MEDITERRANEAN WETLANDS AND CLIMATE MITIGATION

Handbook for adding a climate-mitigation perspective to wetland management and restoration

www.wetlands4climate.eu

This manual has been prepared within the framework of the **LIFE Wetlands4Climate** project, which is a European project supported by the European Commission through the LIFE funding instrument. The project is coordinated by the Fundación Global Nature in partnership with the EFE Agency, the València Clima i Energia Foundation, and the Cavanilles Institute of Biodiversity and Evolutionary Biology at the University of Valencia. The project has also received the support of the Department of Agriculture, Rural Development, Climate Emergency and Ecological Transition of the Generalitat Valenciana, the Department for Conservation of Natural Areas and the Devesa-Albufera area of the València City Council, the Torreblanca City Council, and Naturgy.

With the support of

GOBIERNO DE ESPAÑA

VICEPRESIDENCIA TERCERA DEL GOBIERNO
MINISTERIO PARA LA TRANSICIÓN ECOLÓGICA Y EL RETO DEMOGRÁFICO

Publication

Spanish edition published in 2024

Authors

Carlos Rochera[1], Vanessa Sánchez[2], Ernesto Aguirre[2], Alicia Bello[2], Amanda del Río[2], Eva Gómez[2], Antonio Guillem[2], María López[2], Laura Mediavilla[2], David Miguélez[2], Sonia Monferrer[2], Daniel Morant[1], Antonio Picazo[1], Javier Ruiz[2] y Antonio Camacho[1].

[1] *Cavanilles Institute of Biodiversity and Evolutionary Biology - UVEG*

[2] *Fundación Global Nature - FGN*

Cover image

Rafael Abuín, FGN

Images

- Fundación Global Nature - FGN: 27, 29, 31, 40, 41, 43, 45, 53, 68, 69, 70, 82 y 84.
- Rafael Abuín: FGN: 7 13, 32, 73, 74 y 81.
- Bruno Durán: FGN: 6, 8, 9, 14, 15, 19, 20, 46, 49, 50, 51, 55, 58, 61, 62, 64, 66, 73, 76, 77 y 78
- Archival images: 30. 36. 37. 38. 42. 54 y 79

Layout and Design

Natalia Martín

TABLE OF CONTENTS

1. INTRODUCTION **05**

2. BASIC CONCEPTS **12**

3. PRACTICAL STRATEGIES FOR INTEGRATING CLIMATE CHANGE MITIGATION INTO WETLAND MANAGEMENT AND RESTORATION **18**

3.1. Assessing the ecological and conservation status of a wetland **19**

3.2. Conducting recurring management and/or restorative actions for wetland Development of recurrent management and/or restoration actions for wetland emission reduction .. **24**

3.2.1. Vegetation management **24**
- Mowing of helophytes (not hydrophytes) 26
- Controlled grazing 36
- Macrophyte plantings 40

3.2.2. Soil management **43**
- Soil stripping 43
- Mudding 48

3.2.3. Hydrological management **53**

3.2.4. Summary of costs of the measures **58**

4. PROCEDURE FOR ASSESSING THE EFFECTIVENESS OF ACTIONS IN TERMS OF CLIMATE MITIGATION **60**

4.1. Definition of the spatial and temporal scopes of action .. **61**

4.2. Definition of wetland type and ecological status **63**

4.3. Quantification of the effectiveness of the actions **65**

4.4. Development of a monitoring plan **71**

5. INTEGRATION IN PLANNING **72**

5.1. Policies and the legal framework in Spain **75**

5.2. Possible sources of funding: Voluntary Carbon Market, MITECO Registry **78**

6. KEY STEPS IN THE IMPLEMENTATION OF A CLIMATE MITIGATION PROJECT **80**

7. REFERENCES **86**

1

1. INTRODUCTION

This guide aims to provide an integrated approach to the conservation and management of Mediterranean wetlands, incorporating climate perspectives into the management methods of these ecosystems.

For whom is this guide intended?

The guide is aimed at all those who, in one way or another, need to make decisions regarding conservation plans, programmes or projects for these types of ecosystems. This may include managers seeking to integrate climate change mitigation into their management strategies, scientists, entities implementing restoration projects, public policy makers and any person interested in the preservation and management of these unique ecosystems.

Why should you read this guide?

Here you will find a series of practical strategies for integrating climate change mitigation into the management of Mediterranean wetlands, while maintaining their ecological integrity and ecosystem services.

These strategies are based on the implementation of ecological management and/or restoration measures in wetlands, as well as the subsequent estimation of the reduction of greenhouse gas (GHG) emissions (in terms of CO_2-equivalents) that can be obtained through these actions, using the calculation tools developed through the **LIFE Wetlands4Climate** project.

TYPOLOGY OF MEDITERRANEAN WETLANDS

The LIFE Wetlands4Climate project, from which this guide is derived, has focused on three main groups of Mediterranean wetlands: coastal, inland freshwater, and inland saline.

Coastal WETLANDS

Inland freshwater WETLANDS

Inland saline WETLANDS

What role do wetlands play as carbon sinks?

Mediterranean wetlands are one of the most sensitive and threatened habitat types in the European Union. Despite the importance of these ecosystems, the Ramsar Convention warns that more than 60% of the world's wetlands have disappeared over the last century. The Intergovernmental Panel on Climate Change (IPCC) recognises that reducing or eliminating sources of GHG emissions will no longer be sufficient to achieve the objectives of the Paris Agreement. While drastic reductions in GHG emissions must be the fundamental first step, large-scale carbon sequestration in sinks is also required. Forests are the most well-known of these, but other less-recognised natural areas capable of sequestering large amounts of carbon exist. Among these are wetlands.

Wetlands are terrestrial areas where water covers the soil, at a level close to or above the surface, or one whose soils are saturated for a sufficiently long period of time to support hydrosoil processes, as well as the growth of hydrophilic vegetation and various types of biological activities typical of an aquatic environment.

One of the most salient features of these ecosystems is their biogeochemistry. In terms of carbon transfer, the transport and transformation of carbon through interrelated physical, chemical, and biological processes leads to large flows of carbon between these ecosystems and the atmosphere. Given their high activity potential, the role of wetlands in biogeochemical carbon cycling may be particularly relevant in a context of climate change (**Lolu et al. 2020**). It is precisely the temporary or permanent presence of water that drives a series of ecological processes involving carbon exchange with the atmosphere at much higher relative rates per unit area than in other ecosystem types. This gives wetlands a high capacity to act as regulators of climate change despite their small global area relative to other ecosystem types (**Dudgeon et al. 2006**). Wetlands are therefore considered to be one of the most active ecosystem types in terms of carbon exchange with the atmosphere.

The mechanisms that regulate carbon cycling in wetlands depend on multiple factors. On one hand, there are environmental and climatic factors, which can be considered external, and on the other, there exist those that are more intrinsic to the wetland. The latter include the ecological characteristics of each type of wetland (**Fennessy et al. 2017**; **Lu et al. 2017**) and also, albeit more transiently, the conservation status of the wetland in question (**Bernal y Mitsch 2012**). These wetland characteristics condition the form and magnitude of the carbon exchange with the atmosphere and, therefore, their climate change mitigation capacity (**Morant et al. 2020a, b**). It should be noted, however, that this mitigation capacity lies both in the wetland's potential to sequester carbon, and in its ability for emissions to occur in forms of GHGs with the lowest warming potential (**Camacho et al. 2017**). The warming potential of methane is about 82.5 times higher than that of carbon dioxide over a 20-year horizon and remains 29.8 times higher after 100 years (**Forster et al. 2021**). This means that one tonne of methane would be equivalent to almost 30 tonnes of CO_2 if its impact over a century is considered. With this in mind, strategies, such as those outlined in this guide, that seek to mitigate GHG emissions, but with the additional benefit of also favouring emissions that have the lowest possible warming potential, appear to be favourable.

WETLANDS, MORE THAN JUST WATER

- They create jobs
- They capture greenhouse gases
- They buffer against extreme climate events
- They mitigate climate change
- They generate tourism
- They reduce flooding
- They clean water naturally
- They benefit agriculture and raising livestock
- They promote fish and aquaculture
- They clean the air
- They sustain biodiversity

2

2. BASIC CONCEPTS

2.1. THE ECOSYSTEMIC SERVICES OF WETLANDS

The increase in knowledge of these ecosystems and, above all, public awareness, have changed the way our society perceives wetlands over the last few decades.

The benefits that natural systems provide to humanity, as well as their uses, can be valued within the framework of what are called ecosystem services. These provide ways of estimating, from an anthropic perspective, what these ecosystems offer for the well-being of humanity (**Millenium Ecosystem Assessment 2005**; **Borja et al. 2012**). In addition to the classic perception of the supply of natural resources, consideration of their cultural, spiritual, or recreational value has been added as reasons in favour of the conservation of natural areas. From this new awareness, plans for wetland recovery and restoration have been designed and implemented, which aim not only to restore lost biodiversity, but also to restore the cultural and spiritual value in areas rooted in these wetlands.

What are known as regulating ecosystem services in wetlands rely on the ecological characteristics and functions of these ecosystems to carry out, for example, water purification and waste filtration, or natural buffering during floods and droughts. However, if we were to

highlight a “new” ecosystem service above the rest that are already known, in a context of climate change such as the one we are currently experiencing, it would be that of climate regulation. Bodies of water not only represent a potential regulator of the local climate due to the thermal inertia provided by the high specific heat of water, but also, as has become clear in recent years, these ecosystems are potentially capable of retaining large amounts of carbon taken from the atmosphere. They act as natural sinks that allow for the mitigation of the rise in GHG concentrations in the atmosphere generated by anthropogenic activities (**Mitsch et al. 2013**). This climate mitigation service may be impaired if the ecological status of the wetland is not favourable, e.g. if it is in a poor state of conservation, under inappropriate management or ineffective restoration measures are being used. Such impairment could lead to increases in GHG emissions, including those in the form of gases with higher warming potential, such as methane, thereby reducing the climate change mitigation capacity of the wetland, or potentially inverting it to become a net warming contributor.

