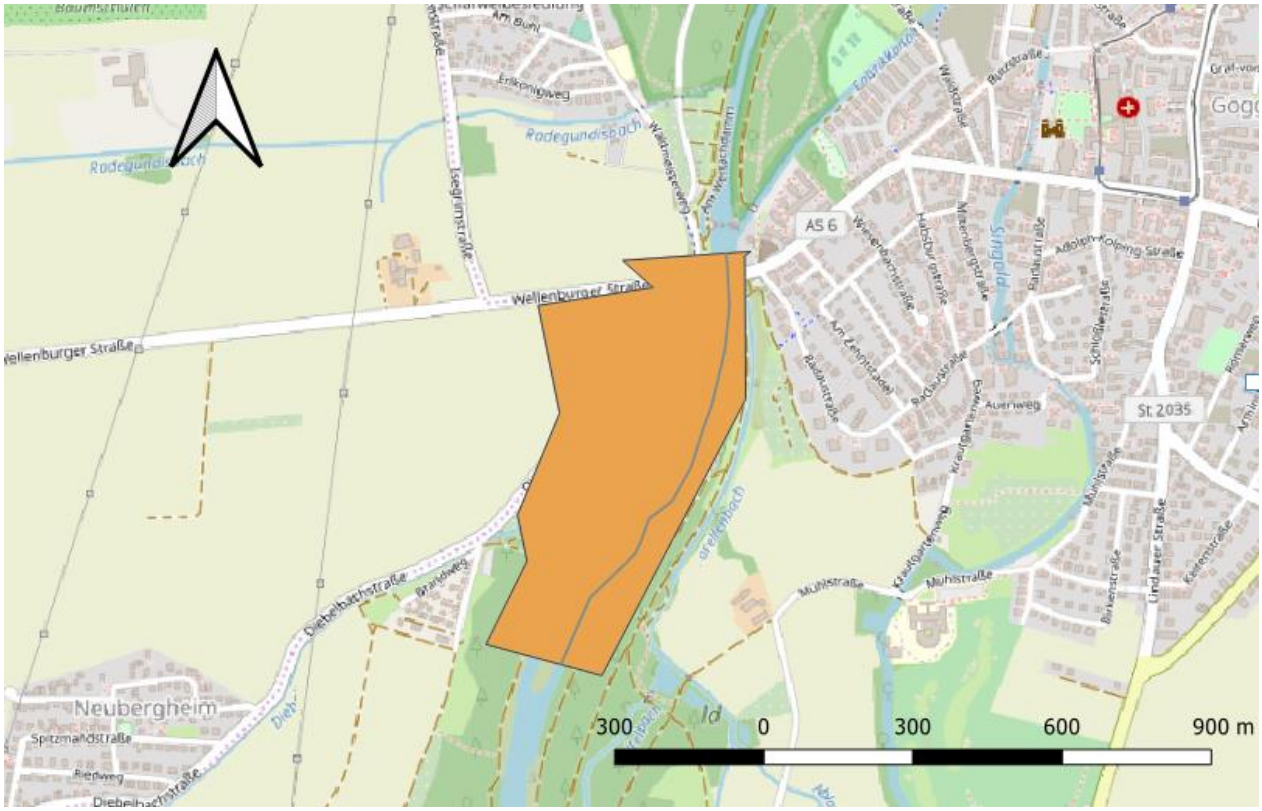


**Figure 1** Wertach River study area.

**Table 1** Length and area of the research unit.

| Id | Length (m) | Area (ha) |
|---|---|---|
| 1 | 857.5 | 26.2 |

The restoration actions that have been implemented in this area are channel widening and reshaping. See Figure 2 for the qualitative effects of this action on hydromorphology and ecosystem services.