2.2. CARBON BALANCE: ANALYSIS OF CARBON DYNAMICS IN WETLANDS

The carbon exchange capacity of wetlands is mainly due to the high biological activity produced by microorganisms living in the wetland substrate and the water matrix, as well as the submerged aquatic plants and helophytes and other emergent vascular plants growing in the transition zone between the water and the terrestrial environment (Figure 1). Wetland primary production, which is fundamentally carried out through photosynthesis by autotrophic organisms, makes the assimilation of CO_2 from the atmosphere possible, thereby reducing the concentrations of carbonaceous GHGs in the atmosphere.

However, carbon is also released from wetlands in the form of greenhouse gases, such as carbon dioxide (CO_2) and methane (CH_4), which are naturally produced by the system from the respiratory (decomposition) processes of organic matter. The balance between carbon intake due to assimilation by primary producers and carbon outputs from consumers provides an estimate of the wetland's metabolism.

The balances of these metabolic processes are further qualified by physical processes, such as those that determine the diffusion of gases, and chemical processes, for example, the precipitation of inorganic carbon in the form of carbonates. These balances can be analysed in units of mitigation or warming power (GWP, given in terms of CO_2 equivalents), quantifying the capacity of the wetland to contribute to climate change mitigation, or, conversely, where the wetland has high GHG emissions, to contribute to global warming.

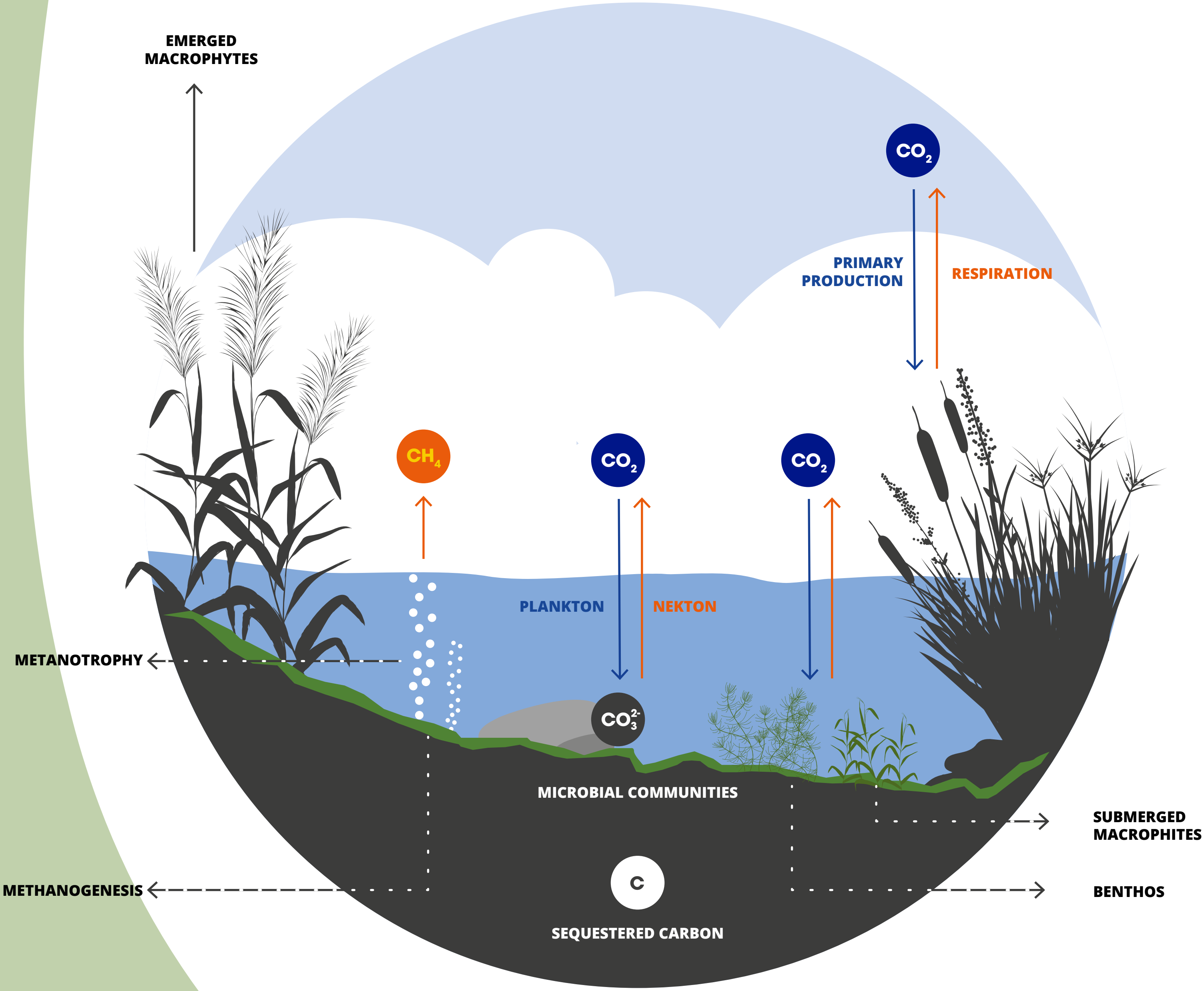


FIGURE 1: A schematic representation of the functioning and processes of the metabolic carbon balance in Mediterranean wetlands. The blue arrows indicate carbon inputs to the system, and the red arrows indicate carbon outputs. The balance between inputs and outputs determines the capacity of the wetland to sequester or release carbon and, therefore, to mitigate or enhance the warming generated by the wetland. Source: own elaboration.

When in a good state of conservation, most types of wetlands tend to act as carbon sinks and thus mitigators of climate change, i.e. the sequestration and fixation of carbon is greater than the emission of greenhouse gases into the atmosphere, with the fixed organic matter then accumulating in the soil. This carbon-rich organic matter is therefore sequestered in the organic soil of the wetland.

However, changes in the conservation status can affect this balance, favouring carbon outflows over inflows, reducing the natural capacity of wetlands to sequester carbon, and even converting them into a source of GHG emissions (**Morant et al. 2020a**),Such emissions may include gases that generate greater warming power or GWP per unit mass than carbon dioxide (CO_2), such as methane (CH_4).

Wetlands can thus play a key role in helping mitigate the disproportionate increase in the greenhouse effect caused by massive anthropogenic carbon emissions from the burning of fossil fuels. But inadequate management or continued threats to a wetland's conservation status could increase its GHG emissions, and significantly reduce the ecosystem service of climate mitigation that it provides.

3

3. PRACTICAL STRATEGIES FOR INTEGRATING CLIMATE CHANGE MITIGATION INTO WETLANDS MANAGEMENT AND RESTORATION

3.1. ASSESSMENT OF THE ECOLOGICAL AND CONSERVATION STATUS OF THE WETLAND

The first step in establishing a management and/or restoration strategy that integrates climate change mitigation is to assess the condition of the wetland.

In this sense, it is important to highlight that any management and/or restoration actions implemented to strengthen the mitigation service and carbon sequestration capacity must never compromise the conservation of the ecological character and integrity of the wetlands. Therefore, it is necessary to first assess the state of the wetlands under consideration. This should be done following the criteria established in the applicable legislation for the protection and conservation of these ecosystems. These criteria should include the use of monitoring indicators which can then provide the basis upon which the objectives of the conservation or restorative actions can be defined.

The two main standards that, in their deployment, establish the criteria for assessing the status of aquatic ecosystems at the European level are the **Water Framework Directive 2000/60/EC** (for the ecological status of bodies of water) and the **Directive 92/43/EEC** (for the status of Habitat Types of Community Interest).

The **Water Framework Directive** establishes the legal framework for European Community action in the field of water policy. In Spain, this directive is implemented through **Royal Decree 817/2015** (**BOE, 2015**), which sets forth the criteria for monitoring and assessing the status of surface waters, and for environmental quality standards. Spanish legislation establishes the need to achieve **good ecological status** in which parameterised requirements are met. This ensures compliance, attaining good ecological status with a level of quality in the structure and functioning of the aquatic ecosystems associated with surface bodies of water.

For the assessment of ecological status, a series of quality elements and other indicators are established whose values must demonstrate low levels of distortion with respect to the natural (unaltered) conditions of the bodies of water assessed. For lake-type bodies of water, which correspond to lentic ecosystems (lakes, lagoons, and wetlands), the biological quality elements and indicators compiled in **Royal Decree 817/2015** (**BOE, 2015**) are grouped into:

1	**Biological quality elements,** whose values for the type of body of water show little alteration caused by human activity, deviating at most only slightly from the values normally associated with the type of body of water in undisturbed conditions (reference values): · **Phytoplankton** · **Other aquatic flora (macrophytes)** · **Benthic invertebrates**
2	**Hydro-morphological** must be consistent with the attainment of these values: · **Hydrological regime** · **Morphology**
3	**Chemical and physiochemical indicators,** which must comply with the ranges or limits that ensure the correct functioning of the specific type of ecosystem, as well as the attainment of values for quality biological elements: · **Thermal conditions** · **Oxygenation** · **Salinity** · **Nutrient status** · **Acidification status**

Taking these types of indicators into consideration, Table 1 shows the nature of the main alterations that can occur in a wetland. These may alter the wetland's ecological status, with the magnitude of these alterations determining a possible status downgrade from good to moderate or poor/bad.

STATUS	Principal alterations
Very good Good	No significant alterations according to the characteristics of the type of wetland
Moderate	Hydro-morphological alterations
	Trophic alterations
	Changes in water physiochemistry
	Combination of alterations
Poor Bad	Significant hydro-morphological alterations
	Substantial trophic alterations
	Significant changes in water physiochemistry
	Combination of alterations

TABLE 1: Main types of alterations that may change the ecological status for each of the wetland types being studied.

Recommendation

Follow the criteria and indicators established in Royal Decree 817/2015 (BOE, 2015) to assess the initial ecological status of the wetland and the guidelines of the Habitats Directive for the evaluation of its conservation status.

In parallel to the assessment of the ecological status of bodies of water, an assessment of the conservation status of the structure and function of Habitats of Community Interest associated with aquatic ecosystems can also be carried out, following the guidelines of the **Habitats Directive**. The purpose of this directive is to protect natural habitat types and populations of wild species. To this end, it establishes the need to assess the **conservation status** of habitats, i.e. the set of influences that act on a natural habitat and on the typical species settled in it and that may affect, in the long term, its distribution, structure and natural functions, as well as the survival of its typical species. Habitats of Community Interest are listed in Annex 1 to the Habitats Directive.

Among the different parameters that determine the overall conservation status, the "structure and function" of habitats is a key element. Assessments of lentic ecosystems (lakes, ponds, and wetlands) are to be carried out following the assessment procedures of the Habitats Directive (**Camacho et al. 2019a**) which provides equivalencies with assessments of ecological status under the Water Framework Directive (**Camacho et al. 2019a**). In Spain, the Ministry for Ecological Transition and Demographic Challenge (MITECO) and the Autonomous Communities of Spain have established the protocols to be followed for the evaluation of the "structure and function" of lentic ecosystems in Spain (lake, lagoon, or wetland) and related habitat types. The evaluation of their conservation status (**Camacho et al. 2009**, **Camacho et al. 2019a**), is to be done by applying the ECLECTIC index, which is an acronym in Spanish that stands for "Conservation Status of Spanish Catalogued Lagoons and Wetlands by Typology: Conservation Indicators". This index includes variables on biological communities and hydro-geomorphological and physiochemical factors, as well as their response to the pressures and impacts experienced by the habitat at a local scale (**Camacho et al. 2019b**), variables which indicate the structure and functionality of the habitat type.

3.2. CONDUCTING RECURRING MANAGEMENT AND/ OR RESTORATIVE ACTIONS FOR WETLAND EMISSIONS REDUCTION

The **LIFE Wetlands4Climate** project, from which this guide is derived, has focused on three main groups of Mediterranean wetlands: coastal, inland freshwater and inland saline. Each of the groups has particular ecological conditions associated with it, and they harbour different habitats of community interest. However, they share unified management strategies in three categories: vegetation, soil, and the wetland hydrological cycle.

3.2.1. Vegetation management

The wetland vegetation management actions included in this manual are:

A	**Mowing of helophytes** (but not hydrophytes)
B	**Controlled grazing**
C	**Subaquatic plantations of helophytes and macrophytes**

Principal results attained from vegetation management in the LIFE Wetlands4Climate project

Observations have shown that this practice significantly enhances the productivity of the vegetative mass, thereby increasing the system's sink capacity through carbon sequestration. The reduction in emissions is due to the regenerative capacity of the helophytes (resprouts). The mitigation potential is increased when the by-product of mowing (the plant material) is used in a sustainable way, through the secondary use of the mown vegetation on farms, either as fodder or bedding for livestock, or use after shredding as soil structuring or mulching, etc.

However, in grazed areas, the higher productivity of the regrowth vegetation that replaces the grazed vegetation (which has been removed by livestock) is favourable to greater carbon sequestration than in areas where such management is not carried out. Emissions produced by the grazing livestock were not considered in the assessment.

A Mowing of Helophytes

Mowing involves cutting back vegetation that is either overhanging or that is taller in relation to other vegetation. This management is recurrent in wetlands, being repeated at least once per annual vegetation cycle. Depending on the depth of the water, this can be done using agricultural machinery, amphibious machines, or manually. Details on the application of each of the mowing typologies are described in the following sections.

Mitigation of climate change

Mowing of helophytic vegetation for climate mitigation purposes should be done at a height of about 20-30 cm above the ground at a time close to the middle of the growing season (ideally around June). Thus, by being done during the growing season, the net production of helophytes is increased. Helophytes are one of the main drivers of carbon sequestration in the overall wetland balance (**Morant et al. 2020a**). So, greater net production means a greater carbon sequestration capacity, which, being stored in a more recalcitrant form as it occurs in most helophyte tissues, is more difficult to degrade. In the long run, this means greater carbon sequestration due to greater fixation in the plants as their growth is stimulated. The management of plant remains is also crucial to ensuring climate mitigation through methods that guarantee their incorporation as soil components, which function as sinks, or their secondary use as food (fodder) or bedding for livestock. These uses for livestock reduce the corresponding demand for straw and, therefore, reduce GHG emissions into the atmosphere by generating products that limit or reduce the carbon footprint of the production of those they replace.

Co-benefits for Biodiversity

Mowing practices, whether for climate change mitigation or to promote biodiversity, have a significant impact on wetlands. Both approaches, especially when properly planned, temporarily increase the area of free water surface, favouring the maintenance of Habitats of Community Interest (HCI), such as 3140, 3170*, 1410, 1150*, and 7210*. They also allow wetlands with dense, monospecific vegetation (such as reeds or bulrushes) to diversify, allowing other plant species or communities to thrive, such as meadows of submerged macrophytes (**Jubete et al. 2006**). When the mown areas become submerged once again, extensive areas of silt are generated that increase the availability of food resources, e.g. rhizomes and tubers. Waterbirds such as ducks, spoonbills, cranes, and waders actively use these zones as feeding areas. This scenario lasts until the vegetation grows back and wetland can be re-occupied by other breeding bird species, such as marsh passerines or rails, which require these spaces as nesting sites.

Socio-economic considerations

Socio-economic considerations vary depending on the method of mowing, whether it be by hand, amphibious machine, or tractor. Each approach has different costs, labour implications, and potential benefits for local stakeholders. It is therefore essential to assess each option in the specific context of wetland management.

Mowing of helophytic vegetation with the use of agricultural machinery

This type of mowing is carried out in wetlands with a certain level of seasonality, allowing it to be performed during dry summer periods. It involves mowing marsh/lacustrine vegetation such as sedges (*Carex divisa*), spike-rush (*Eleocharis palustris*), rushes (*Juncus* spp. y *Schoenoplectus lacustris*), sea clubrush (*Bolboschoenus maritimus*), reeds (*Phragmites autralis*) and bulrushes (*Typha domingensis* y *Typha latifolia*), using agricultural machinery. This type of mowing is preferably carried out around June, before the vegetation dries out in the summer. At this time, the soil will likely be dry enough for the machinery to carry out the relevant work without causing any negative impact on the terrain. After the mowing process, the plant remains are removed and are shredded and/or baled for subsequent use for agricultural or livestock purposes. Once mowed and baled, the plant remains must be removed from the wetland (to avoid the accumulation of plant remains that could generate GHG emissions and the clogging of the basin) and must be given a secondary use in agricultural and livestock farms. The mowing must also be carried out in a controlled manner to avoid damage to biota, for example, to the most sensitive and endangered species of nesting birds. Vegetative production after mowing in these ecosystems is usually very high and therefore mowing periods should be annual.

SOCIO-ECONOMIC CONSIDERATIONS: the mowing of helophytic vegetation with the use of agricultural machinery in lagoon areas has traditionally been required by local livestock farmers in order to make use of the plant remains, either as fodder or as bedding for livestock. However, the decline of traditional stock raising may lead to the disappearance of these uses. However, given the increase in fodder prices, due to the scarcity of rainfall and the increase in fertiliser and fuel prices, it may be in the interest of the local agricultural sector to put these local by-products to good use. It should be borne in mind that the abandonment of traditional uses would mean that the management of helophytic vegetation would be transferred to the administrations managing the wetlands, entailing an added cost to their management.

The average per-hectare cost for mowing with a tractor (calculated during the implementation of this action in the three years of the **LIFE Wetlands4Climate**, project, 2021-2023, in the pilot wetlands of Castile and León), including management costs, is estimated at **around 250€** for each hectare mown in each mowing event. However, it should be borne in mind that these costs could vary depending on inflation, the cost of fuel, and other factors. This action is carried out in the same area, either annually in June, or at a frequency previously established by the wetland managers. It is advisable to establish a vegetation management plan, and more specifically, a mowing plan, in order to rotate or repeat mowing areas according to the conservation needs of each wetland.

Manual mowing of helophytic vegetation

Manual mowing is used in wetlands where the hydroperiod is irregular. Such a situation would prevent both the use of amphibious machines due to the lack of a sufficiently deep covering of water and the use of agricultural machinery because the soil is partially waterlogged or poorly drained and it would have a high impact on the stability of the soil of the lagoon and its peripheral areas. The mowing tasks are carried out by a team of workers using manual tools, such as brush cutters, to cut down the helophytes, while another team removes them for secondary use. Manual mowing has the advantage of greater precision in the selection of the areas to be mowed. This makes it possible to let unmown patches remain, leading to a greater diversification of the habitat.

SOCIO-ECONOMIC CONSIDERATIONS: as it requires more staff and longer periods of time for its execution, this form of mowing is more expensive than mowing with machinery. The average cost of manual mowing is **around 4,000€/ha** per mowing event (estimates made during the implementation of the **LIFE Wetlands4Climate**, project, 2022-2023). A vegetation management plan should be established jointly with the wetland managers. More specifically, it is advisable to create a mowing plan to rotate or repeat mowing areas with the appropriate frequency, doing so in accordance with the conservation needs of each wetland.

Mowing of helophytic vegetation with amphibious machinery

This mowing procedure is used in coastal wetlands or marshes that are permanently covered in water. In this scenario, an amphibious mowing machine is used, which allows mowing when the water depth is between 60 and 120 cm. Additionally, if the machinery is reconfigured, it is possible to remove the mown vegetation from the lagoon basin. The operator of this machinery must have specialised knowledge of both management and the physical environment (in terms of the species of vegetation present), in order to mow selectively and avoid collateral damage to the biota.

The working time for mowing and the collection of mowing residues from the surrounding areas is estimated at 6 days per hectare of reeds with a surface occupation density of between 60 to 75%, and 7 days in the case of higher densities. The machine mows the vegetation below the surface of the water, using a saw blade that cuts the aerial part of the plant, leaving the rhizome, favouring its regrowth. All the mown vegetation must then be collected with another implement and deposited on the bank closest to the mowing area. Once again, these plant remains must be removed from the wetland to prevent the accumulation and clogging of the basin and to give it a secondary use in agricultural and livestock farms.

Regarding the frequency of use of this management measure, it is advisable to plan its use on the basis of the renewal rates of helophytic vegetation in the different wetlands. After the experience verified through **LIFE Wetlands4Climate**, these helophytic vegetation renewal rates may vary, for example, in the case of the Marjal dels Moros, the renewal rates are low and therefore the recommendation is to implement this type of mowing with an amphibious machine every two years. However, in wetlands such as the Pego-Oliva Marsh, with high renewal rates, it is advisable to mow annually.

SOCIO-ECONOMIC CONSIDERATIONS: the execution of this type of action has repercussions on different interest groups or local actors. For example, people working in the agricultural sector can benefit from the secondary use of the mowing waste, which they can get at no cost by handling of the removal of the waste. If mowing actions are carried out on a larger scale and on a continuous basis in wetlands, the marketing of the different by-products obtained (derived from the use of plant remains) could be considered as a way of generating economic resources for the management of the wetland.