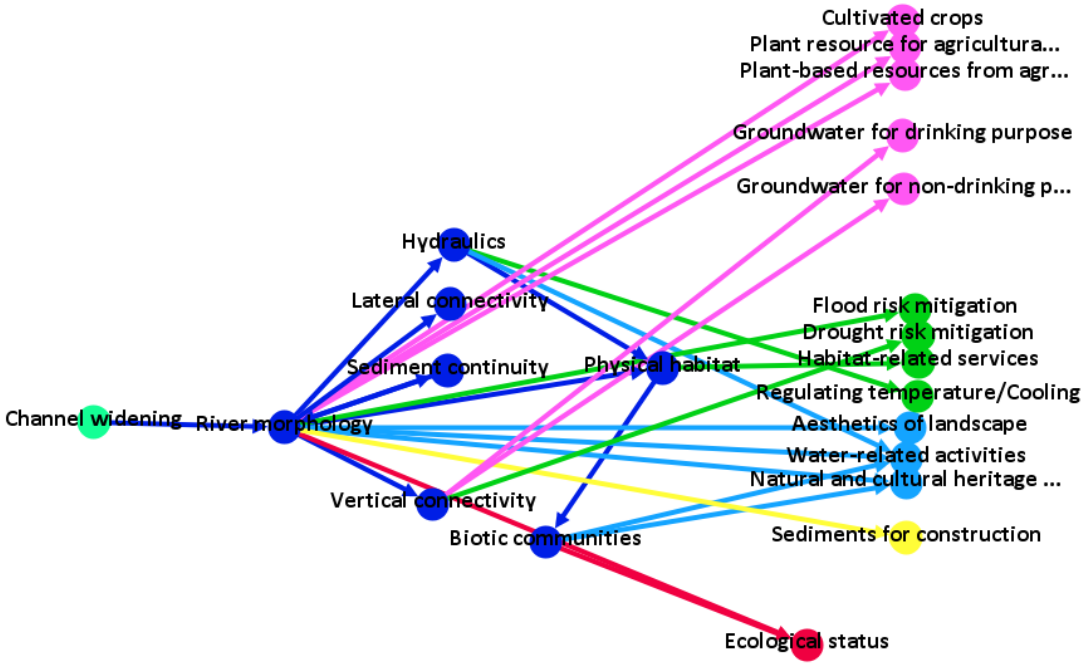


**Figure 2** Hydromorphological processes and ES for "Channel widening" restoration action.

## 1.2 Lech River

The case study starts of the Lech River are limited in space, since it is the creation of a lateral pool to improve fish habitat.