Depending on the final use of the plant remains extracted, the following costs are estimated:

- The total cost per hectare of "mowing with amphibious machine and removal of **mown vegetation for livestock use**," including coordination costs (planning and coordination of tasks and purchase of consumables), is approximately **2,500€/ha*** for each mowing event.

- The total cost per hectare of "mowing with amphibious machine and **shredding of plant remains for secondary use as mulch or structuring of agricultural soils**," including coordination costs (planning and coordination of the tasks and purchase of consumables) and shredding of the mown vegetation, is approximately **3,000€/ha*** for each mowing event.

** Estimates made during the implementation of the* LIFE Wetlands4Climate *project, 2020-2023.*

Secondary use of plant waste

In all helophyte mowing practices, the removed plant debris should be put to a secondary use. This promotes a net effect in reducing emissions, and not only in the wetland. Emissions are also reduced when materials removed from wetlands are used to replace products that produce emissions. There is a wide range of possibilities for these types of reductions. The secondary uses tested in the LIFE Wetlands4Climate project are described below:

A

Agricultural uses: in this case, it is recommended that plant waste be shredded, after which it can be used as an organic fertiliser that replaces mineral fertilisers (**Thesiger 1964**.; **Kim et al. 2018**), This allows for the consequent reduction of GHG emissions by avoiding the emissions generated by the fertilisers that are being replaced. Composting is an aerobic biological process (in the presence of oxygen) that, under controlled conditions of ventilation, humidity, and temperature, transforms degradable organic waste into a stable and sanitised material called compost, which can be used as an organic additive (**Ministerio para la Transición Ecológica y el Reto Demográfico, s.f**.). Plant waste can also be used for mulching, which fulfils two functions: crop protection and moisture retention. These reduce water consumption (**Ma et al. 2024**) and the need for phytosanitary treatments, as the mulch spread between crop rows covers the soil and prevents the growth of adventitious weeds (**Schäfer et al. 2002**; **Mairata et al. 2023**).

B

Livestock uses: either as fodder (feed) or as bedding for livestock. The plant wastes must be left to dry and then baled and transported to the farms. Depending on the type of vegetation being mowed, it may be necessary to pre-shred it, especially in the case of reeds and bulrushes. Use for either fodder or bedding helps avoid the purchase of bales of cereal straw, thus reducing GHG emissions. Raw materials used for feed have a full life-cycle climate footprint, including carbon coefficients for by-products (straw bales) that can be calculated with digital tools such as CFPAN FeedPrint (**Vellinga et al. 2013**).

WETLANDS, ALLIES TO TACKLE CLIMATE CHANGE

Healthy wetlands, in a good state of conservation, can help mitigate climate change by offsetting the balance of GHG emissions.

B Controlled grazing

Grazing by herbivores to control helophytic vegetation is a widely used vegetation management tool in many natural areas (Miguélez 2023). The effect of grazing on wetlands can be beneficial or detrimental to wetland restoration and maintenance processes, and positively or negatively affect their wildlife communities and water and soil quality (Reeves y Champion 2004).

In fact, strictly in the interests of climate mitigation, grazing should always take place outside and at a prudent distance from the lagoon basin to avoid eutrophication. For example, grazing should only be done on the outermost part of the helophyte belt, which grows away from the banks and acts as a filter. For this reason, it is necessary to have an integrated approach to wetland management actions, including grazing, in order to harmonise biodiversity conservation and water quality objectives, e.g. those set out in the Birds, Habitats and Water Framework Directives, or the Management Plans of the Natura 2000 Network, and other natural areas (Farinós-Celdrán 2014). Thus, for the management of extensive livestock, it is necessary to establish grazing plans, with strict control of the type of livestock and the densities of use, dates, time of stay and grazing areas in each type of wetland. In terms of climate change issues, sheep farming is preferable and, in principle, widespread use in cattle farming should be ruled out because, in general terms, it would lead to an increase in GHG emissions.

Climate Change Mitigation

Moderate grazing with sheep, and always outside the basins, increases the vegetative growth of marginal plant species that often have high growth and production rates. It is important to control the grazing in order to avoid overgrazing that may reduce this vegetative growth.

Co-benefits for Biodiversity

Controlled extensive grazing favours the improvement of habitats and vegetation structure in wetlands as it supports processes of differentiation in the structures and physiognomy of the vegetation (**Tolhurst 1997**; **Jubete et al. 2006**). It also generates heterogeneous and mosaic habitats that serve as breeding, feeding, and refuge areas for numerous fauna species such as birds and aquatic invertebrates (**Schmidt et al. 2005**; **Jubete et al. 2006**; **Voslamber y Vulink 2010**; **Lehikoinen et al. 2017**; **Monrós et al. 2018**; **Vera 2020**). Additionally, it permits the maintenance and/or enhancement of several HCIs such as 1410, 1150*, 6420, and 7210*. Controlled grazing encourages a greater variety of species and flora communities as it increases plant biomass consumption, plant trampling, including underground parts and soil and nutrient input, as well as the introduction and dispersal of seeds and other propagules (**Tanner 1992**). Grazing also encourages active foraging by birds when livestock are on the move (**Palomino 2016**). In addition, microhabitats are created by the effect of low intensity trampling. Such trampling halts the massive colonisation of shrub formations and dense, tall, helophytic vegetation, which leads to homogenisation in wetlands. It combats the proliferation and/or expansion of invasive exotic plant species that alter and homogenise natural habitats. It acts as a natural firebreak to prevent fires in dense and extensive stands of marsh vegetation(**Miguélez 2023**).

Socio-economic considerations

Grazing can bring added socio-economic benefits, beyond that of vegetation management, such as the maintenance of native or endangered livestock breeds. A grazing plan should be in place to regulate activity on wetlands. Such plans should include strategic planning to ensure that livestock grazing is economically viable, socially acceptable, and environmentally sustainable. These plans should be adapted to the specific conditions of each wetland and define the recommended grazing time, zoning, and stocking rate. Monitoring of these plans will also be required to ensure compliance. The cost of establishing the grazing plan and its monitoring should be considered in all cases.

It is also advisable, in each case, to establish a payment for ecosystem services to livestock keepers who comply with the requirements established in the grazing plans. The amount of these payments should be established which consider the extra costs for the livestock sector for complying with the grazing plans in each wetland. This implies taking into account the need for investment in infrastructure according to the requirements of each case or wetland (electric shepherds, mobile sanitary chutes, salaries for new shepherds if it is necessary to divide the herd to comply with the zoning, established stocking rates, etc.), as well as the necessary compensation for moving the animals or for additional feed.

C Planting of macrophytes

For the planting of macrophytes, both those growing on land (helophytes) **and those that are aquatic** (hydrophytes)**, it is crucial to use plants of the same genotype as those in the planting area in order to preserve genetic diversity, to ensure adaptation to the environmental conditions, thereby increasing their survival rate. The number of plants shall be determined according to the working area.**

Climate Change Mitigation

The growth of vegetation leads to carbon retention, which, in the long run, translates into net carbon sequestration as these plants are made up of relatively recalcitrant material, especially the on-land helophyte species (hydrophytes to a lesser degree).

Submerged macrophytes are indicators of good water quality and promote oxygenation, which reduces the release of methane and nitrogen oxides by aiding oxidation by micro-organisms in the water column. They also protect the lagoon floor from disturbances that could trigger the release of the carbon accumulated in the soil.

Co-benefits for Biodiversity

Macrophyte plantations can improve the diversity and structure of wetland habitats, promoting the recovery and maintenance of protected species and HCIs (such as 1150*, 3140, 3150, 3170*, and 7210*). These plantations can also act as refuges for wildlife and as protective barriers against disturbances, including floods, fires, or earth movements due to water projects.

Socio-economic considerations

The planting of macrophytes in wetlands is an agri-environmental measure within the framework of the Rural Development Plans of the second pillar of the CAP. Owners of farms located in the vicinity of wetlands located in RN2000, listed in the RAMSAR list of wetlands of national importance, or listed in the Spanish Inventory of Wetlands (IEZH), would benefit from this measure. The estimated cost of planting submerged macrophytes is 2,663€/ha, considering the costs of personnel, machinery, and coordination, e.g. planning and coordination of the tasks (these estimates were made during the implementation of the **LIFE Wetlands4Climate** project in 2021). This action can be part of wetland management or restoration and generally does not require additional maintenance costs, as the plants are adapted to the conditions of the environment.

3.2.2. Soil management

A Soil stripping

Soil stripping management involves the mechanical removal of topsoil layers when they have high levels of organic matter content. This can help the soil regain its carbon sequestration capacity and make GHG emissions from the wetland to the atmosphere less harmful as they occur through gases that have lower warming capacity. For the action to have the net effect of reducing emissions, the removed soil must be used in farming or be put to some other use that locks up the removed carbon, preventing its release into the atmosphere.

Soil stripping is carried out when the area is not under water. The procedure consists of removing the topsoil layer, which usually contains the most organic matter, using machinery such as backhoes, graders, or bulldozers. The height of the layer is determined by measuring the organic matter content in the vertical profile of the soil, usually in the first 15-20 centimetres of the soil.

In soil stripping, not only is the accumulated plant matter removed, but also the rhizomes of the plants and the seed bank, thus delaying their recolonisation in areas where their growth is not desirable for wetland management reasons (e.g. maintenance of open water areas).

If rapid recolonisation is desired, small areas can be left unploughed within the ploughing area to act as a seed bank or for the dispersal of rhizomes. Soil conditions such as humidity, structure and topography have a major influence on the effectiveness of this action.

Specialised machinery is required to remove and transport the extracted organic matter and, as in the previous cases, the removed soil needs to have a secondary use (e.g. agricultural, as fertiliser in surrounding crop areas).

To strip the soil of one hectare, the estimated working time is 4 days, including the transport and spreading of the organic matter in fields close to the site.

In some cases, stripping can create areas of freestanding water that may then be occupied by growths of hydrophytes that help to oxygenate the water and establish a more diverse invertebrate community. In addition, the removal of decomposing organic matter and silt accumulated over the years helps to combat eutrophication, reduce methane and nitrogen oxide emissions, and alleviate siltation.