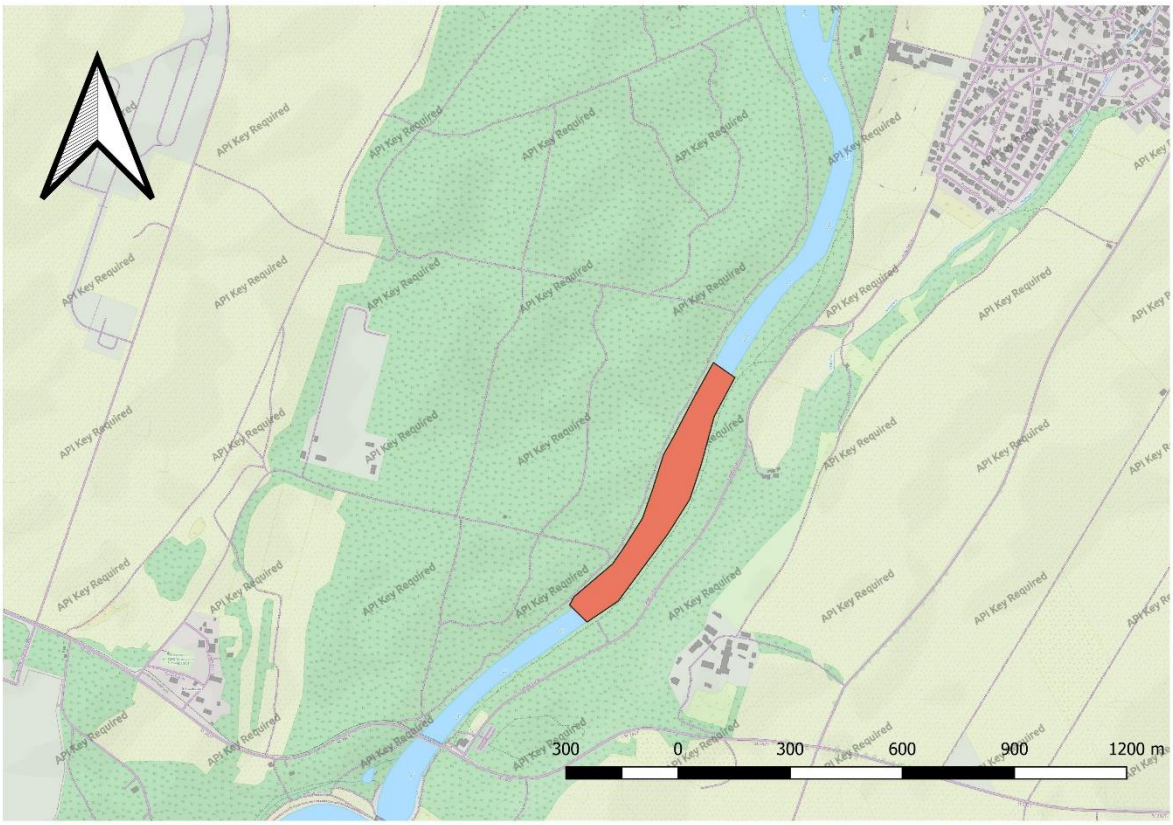


**Figure 3** Lech River study site.

**Table 2** Length and area of the research unit.

| Id | Length (m) | Area (ha) |
|---|---|---|
| 1 | 772.4 | 6.3 |

The restoration actions that are taken into consideration for this area are, according with DT.1.2, the recreation of macroforms. See Figure 4 for the qualitative effects of this action on hydromorphology and ecosystem services.

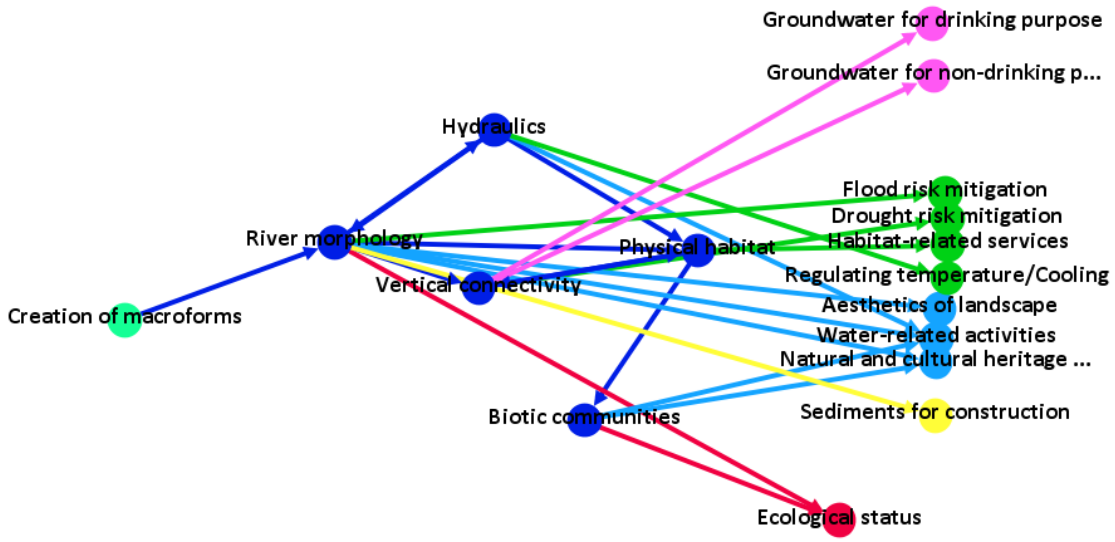


**Figure 4** Hydromorphological processes and ES for "Recreation of macroforms" restoration action.

# 2 ES selection

## 2.1 Wertach River

Following the HyMoCARES framework, the ecosystem services affected by the restoration actions are summarized in Table 3. We selected the services that have been found relevant according with the local agencies.