One of the positive effects of soil stripping is that it removes the very source of the emission production by removing excess organic matter from the wetland. This means that the mitigation effect remains as long as there is no further saturation of the basin with new organic material.

It is difficult to predict the optimum frequency between soil stripping operations, defined by the time at which clogging will recur. However, from previous experience it is estimated that it may be required every 10 years. This depends on the specific dynamics of the wetland and may vary if conditions favouring organic matter deposition change. For example, the time needed to reach clogging may be longer if there are spills or other eutrophication processes, as these favour the depositing of new organic matter.

Climate Change Mitigation

The removal of excess organic matter and decaying vegetation accumulated over time by soil stripping will reduce the organic carbon load in the soil, increasing not only the uptake capacity of new organic matter, but also preventing the removal of accumulated soil matter from being emitted as GHGs (**Geissen et al. 2013**). Such emissions, in the case of methane, are more detrimental as they generate increased warming. It should be noted that accumulated organic matter is susceptible to being oxidised (respired) under anaerobic conditions with the consequent release of methane. In addition, the secondary use of the stripped soil, rich in organic carbon, after its application on farms, will mean the replacement, in part, of fertilisers of mineral origin, thus eliminating the GHG emissions associated with the manufacture of these products.

Co-benefits for Biodiversity

As with vegetation management measures, the co-benefit of soil stripping in wetlands is to improve the diversity and structure of their habitats. In particular, within the scope of this project, soil stripping led to improvements in several HCIs such as 3140, 1410 and 1510*. This allowed for an increase in the surface area of freestanding water that was colonised by macrophyte meadows, and at the same time, the process of homogenisation of helophytic vegetation was slowed. This diversification of environments makes it possible to maintain high biodiversity values of flora and fauna in the wetlands. Thus, for example, for aquatic birds, the creation of areas of somewhat deeper water favours species with diving behaviours. Conversely, when water is present for longer periods at shallower levels, the wetlands serve as refuge and feeding areas for ducks and wading birds. These areas can also be used as drinking places by steppe birds when these are the only areas present with standing water. Areas where the soil has been cleared and stripped also allow greater accessibility to roots, rhizomes, and small tubers that have not been removed and which remain readily available to waterfowl.

Socio-economic considerations

The average cost per hectare of soil stripping can vary depending on several factors, including the geographical area, accessibility to the wetland, proximity of the machinery to the wetland, cost of inputs, cost of fuel, etc. In the experience obtained in the execution of this project, the cost ranged from 10,766.23€/ha (result obtained in the wetlands of Castilla y León, in the year 2021) to 23,586.96 €/ha (result obtained in the wetlands of Castilla-La Mancha, in 2023). The cost of soil stripping includes various tasks: preliminary clearing of vegetation (if necessary), soil removal of from 15-20 cm of the soil surface, transport to the receiving agricultural plot, and the spreading of the soil there, purchase of consumable materials such as stakes for the delimitation of the areas of action, and coordination costs (contracting external assistance, requesting the relevant permits from the competent authorities, field visits, etc.). Despite the high cost, soil stripping is considered a restorative action with medium to long-term effects, as it is an action that does not require annual maintenance work. Its positive effects can last for at least 7 to 10 years after implementation, depending on the degree of eutrophication and clogging to which the wetland is subjected.

Secondary use of stripped soil

The extracted by-product composed of fertile soil (with a large amount of organic matter), with some remains of vegetation and roots, can be used on farms as a soil additive or as a complement to fertilisation, or even directly as organic fertiliser, replacing part of the mineral fertiliser used on the farm where the stripped soil is applied.

B Mudding

Mudding is an agricultural practice traditionally used in rice cultivation that involves churning the stubble and remains of the previous harvest into the mud to encourage soil aeration and aerobic mineralisation of organic matter. A tractor with iron rear wheels known as “gavias” is used for this purpose.

At the wetland level, this technique can be used in coastal wetlands or marshes as follows:

1	**Vegetation must be removed prior to mudding.** If the area has a dense vegetation cover, a first pass is made using machinery with a cutting tool which shreds the aerial part of the plants. This step is not necessary when mudding is done in areas without vegetation or in those which have very little density. The shredded plant remains are then piled up in rows with a windrower and baled with a baler.
2	**A tractor with iron rear wheels is used to churn and aerate** the upper 30-40 centimetres of the soil. The roots of the plants are cut up by the metal tractor wheels.

Regarding the frequency of using this soil management technique, given that these areas of mudflats and their subsequent flooding see slower growth of helophytic vegetation, it is estimated, based on the experience of the **LIFE Wetlands4Climate project**, that it is necessary to carry out mudding every three years.

Climate Change Mitigation

In contrast to soil stripping, mudding does not involve the removal of soil, but rather its mechanical aeration and subsequent oxygenation.

The goal of the procedure is to drive the decomposition of organic matter (taking place in situ as soil stripping has not been done) towards the production of GHGs with lower global warming potential, such as CO_2. Such production is mainly the result of aerobic respiration. In contrast, GHGs that have significantly greater warming potential, such as CH_4, are produced by anaerobic metabolisms.

Co-benefits for Biodiversity

Mudding, within the framework of this project, has contributed to improving habitats 1150* and 7210*, while improving the biodiversity associated with the wetland as a whole. The positive effects of mudding have been observed in previous implementations of other projects and their co-benefits are similar to those obtained from soil stripping. Thus, mudding activities made it possible to create permanent areas of freestanding water in monospecific reed environments. In the season following a mudding operation, these areas were either extensively colonised by hydrophytes (due, in part, to the germination of spores and seeds that had been dormant in the lower layers of the soil) or they became feeding areas for waterfowl.

Socio-economic considerations

It should be borne in mind that this procedure is derived from an agricultural practice. Therefore, machinery is not usually available or adapted to wetland areas, but rather to farm fields that have been worked for years and do not present risks or unexpected elements. The availability or lack of suitable machinery in the working area can result in an important variation in the cost of the action. If machinery needs to be brought to the site, it can mean an increase of 35% in the cost of the action (depending also on the distance).

The cost can therefore vary between **1,000€/ha per year** (if the work area has a tractor with iron rear wheels and the plot to be mudded has no plant cover that must first be to be removed) up to **6,000€/ha** (if the machinery needs to be transported and the plot has plant cover that ought to be removed before the mudding can be done).

Given this difference, it is recommended, if this action is chosen as a necessary management or restorative measure for the wetland, that implementation be done on an area of at least 3 hectares. In this way, the transport cost can be better amortised, resulting in a lower per-hectare cost for the action.

Main results achieved with soil management in the LIFE Wetlands4Climate project through mudding and soil stripping

After the first month following the action, GHG emissions in stripped or mudded areas are lower than in areas without soil management. In other words, in the short term, this type of management is beneficial in mitigating emissions. On a large scale, areas of recently stripped soil have lower CO_2 fluxes than older stripped areas.

After aeration of the topsoil layers by mudding, changes in the microbial community composition are observed. These indicate a stimulation of aerobic metabolism to the detriment of anaerobic respiratory processes such as methanogenesis. This is consistent with the decrease in CH_4 emissions with respect to CO_2 observed in these procedures.

As in the case of plant residues from mowing, it is essential to make secondary use of the stripped soil containing organic matter, for example, for use as fertiliser on farms, substituting for chemical fertilisers.

3.2.3. Hydrological management

The hydrological management as mentioned in this text mainly refers to natural flooding management of the wetland, maintaining it in its natural, permanent, or temporary hydroperiod condition, as the case may be. On the other hand, there are wetlands that have been transformed into wet pastures for livestock or agricultural use. Those abandoned areas where this use no longer exists could be flooded again on a semi-permanent basis to recover their environmental use.

Climate Change Mitigation

Controlled flooding during warmer months may encourage the growth of plant biomass, a driver of carbon sequestration, but methane emissions from methanogenesis will also increase. Such generation is produced by anaerobic conditions in the soil, which is favoured by the higher (exponential) activation rate of methanogenesis with temperature relative to primary production and aerobic respiration (**Camacho et al. 2017**). However, a deeper water column may also facilitate methane consumption by methanotrophy, so the balance of this activity on climate mitigation will depend on the temporal and spatial patterns of the flooding. The degree of soil moisture is also relevant for GHG emission rates for gases such as CO_2 and CH_4. On the other hand, the regulation of the water regime can also influence the physiochemical characteristics of water, which are also directly related to carbon transfer processes in the system and in the atmosphere. The complexity of water management to maximise carbon sequestration and reduce greenhouse gas emissions requires a detailed analysis of each wetland type, considering its ecological characteristics and conservation status as determining factors in the carbon equation.

Co-benefits for Biodiversity

Improvements to the hydrological regime (hydroperiod, filling and emptying systems) in wetlands can lead to increases in the duration and surface area of the inundation. However, these actions should always try to mimic the natural flooding and drying periods. Re-flooding actions provide the wetlands with greater heterogeneity, favouring a greater variety of habitats that promote biodiversity in the wetlands. Thus, they contribute to the maintenance of HCI 3170*, typical of temporary flooding patterns, and to the recovery of other HCIs more closely linked to longer inundation conditions, such as HCI 1410 and 3140. These latter areas often host submerged charophyte meadows or threatened plant species. Other faunal communities benefit from these changes, such as waterbirds, which see their resting, feeding, sheltering, roosting, migrating, and nesting areas expanded and improved.

Socio-economic considerations

In case new canal works for re-flooding the plots are not necessary, the cost of the action will be determined by the number of personnel assigned to coordinate the project. The cost of water management can reach as high as 115.79€/ha.

Additionally, the cost of water as a resource can be used as a reference. The average cost for water irrigation services is estimated at 263€/ha per year, therefore, the average cost of a re-flooding action could reach **378,79€/ha.**

Flooding can be considered a recurrent action in wetland management, so implementations of it can be planned on an annual basis.

Main results obtained in relation to the hydrological management in the LIFE Wetlands4Climate project

The activities that were carried out consisted mainly of observing the variation in the exchange of gases with the atmosphere along the flood gradients of the wetland basins.

- **Flood level has been shown to be a key factor in explaining carbon fluxes.** Given the high seasonality of the wetlands studied, this is a particularly important management factor. Several environmental factors that regulate these fluxes, such as the activity of the autotrophic community, the chemical balances of carbon in the water, the oxidation/reduction state of the sediments, and salinity, show a strong dependence on flood levels.