**Table 3** River ecosystem services suggested in deliverable DT.1.2 (Second column), highlighted as relevant for the case studies (Third column) with some additional comments (Fourth column).

| Ecosystem service | Relevant | Comments |
|---|---|---|
| Cultivated crops | | |
| Plant resources for agricultural use - Pasture | | |
| Ground water for drinking purpose | | |
| Ground water for non-drinking purposes in industry and agriculture | | |
| Plant-based resources from agriculture, short rotation coppice, forestry | | |
| Flood risk mitigation | X | |
| Drought risk mitigation | X | |
| Regulating temperature/Cooling (water bodies and ground) | X | |
| Habitat-related services | X | |
| Aesthetics of landscape | X | |
| Natural and cultural heritage | X | |
| Water-related activities | X | |
| Sediments for construction | X | |
| Ecological status | X | |

## 2.2 Lech River

Following the HyMoCARES framework, the ecosystem services affected by the restoration actions are summarized inTable 4. We selected the services that have been found relevant according with the local agencies.

**Table 4** River ecosystem services suggested in deliverable DT.1.2 (Second column), highlighted as relevant for the case studies (Third column) with some additional comments (Fourth column).

| Ecosystem service | Relevant | Comments |
|---|---|---|
| Ground water for drinking purpose | | |

| Ecosystem service | Relevant | Comments |
|---|---|---|
| Ground water for non-drinking purposes in industry and agriculture | | |
| Flood risk mitigation | X | |
| Drought risk mitigation | X | |
| Regulating temperature/Cooling (water bodies and ground) | X | |
| Habitat-related services | X | |
| Aesthetics of landscape | X | |
| Natural and cultural heritage | X | |
| Water-related activities | X | |
| Sediments for construction | X | |
| Ecological status | X | |

# 3 ES analysis

For each case study, please describe: a) the protocol chosen in DT.3.3.1 (BA, BACI etc.); b) the indicators used for the ES analysis (refer to DT.1.3, but feel free to suggest additional indicators); c) the data used for the analysis.
Please provide the final results of the ES analysis that should be used for the online maps (shapefile, Excel or a table that explicitly links every segment with ES value).

## 3.1 Wertach River

According with available data, with tools selected for hydromorphological assessment and with DT.1.3, we selected a set of indicators to perform the analysis of the ES. As soon as in this case the areas are not equivalent, we weighted each indicator for the percentage of the total area covered by each sub-unit if necessary.

**Table 5** Ecosystem services, indicators and data

| Ecosystem service | Indicator | Data |
|---|---|---|
| **Cultivated crops** | Total production | Corine Land Cover<br>Crop yield (Bayerisches Landesamt für Statistik und Datenverarbeitung) |
| **Habitat-related services** | Hydromorphological status | regional morphological rating |
| **Aesthetics of landscape** | Diversity of landscapes | Corine Land Cover |

| Ecosystem service | Indicator | Data |
|---|---|---|
| | Rare morphologies | Satellite picture |
| **Natural and cultural heritage** | Ratio of protection areas | Natura 2000 map<br>Landscape protection map |
| **Ecological status** | Ecological status | Regional rating |
| **Flood risk mitigation** | Ratio of safe floodplain | Floodplain map<br>Risk map |

### 3.1.1 ES assessment pre-intervention Wertach River

*Aesthetics of landscape*

The aesthetics of landscape is one of the most subjective services to assess. A questionnaire could not be set up, thus we decided to use the indicator adapted from Hermes et al. (2018) and described in D.T1.3.1.

**Table 6** Value of the indicator for the research unit.

| Id | Standardized indicator |
|---|---|
| 1 | 0.18 |

*Cultivated crops*

The cultivated crops are not marked as a relevant ES for the area of the Wertach, nevertheless a consideration could be interesting because data pre- and post-intervention were avaible and there is a significant difference.

**Table 7** Value of the indicator for the research unit.

| Id | Area (ha) | Total area (ha) | Percentage |
|---|---|---|---|
| 1 | 7.55 | 26.2 | 28.82 |

*Ecological status*

According with the data from the WFD, all the sub-units are in moderate ecological status. Data about the ecological status before the intervention are missing because the intervention was prior than or during the early stages of WFD. Thus, as a proxy, we decided to use the data from the area upstream the intervention.

**Table 8** Value of the indicator for the research unit.

| Id | Ecological status |
|---|---|
| 1 | moderate |

*Flood risk mitigation*

This service is assessed using the proportion of the total area for each sub-unit that is classified as the lowest and the second lowest risk class, expressed as hectares and normalized. The data about flood risk pre intervention are missing because the intervention dates back the beginning of 2000s. The action has been taken with the purpose of mitigate the flood risk in the downstream city of Augsburg, thus we can assume qualitatively that the risk has been reduced, but we cannot quantify this reduction.

*Habitat-related services*

For the habitat related service, we calculate for each sub-unit and each LAWA score the area. Data about the ecological status before the intervention are missing because the intervention was prior than or during the early stages of WFD. Thus, as a proxy, we decided to use the data from the area upstream the intervention.

**Table 9** Value of the indicator for the research unit.

| Id | LAWA value | Standardized indicator |
|---|---|---|
| 1 | 7 | 0 |

*Natural and cultural heritage*

This service has been assessed by considering the Natura 2000 areas and the landscape protection areas.

**Table 10** Value of the indicator for the research unit.

| Id | Area (ha) | Total area (ha) | Percentage | Standardized indicator |
|---|---|---|---|---|
| 1 | 15.97 | 26.2 | 60.9 | 0.30 |

*Reduction of greenhouse gas emission / carbon sequestration*

The chosen indicator for this service is the carbon uptake/sequestration indicator proposed in the Invest model. For details see D.T1.3.1.

**Table 11** Value of the indicator for the research unit.

| Id | Tonnes C | Potential Max tonnes of C | Ratio |
|---|---|---|---|
| 1 | 1480.5 | 2288.1 | 0.65 |

*Retention of nutrients*

Data for retention of nutrients were not available, thus we decided to apply the approach suggested in Burkhard et al. (2014), based on expert opinion and Land use/ Land Cover. For details see D.T1.3.1.

**Table 12** Value of the indicator for the research unit.

| Id | Nutrient retention score | Normalized |
|---|---|---|
| 1 | 4 | 0.8 |

**Table 13** Summary of the scores for the ES

| Id | AES | ES | FRM | HRS | NCH | CS | RN |
|---|---|---|---|---|---|---|---|
| 1 | 0.18 | moderate | | 0 | 0.30 | 0.65 | 0.8 |

### 3.1.2 ES assessment post-intervention Wertach River

*Aesthetics of landscape*

The aesthetics of landscape is one of the most subjective services to assess. A questionnaire could not be set up, thus we decided to use the indicator adapted from Hermes et al. (2018) and described in D.T1.3.1.

**Table 14** Value of the indicator for the research unit.

| Id | Standardized indicator |
|---|---|
| 1 | 0.42 |

*Cultivated crops*

The cultivated crops are marked as a relevant ES for the area of the Wertach, nevertheless a consideration could be interesting because data pre- and post-intervention were avaible and there is a significant difference.

**Table 15** Value of the indicator for the research unit.

| Id | Area (ha) | Total area (ha) | Percentage |
|---|---|---|---|
| 1 | 0 | 26.2 | 0.00 |

*Ecological status*

According with the data from the WFD, all the sub-units are in moderate ecological status.

**Table 16** Value of the indicator for the research unit.

| Id | Ecological status |
|---|---|
| 1 | moderate |

*Flood risk mitigation*

This service is assessed using the proportion of the total area for each sub-unit that is classified as the low hazard area, expressed as hectares and normalized.

**Table 17** Value of the indicator for the research unit

| Id | Area (ha) | Total Area (ha) | Percentage | Standardized indicator |
|---|---|---|---|---|
| 1 | 26.2 | 26.2 | 100.00 | 1 |

*Habitat-related services*

For the habitat related service, we calculate for each sub-unit and each LAWA score the area.

**Table 18** Value of the indicator for the research unit.

| Id | LAWA value | Standardized indicator |
|---|---|---|
| 1 | 3.8 | 0.46 |

*Natural and cultural heritage*

This service has been assessed by considering the Natura 2000 areas and the landscape protection areas.