- **When considering CO_2 and CH_4 flux patterns together, one would expect an undesirable stimulation of carbon emissions in hydrologically stressed scenarios.** Similarly, in situations in which the basin is only slightly saturated, an increase has been seen in GHG emissions. In contrast, when the water column is higher, there are reductions in GHG emissions.

- **Significant differences in gas exchange rates can be seen depending on the type of wetland.** Rates of carbon flux are higher in more productive wetlands, due to the characteristics of the basin and its geographical position, for example, those of coastal freshwater wetlands. In contrast, inhibitory effects such as salinity, particularly on methane production, mean that emissions, under similar conservation conditions, are comparatively lower in saltwater ecosystems.

3.2.4. Summary of costs of the measures

As a summary, Table 2 shows the costs associated with the different actions described:

	Action		Action frequency	Average cost of execution of event (€/ha)[1]	Average annual cost per action (€/ha/year)
	Mowing with tractor		Annually in freshwater inland wetlands; to be determined by managers and with a conservation plan	250€	250,00€
Vegetation management actions	Mowing with amphibious machinery	Direct use of harvested vegetation for fodder	Annual/Biennial[2]	2.500€	2500€ / 1.250€[3]
		With shredding		3.000€	3.000€ / 1.500€[4]
Soil management actions	Soil stripping		10 years	10.766,23€ – 23.586,96€	1.076,62€ – 2.358,70€
	Mudding		Triennial	1.000,00€ - 6.000,00€	333,33€ – 2.000€
Water management actions	Mudding		Annual	378,79€	378,79€

[1] Implementation costs have been calculated for the years of implementation of **LIFE Wetlands4Climate** 2021-2023. These include maintenance costs (where necessary) as well as coordination costs (planning of tasks, procurement of necessary consumables, contracting of necessary external assistance, application for relevant permits from competent authorities, field visits, etc.). Please note that these data are for each time the action is carried out and may vary depending on inflation and fuel costs.
[2] Depending on the renewal rates of helophytic vegetation in the wetlands where the action is to be implemented, mowing should be carried out on an annual or biennial basis.
[3] In case of biennial mowing, the cost of the mowing action with direct re-use of the mown vegetation would be 1,250€.
[4] If mowing is carried out biennially, the cost of the mowing action with shredding of the mown vegetation would be 1,500€.

TABLE 2: Summary of costs associated with management of and/or restoration actions for Mediterranean wetlands.

4

4. PROCEDURE FOR ASSESSING THE EFFECTIVENESS OF CLIMATE MITIGATION ACTIONS

4.1. DEFINITION OF THE SPATIAL AND TEMPORAL FIELDS OF ACTION

The **geographical boundaries** are defined by the location where the project activities will be carried out under the supervision of the project participants. The project promoter must provide the geographical coordinates of the land where the project will take place in order to ensure an accurate delimitation. This task involves the use of data collected in a variety of ways: remotely, topographic information, published maps, land administration and tenure records, as well as other official documents that contribute to a clear delineation of the project area.

The **start date of a project** that is eligible to be financed through the sale of carbon credits via a voluntary carbon market standard does not necessarily have to coincide with the time when the operations (management/restoration actions) of the project commence. The start date is a key concept used to indicate that certain decisions have been taken without which it would not be possible to begin project activities. For example, the demonstration of having taken into consideration the calculation of avoided emissions prior to the start of the project is one such decision. This start date must include a commitment that the project participants have pledged funding for conducting the project actions.

The **duration** of an action on a wetland depends on its nature, whether it is a recurrent activity such as seasonal mowing, which tends to be repetitive, or more ad hoc interventions, such as restoration by soil stripping, which are of relatively short duration and are not repeated frequently.

The crediting period corresponds to the period of time in which a project can apply for GHG emission reduction certification units for wetland management/restoration activities. It should be noted that one certification unit is equal to one metric tonne of CO_2 equivalent of certified net benefit resulting from a soil emission reduction activity. Under the EU CRCF regulatory framework, which was pending approval at the time of writing this methodology (March 2024), soil emission reduction projects (in which this methodology will be framed) will have to be carried out for at least 5 years to obtain certification of emission reduction units (**Consejo Europeo, 2024**).

4.2. DEFINITION OF WETLAND TYPE AND ECOLOGICAL STATUS

In a project, it is essential to define **the ecological type of the wetland** in question. This is because the characteristics of each typology will delineate the bio-geochemical processes in the carbon cycle and the wetland-atmosphere interaction in the flows of GHGs. The **LIFE Wetlands4Climate** project, from which this guide is derived, has focused on three main groups of Mediterranean wetlands: **coastal** (C), **freshwater inland** (FI) **and saline inland** (S). These groups have particular ecological reference conditions associated with them within the ecological status classification system, and they include different habitats of European Community interest.

In addition to the type of wetland, GHG exchange is also conditioned by **the ecological or conservation status of the wetland** on which the action or set of actions is intended to be carried out. This ecological status provides a frame of reference for the wetland's carbon sequestration capacity, as it has been shown that this mitigation capacity can be compromised when the conservation status of the wetland is insufficient (**Camacho et al. 2017**; **Morant et al. 2020a, b**). It is possible to improve the mitigation capacity through restoration by selecting the most appropriate measures in this regard.

When determining the ecological status of the wetland (Table 1), the protocols established by the legislation for the evaluation of the status of bodies of water (**BOE, 2015**) can be followed. These use specific indicators related to water physiochemistry, hydromorphology, and, above all, biological elements (phytoplankton, other aquatic flora, and benthic invertebrates). The limits of each of these indicators for classifying status as very good, good, moderate, poor, and bad are compiled by the type of body of water (associated with the relevant ecological characteristics) in RD 817/2015 (**BOE, 2015**).

The definition of the type and ecological status of the wetland is necessary for the following decisions, both in terms of the selection of the type of actions to be carried out and the correct definition of the baseline scenario. With regard to the selection of actions, in those situations where, due to the good conservation status of the wetland, there is no possibility of significant improvement in its ecological status, those actions aimed at maintaining the good ecological status of the system, but which can further improve its mitigation capacity can be considered to be priority management items. On the other hand, in those scenarios with room for improvement of the ecological status, and with it a possible greater capacity for wetland sequestration associated with its improvement, both management and restoration measures can be considered from among those tested in the project, and which are described in section 3 of this document.

However, for any restoration project to be considered, it is necessary that all pressures that have led to the poor state of conservation of the wetland have been removed. For example, if the degradation of the wetland is due to discharges of polluted effluent, there is no point in carrying out any restoration if these polluting inflows are not eliminated.

The conditions related to the type and conservation status of the wetland and the selection of the baseline scenario are linked to the calculation procedure described in the following section.

4.3. QUANTIFICATION OF THE EFFECTIVENESS OF ACTIONS

This section details the method for measuring the mitigation capacity of wetlands, based on the experimentation and methodology of the **LIFE Wetlands4Climate project**. The calculation tools consider the capacity of wetlands to sequester carbon through biogeochemical processes in the wetland that interact in the transfer of GHGs to the atmosphere, taking into account various functional components. The capacity of a wetland to sequester carbon is defined by the balance between GHG sequestration and the emission processes.

The increase in climate change mitigation capacity (reduction of warming) of the project is primarily determined by the direct reduction in the wetland (under the term 'GHG wetland' in Equation 1) plus the benefits from the secondary use of products such as plant material or soils (termed 'GHG products' in Equation 1). However, emissions associated with the implementation of management actions, such as emissions from the use of machinery (labelled as 'GHG increase' in Equation 1), must be discounted.

Based on the above, the success of the project in terms of net emission reductions (mitigation of warming, which is referred to as 'GHG project' in Equation 1) will be quantified by the result of Equation 1. This result is analogous to the Net Carbon Removal Benefit concept proposed by the European Union to establish carbon removal certification, but it is adapted in this case to the particular nature of wetland management projects:

$$GHG_{project} = (GHG_{wetland} + GHG_{products}) - GHG_{increment} \quad \text{EQUATION 1}$$

The term ‘GHG $_{wetland}$’ in the equation above defines the expected mitigation in the wetland (decrease of GHG emissions in tCO_2eq) as a consequence of the implementation of one or more management actions. It is the observed difference between the GHG exchanges with the atmosphere in a baseline scenario (i.e. a situation in which no action is taken) and the GHG exchanges produced in an improved scenario in which these actions are carried out.

$GHG_{wetland} = \sum (GHG_{baseline\ scenario} \times Cf_{improvement} \times T \times A)n$	**EQUATION 1.1**

The terms in Equation 1.1 correspond to: GHG $_{wetland}$ = sum of GHG $_{emission}$ avoided in the wetland as a consequence of carrying out the action(s) (tCO_2eq); GHG baseline scenario = GHG balance in the absence of action (tCO_2eq/ha-year); Cf improvement = GHG $_{emission}$ reduction coefficient for the action (average per year over the lifetime of the effect of the action); T = time in years of the lifetime of the effect of the management/restoration action; Area = area implemented in hectares of the management/restoration action; n: actions carried out jointly in the same mitigation project.

Baseline scenarios refer to conditions where there is room for improvement through management and/or restoration actions. They therefore represent the situation of the wetland, in terms of GHG exchange, prior to a management/restoration action. Similarly, this term can also be understood as the GHG exchange in the absence of action. Thus, it is on the GHG balance in the baseline scenario that the expected mitigation coefficients can be applied if one or more of the management projects described in section 3 of this guidance are implemented. The value used for the base scenario GHG term in Equation 1.1. depends on the type and conservation status of the wetland. In this sense, the following two possibilities are possible, the calculation of which can be found in more detail in the methodology document for the calculation of mitigation, also derived from the **LIFE Wetlands4Climate** project:

SCENARIO 1	**The wetland type and conservation status match those tested in the LIFE Wetlands4Climate project**, i.e. it is a Mediterranean coastal, inland freshwater, or inland saline wetland and is in a good conservation status. In this case, the baseline scenario GHG value (i.e. GHG balance in the absence of action) measured in the **LIFE Wetlands4Climate** project for that wetland type can be used.
SCENARIO 2	**The wetland type fits with those tested in the LIFE Wetlands4Climate project**, i.e. it is a Mediterranean coastal, inland freshwater, or inland saline wetland, but it is not in a good state of conservation. In this case it would be necessary to recalculate the baseline scenario GHG value (i.e. GHG balance in the absence of action) in order to apply the corresponding mitigation factors. This estimation should be done by measuring the actual GHG exchange rates of that wetland prior to the management/restoration measures to be conducted in the action areas.