**Table 19** Value of the indicator for the research unit.

| Id | Area (ha) | Total area (ha) | Percentage | Standardized indicator |
|---|---|---|---|---|
| 1 | 15.97 | 26.2 | 60.9 | 0.30 |

*Reduction of greenhouse gas emission / carbon sequestration*

The chosen indicator for this service is the carbon uptake/sequestration indicator proposed in the Invest model. For details see D.T1.3.1.

**Table 20** Value of the indicator for the research unit.

| Id | Tonnes C | Potential Max tonnes of C | Ratio |
|---|---|---|---|
| 1 | 1308 | 2288.1 | 0.57 |

*Retention of nutrients*

Data for retention of nutrients were not available, thus we decided to apply the approach suggested in Burkhard et al. (2014), based on expert opinion and Land use/ Land Cover. For details see D.T1.3.1.

**Table 21** Value of the indicator for the research unit.

| Id | Nutrient retention score | Normalized |
|---|---|---|
| 1 | 4 | 0.8 |

**Table 22** Summary of the scores for the ES

| Id | AES | ES | FRM | HRS | NCH | CS | RN |
|---|---|---|---|---|---|---|---|
| 1 | 0.42 | moderate | 1 | 0.40 | 0.30 | 0.57 | 0.8 |

**Table 23** Comparison of the ESs pre- and post-intervention.

| | AES | ES | FRM | HRS | NCH | CS | RN |
|---|---|---|---|---|---|---|---|
| pre | 0.18 | 3 | | 0 | 0,30 | 0.65 | 0.8 |
| post | 0.42 | 3 | 1 | 0.54 | 0.30 | 0.57 | 0.8 |

## 3.2 Lech River

**Table 24** Ecosystem services, indicators and data.

| Ecosystem service | Indicator | Data |
|---|---|---|
| **Cultivated crops** | Total production | Corine Land Cover<br>Crop yield (Bayerisches Landesamt für Statistik und Datenverarbeitung) |
| **Habitat-related services** | Hydromorphological status | regional morphological rating |
| **Aesthetics of landscape** | Diversity of landscapes<br>Rare morphologies | Corine Land Cover<br>Satellite picture |
| **Natural and cultural heritage** | Ratio of protection areas | Natura 2000 map<br>Landscape protection map |
| **Ecological status** | Ecological status | Regional rating |
| **Flood risk mitigation** | Ratio of safe floodplain | Floodplain map<br>Risk map |

### 3.2.1 ES assessment pre-intervention Lech River

*Aesthetics of landscape*

The aesthetics of landscape is one of the most subjective services to assess. A questionnaire could not be set up, thus we decided to use the indicator adapted from Hermes et al. (2018) and described in D.T1.3.1.

**Table 25** Value of the indicator for the research unit.

| Id | Standardized indicator |
|---|---|
| 1 | 0.35 |

*Ecological status*

The ecological potential pre intervention is moderate.

**Table 26** Ecological status score.

| Id | Status |
|---|---|
| 1 | moderate |

*Flood risk mitigation*

The indicator is described in D.T1.3.1 deliverable. The scale of the intervention in this case is too small to have an effect on the flood risk mitigation.

*Habitat-related services*

For the habitat related service, we calculate for each sub-unit and each LAWA score the area.

**Table 27** Value of the indicator for the research unit.

| Id | LAWA value | Standardized indicator |
|---|---|---|
| 1 | 5 | 0,29 |

*Natural and cultural heritage*

This service has been assessed by considering the Natura 2000 areas and the landscape protection areas.

**Table 28** Value of the indicator for the research unit.

| Id | Area (ha) | Total area (ha) | Percentage | Standardized indicator |
|---|---|---|---|---|
| 1 | 6.3 | 6.3 | 100.00 | 1 |

*Reduction of greenhouse gas emission / carbon sequestration*

The chosen indicator for this service is the carbon uptake/sequestration indicator proposed in the Invest model. For details see D.T1.3.1.

**Table 29** Value of the indicator for the research unit.

| Id | Tonnes C | Potential Max tonnes of C | Ratio |
|---|---|---|---|
| 1 | 120.7 | 552.45 | 0.22 |

*Retention of nutrients*

Data for retention of nutrients were not available, thus we decided to apply the approach suggested in Burkhard et al. (2014), based on expert opinion and Land use/ Land Cover. For details see D.T1.3.1.