Within the mitigation project framework, it is essential to consider the secondary use of products, such as plant biomass or organic matter from soil, extracted in every recurrent management or restoration action. This secondary use of products in agricultural activities is considered a mandatory condition in mitigation projects because if they are removed from the wetland but GHGs are later emitted, the mitigation objective is not achieved.

This secondary use may involve, for example, the substitution of industrial fertilisers with wetland products extracted in the action (counting the full carbon footprint of these), the substitution of plant protection products, and also the substitution of fodder and bedding for livestock from farms. The formula also introduces the term GHG other, thus leaving open the possibility of establishing uses for the extracted material that are not defined a priori in this project but which may be equally beneficial for reducing the carbon footprint of an industrial or manufacturing process. When this materialises, the emission reduction coefficients associated with the secondary use of the by-products extracted from wetland management actions as a substitute for specific agricultural practices will be incorporated into the calculation. It is this circumstance that defines the GHG output term in Equation 1:

$GHG_{products} = [GHG_{fertiliser} + GHG_{phytosanitary} + GHG_{fodder} + GHG_{others}]$	**EQUATION 1.2**

The terms in Equation 1.2 correspond to: $GHG_{products}$ = sum of $GHGs_{mitigated}$ as a consequence of the secondary use of the products derived from the set of implemented actions (tCO_2eq); $GHG_{fertiliser}$ = avoided emissions from the production of mineral fertiliser (tCO_2eq); $GHG_{phytosanitary}$ = avoided emissions from the production of phytosanitary (tCO_2eq); GHG_{fodder} = avoided emissions from the production of fodder (tCO_2eq); GHG_{forage} = avoided emissions from the production of fodder (tCO_2eq).

Finally, to the mitigation associated with the actions that have been calculated in Equations 1.1 and 1.2, it is necessary to subtract those emissions linked to emissions generated in the course of performing the action, which are mainly associated with the use of fuel for machinery (or others, in this case, derived by the same reasoning) during the implementation of these actions. This is defined by the term 'GHG increase' which is included in Equation 1.

The calculation in this case consists of extrapolating the average consumption per hectare to the total action area (A), considering the application of the corresponding CO_2 emissions equivalence factor (**Ministry for Ecological Transition and Demographic Challenge, 2023**). This approach ensures an accurate estimation of the emissions associated with the implementation of the actions, allowing for a more complete assessment of the carbon footprint of the project:

$GHG_{increase} = Fc \times_{Consumption} \times A$	**EQUATION 1.3**

4.4. DEVELOPING A MONITORING PLAN

Monitoring GHG mitigation in the wetlands where the project will be implemented is essential for measuring the success of the project in terms of the net GHG reduction levels attained by the project. Therefore, in order to perform this monitoring effectively, the following aspects must be clearly described and included:

1	**Design of a monitoring system: including the collection and recording of relevant data, such as the evolution of GHG exchange process rates.**
2	**Selection of measurement tools: Describe which tools will be used to measure GHG emissions.**
3	**Data collection: Data should be accurate, reliable, and consistent. It should describe representative sampling methods to be used, how to collect, store, and share them.**
4	**Duration of monitoring: It must comply with the standards prescribed by European, national, and regional regulations.**

5

5. INTEGRATION IN PLANNING

When implementing wetland management/restoration actions, all international (in particular European)**, national, regional, and local laws, as well as other standards and regulatory frameworks must, of course, be complied with. In addition, all necessary permits for the full realisation of the project must be in place, as well as adequate and stable funding to complete the project.**

If you are going to seek carbon credit certification through one of the available carbon credit standards, you must have some proof that the ownership of the project is vested in the project executor. Ownership is defined as the legal right to control and manage project activities.

The information that can be submitted to verify ownership can be of the following types:

- **Original ownership of the project or that granted by law, decree, or collaboration agreement, by a competent authority.**

- **Original project ownership through an agreement with the property owner or through contractual rights to the land,** which must indicate the necessary permits to carry out the specific management/restoration process, from which the GHG emission reductions or removals are generated.

Under all current international certification standards, such as the Verra VCS methodologies, projects are subject to a 30-day public comment period. These consultations are intended to allow local stakeholders to assess impacts, raise questions about negative impacts, and contribute ideas for project design. It is advisable to conduct these public consultation processes to avoid future conflicts.

It is recommended that the person responsible for the project or for the implementation of the management/restoration measures establishes the necessary mechanisms to ensure a continuous flow of communication with local stakeholders and to enable questions to be asked about negative impacts that may occur during the project. A plan for coordination, if necessary, with other projects should also be presented in order to avoid duplication of efforts and to maximise the benefit.

5.1. POLICIES AND THE LEGAL FRAMEWORK IN SPAIN

Although it is not the aim of this document to delve into the legal framework concerning wetlands, it is important to at least be aware of the relevant regulations. Knowledge of these regulations is relevant to grasping the importance of the consequent monitoring and for understanding the indicators of the conservation status of wetlands.

Thus, in Spain the legislation on wetlands is based, mainly, on the following regulations:

International Legislation

- **The Ramsar Convention**

- **Directive 2009/147/CE (Birds Directive)** (DOCE n.º 20, of January 26th, 2010).

- **Directive 92/43/CEE (Hábitats Directive),** on the conservation of natural habitats and of wild fauna and flora. Habitats Annexes and subsequent modifications (Directive 97/62/EC) (DOCE no. L 305, of November 8th, 1997).

- **Directive 2000/60/CE (Water Framework Directive)**, (DOCE n.º 327, of December 22nd, 2000).

- **Communication from the Commission to the European Parliament and the Council of May 29th, 1995 - Wise use and conservation of wetlands.**

Spanish National Legislation

- State Commission for Natural Heritage and Biodiversity; Royal Decree 1424/2008. BOE No. 221, September 12th, 2008

- Instrument of Accession of Spain to the Ramsar Convention of March 18, 1982, BOE No. 199 of August 20th, 1982.

- Spanish Inventory of Natural Heritage and Biodiversity; Royal Decree 556/2011. BOE No. 112, May 11th, 2011

- National Inventory of Wetlands; Royal Decree 435/2004. BOE No. 73, March 25th, 2004.

- Law 42/2007 of December 13 on Natural Heritage and Biodiversity. BOE No. 299, December 14th, 2007.

- **Strategic Plan for wetlands to 2030 (MITECO, 2022).**

- **State strategic plan for natural heritage and biodiversity to 2030; Royal Decree 1057/2022. BOE No. 313, of December 30th, 2022.**

- **Protocol of amendment to the Convention ratified by Instrument of May 19, 1987, BOE No. 167 of July 14th, 1987, (ratification of the amendment to the Ramsar Convention by the Paris Protocol).**

- **Criteria for monitoring and evaluating the state of surface waters and environmental quality standards. Royal Decree 817/2015 of September 11. BOE No. 219 of December 09th, 2015.**

5.2. POSSIBLE SOURCES OF FUNDING: VOLUNTARY CARBON MARKET, MITECO REGISTRY

Carbon markets were established under the Kyoto Protocol (1997) and implemented through the Marrakech Accords (2001) to support members of the United Nations Framework Convention on Climate Change (UNFCCC) in meeting their emission reduction commitments. Since the Paris Agreement (2016) the structure of these markets has changed, but in particular, what is now known as the Voluntary CO_2 Emissions Offset Market is a trading system in which carbon credits are bought and sold. This system allows companies and organisations to offset, on a voluntary basis, the CO_2 emissions they cannot reduce. They do this by purchasing carbon credits generated by CO_2 absorption and/or emission reduction projects. These projects are verified and certified by independent bodies to ensure that they actually reduce CO_2 emissions and that such sequestration is not part of compliance with mandatory national or international regulations.

In Spain, the voluntary actions of Spanish companies, administrations and other organisations in the calculation, reduction, and compensation of the GHG emissions generated by their activity are mostly registered in the standard known as: Carbon footprint registry, compensation, and carbon dioxide absorption projects, sponsored by the Ministry for Ecological Transition and Demographic Challenge.

6

6. KEY STEPS IN THE IMPLEMENTATION OF A CLIMATE MITIGATION PROJECT

- **A comprehensive survey of the wetland is recommended** to determine its ecological/conservation status, including its extent and biological diversity.

- **Identify the areas of the wetland to be managed/restored,** where the GHG balance can be improved. It is important at this stage to define the ownership of the land where the actions are to be carried out, and to start making the relevant agreements with the owners and/or competent administrations.

• **Define the ecological type to which the wetland belongs and establish the temporal and geographical limits of the project.**

• **Determination of the GHG balance in the baseline scenario.** This represents the GHG emission/sequestration balance in the area affected by the project in the absence of intervention. It is therefore the condition that indicates the possibilities for improvement through management and/or restoration actions.

• **Design strategies and actions for vegetation, soil, and water management/ restoration.** For vegetation and soil management actions, secondary use of the materials removed from the wetland, e.g. for agricultural and/or livestock purposes should always be planned.

• **Work schedule.**

- **Legal compliance, funding, and safeguards.** Establish a budget and an economic viability and financing plan.