**Table 30** Value of the indicator for the research unit.

| Id | Nutrient retention score | Normalized |
|---|---|---|
| 1 | 3.4 | 0.48 |

**Table 31** Summary of the scores for the ES.

| Id | AES | ES | FRM | HRS | NCH | CS | RN |
|---|---|---|---|---|---|---|---|
| 1 | 0.35 | moderate | | 0.29 | 1.00 | 0.22 | 0.48 |

### 3.2.2 ES assessment post-intervention Lech River

The river restoration has taken place at the beginning of 2019, thus data for the assessment of the effects on ES are still not available, especially for the services that depends on habitat. However, it was possible to calculate the variation for the services that depends on land cover.

*Aesthetics of landscape*

The aesthetics of landscape is one of the most subjective services to assess. A questionnaire could not be set up, thus we decided to use the indicator adapted from Hermes et al. (2018) and described in D.T1.3.1.

**Table 32** Value of the indicator for the research unit.

| Id | Standardized indicator |
|---|---|
| 1 | 0.35 |

*Flood risk mitigation*

The indicator is described in D.T1.3.1 deliverable. The scale of the intervention in this case is too small to have an effect on the flood risk mitigation.

*Reduction of greenhouse gas emission / carbon sequestration*

The chosen indicator for this service is the carbon uptake/sequestration indicator proposed in the Invest model. For details see D.T1.3.1.

**Table 33** Value of the indicator for the research unit.

| Id | Tonnes C | Potential Max tonnes of C | Ratio |
|---|---|---|---|
| 1 | 118.2 | 552.45 | 0.21 |

*Retention of nutrients*

Data for retention of nutrients were not available, thus we decided to apply the approach suggested in Burkhard et al. (2014), based on expert opinion and Land use/ Land Cover. For details see D.T1.3.1.

**Table 34** Value of the indicator for the research unit.

| Id | Nutrient retention score | Normalized |
|---|---|---|
| 1 | 3.4 | 0.48 |

**Table 35** Summary of the scores for the ES.

| Id | AES | ES | FRM | HRS | NCH | CS | RN |
|---|---|---|---|---|---|---|---|
| 1 | 0.35 | | | | | 0.21 | 0.48 |

**Table 36** Summary of the scores for the ES.

| Id | AES | ES | FRM | HRS | NCH | CS | RN |
|---|---|---|---|---|---|---|---|
| Pre | 0.35 | 0.5 | | 0.29 | 1.00 | 0.22 | 0.48 |
| Post | 0.35 | | | | | 0.21 | 0.48 |

# 4 Conclusions and perspectives

### 4.1.1 Wertach River

The channel widening of the Wertach River had a partial effect on ES. We had an increase in Aesthethics of landscape and a slight decrease in Carbon sequestration, due to the removal of the forested area. Using the upstream reach as a proxy, we can suggest that the restoration action had a positive effect on habitat. The project dates back several years, and data for the evaluation of the ES are not available or not comparable with the data that are currently collected and available. Aesthethics of landscape for example should be assessed directly with a questionnaire before-after the invertvention, but this is obviously not feasible. Data about Flood Risk before the intervention are not available.

### 4.1.2 Lech River

The effects of the creation of macroforms in the Lech River on ES pre and post the intervention were possible to assess only regarding the ES using land cover as input data. The scale of the intervention is too small to influence downstream flood risk. A very slight decrease in Carbon sequestration has been detected, due to a small reduction in the forested area. The intervention is still too recent to have data about habitat and in general about the hydromorphological and ecological consequences. However, first qualitative data (pictures) about fish species, suggest that we can expect an improvement in habitat quality and habitat-related services.

# 5 References

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Burkhard, B., Kandziora, M., Hou, Y., & Müller, F. (2014). *Ecosystem service potentials, flows and demands-concepts for spatial localisation, indication and quantification*. Landscape Online, 34(1), 1–32. https://doi.org/10.3097/LO.201434

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