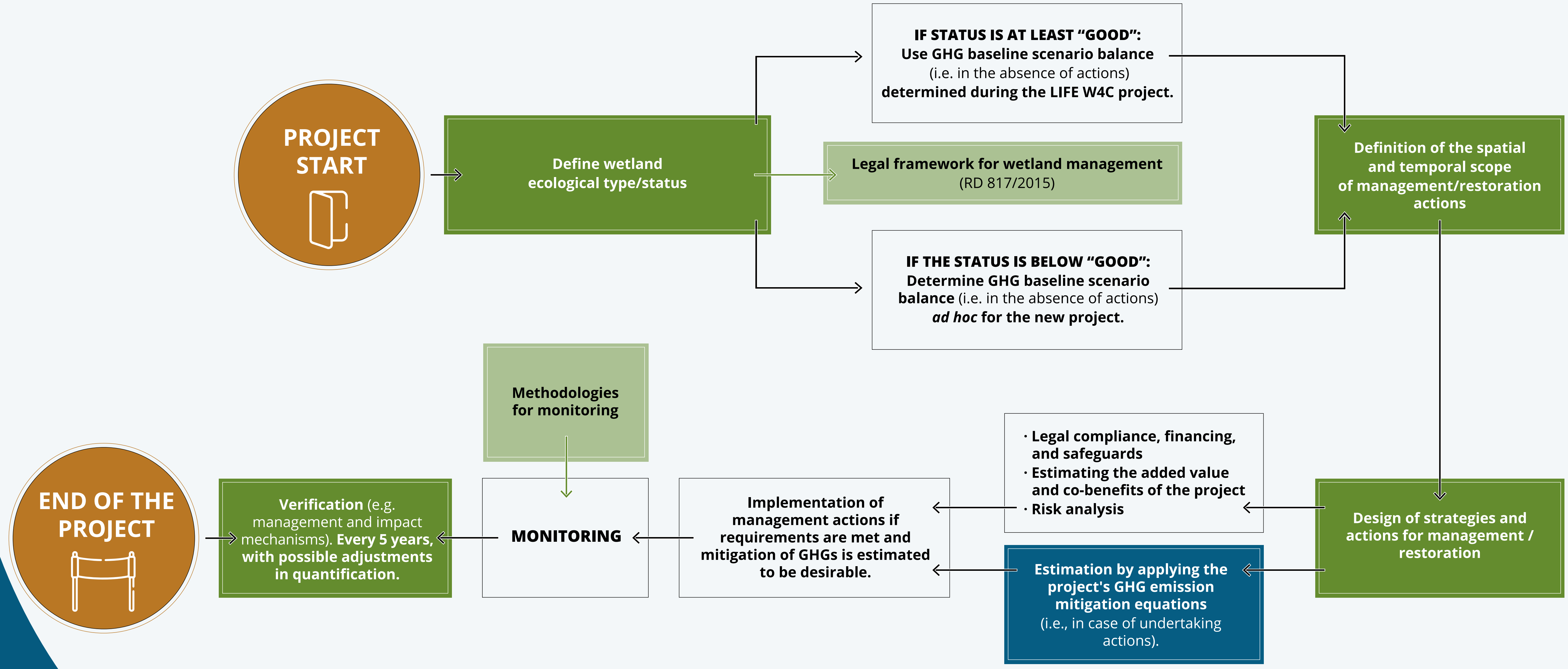
- **Estimate the added value and co-benefits of the project.** Although the primary purpose of Mediterranean wetland management/restoration projects as carbon sinks is to reduce GHG emissions, they can also generate positive aggregate impacts on biodiversity, adaptation to climate change, improved food security, improved human health, and socio-economic improvements in the environment. It is advisable to estimate these benefits through verifiable information.

- **Risk analysis.** To ensure that wetland conservation and management/restoration projects maintain the permanence of CO_2 equivalent removals, a non-permanence risk analysis is required that identifies the risk of potential carbon losses due to accidental or unintentional emissions. Internal risks, external risks and natural risks also need to be assessed.

- **Establish a monitoring plan,** including the collection and recording of relevant data and defining measurement tools.

- **Implementation of management and monitoring actions.**

- **Quantification of real GHG reductions.**



Process / Task

Result (Input / Output)

Decision-making

Methodology / Standard

FIGURE 3: Workflow describing the phases to be developed during the implementation of a mitigation project.

7

7. REFERENCES

Bernal B., Mitsch W.J., 2012. *Comparing Carbon Sequestration in Temperate Freshwater Wetland Communities.* Global Change Biology, 18(5): pp. 1636-1647.
www.doi.org/10.1111/j.1365-2486.2011.02619.x

BOE. 2015. Royal Decree 817/2015 establishing the criteria for monitoring and evaluation of the state of surface waters and environmental quality standards [in Spanish]. BOE num. 219, 12 September 2015, Official State Gazette, Madrid.

Borja C., Florín M., Camacho A., 2012. *Lakes and Wetlands in the Spanish Millennium Ecosystem Assessment* [in Spanish]. Ambienta, 98: pp. 82-91.
www.hdl.handle.net/10578/2486

Camacho A., Borja C., Valero-Garcés B., Sahuquillo M., Cirujano S., Soria J. M., Rico E., de la Hera A., Santamans A.C., García de Domingo A., Chicote A., Gosálvez R.U., 2009. 31. Retained Continental Waters. Inland Lenitic Ecosystems [in Spanish]. In: VVAA. Bases ecológicas preliminares para la conservación de los tipos de hábitat de interés comunitario en España (Preliminary ecological basis for the conservation of habitat types of Community interest in Spain), Ministry of the Environment and Rural and Marine Affairs, Madrid.
www.miteco.gob.es/es/biodiversidad/temas/espacios-protegidos/31_tcm30-196763.pdf

Camacho A., Picazo A., Rochera C., Santamans A.C., Morant D., Miralles-Lorenzo J., Castillo-Escrivà A., 2017. *Methane Emissions in Spanish Saline Lakes: Current Rates, Temperature and Salinity Responses, and Evolution under Different Climate Change Scenarios.* Water. 9(9): p. 659.
www.doi.org/10.3390/w9090659

Camacho A., Ferriol C., Santamans A. C., Sahuquillo M., Camacho-Santamans A., Morant D., 2019a. *Establishment, for Each Inland Lentic Habitat Type, of a Minimum Set of Variables to Calculate the ECLECTIC Index. Series Methodologies for Monitoring the Conservation Status of Habitat Types* [in Spanish]. Ministry for Ecological Transition, Madrid.

Camacho A., Ferriol C., Santamans A.C., Morant D., Camacho-Santamans A., Picazo A., Rochera C., 2019b. *Description of Procedures to Estimate the Pressures and Threats Affecting the Conservation Status of Each Type of Inland Lentic Habitat. Series Methodologies for Monitoring the Conservation Status of Habitat Types* [in Spanish]. Ministry for Ecological Transition, Madrid.

Dudgeon D., Arthington A.H., Gessner M.O., Kawabata Z.I., Knowler D.J., Lévêque C., 2006. *Freshwater biodiversity: importance, threats, status and conservation challenges*. Biological Reviews, 81(2): pp. 163-182.
www.doi.org/10.1017/S1464793105006950

Farinós-Celdrán P., 2014. *The waterbird community of the Mar Menor (Murcia, SE Spain): Responses to functional processes, structural gradients and implications for management* [in Spanish]. University of Murcia.
www.digitum.um.es/digitum/handle/10201/42710

Fennessy M.S., Wardrop D.H., Moon J.B., Wilson S., Craft C., 2017. *Soil carbon sequestration in freshwater wetlands varies across a gradient of ecological condition and by ecoregion*. Journal of Ecological Engineering, 114(15): pp. 129-136.
www.doi.org/10.1016/j.ecoleng.2017.09.013

Forster P., Storelvmo T., Armour K., Collins W., Dufresne J.L., Frame D., Lunt D.J., Mauritsen T., Palmer M.D., Watanabe M., Wild M., Zhang H., 2021: *The Earth's Energy Budget, Climate Feedbacks, and Climate Sensitivity. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Masson- Delmotte V, Zhai P, Pirani A, Connors S.L, Péan C, Berger S, Caud N, Chen Y, Goldfarb L, Gomis M.I, Huang M, Leitzell K, Lonnoy E, Matthews J.B.R, Maycock T.K, Waterfield T, Yelekçi O, Yu R, Zhou B (eds.). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 923-1054, doi:10.1017/9781009157896.009.

Geissen V., Wang S., Oostindie K., Huerta E., Zwart K.B., Smit A., Ritsema C.J., Moore D., 2013. *Effects of topsoil removal as a nature management technique on soil functions.* Catena,101: pp. 50-55.
www.dx.doi.org/10.1016/j.catena.2012.10.002

Jubete F., Torres M., Gómez E., Cirujano S., Zuazua P. (Eds.), 2006. *The Aquatic Warbler: a Manual for Helophytic Vegetation Management and Population Monitoring* [in Spanish]. Fundación Global Nature.

Kim S., Oh Y., Ryu J., Lee S., Lee J., 2018. *Studies on Potential Supply of Soil Organic Matter Using Phragmites australis in Reclaimed Land*. Korean Journal of Soil Science and Fertilizer, pp. 412-419.
www.doi.org/10.7745/KJSSF.2018.51.4.412

Lehikoinen P., Lehikoinen A., Mikkola-Roos M., Jaatinen K., 2017. *Counteracting wetland overgrowth increases breeding and staging bird abundances*. Scientific Reports, 7, 41391.
www.doi.org/10.1038/srep41391

Lolu A.J., Ahluwalia A.S., Sidhu M.C., Reshi Z.A., Mandotra S.K., 2020. *Carbon Sequestration and Storage by Wetlands: Implications in the climate change scenario.* In: Upadhyay A.K, Singh R, Singh D.P. (Eds). Restoration of Wetland Ecosystem: A Trajectory Towards a Sustainable Environment. Singapore (SGP): Springer; p 45-58.
www.doi.org/10.1007/978-981-13-7665-8

Lu W., Xiao J., Liu F., Zhang Y., Liu C.A., Lin G., 2017. *Contrasting Ecosystem CO_2 Fluxes of Inland and Coastal Wetlands: A meta-analysis of eddy covariance data*. Global Change Biology 23(3): pp. 1180-1198.
www.doi.org/10.1111/gcb.13424

Ma J., Chang L., Li Y., Lan X., Ji W., Zhang J., Han F., Cheng H., Chai Y., Chai S.. 2024. *Straw Strip Mulch Improves Soil Moisture Similar to Plastic Film Mulch but with a Higher Net Income*. Agriculture, Ecosystems & Environment. Volume 362. 108855, ISSN 0167-8809.
www.doi.org/10.1016/j.agee.2023.108855

Mairata A., Labarga D., Puelles M., Huete J., Portu J., Rivacoba L., Pou A. ,2023. *The Organic Mulches in Vineyards Exerted an Influence on Spontaneous Weed Cover and Plant Biodiversity*. European Journal of Agronomy. 151: pp. 1161-031.
www.creativecommons.org/licenses/by/4.0

Miguélez D., 2023. *Extensive Grazing and Conservation of Threatened Marshland Birds. Scientific Tag Monitoring in the Territories of La Nava Lagoon, Prat De Cabanes-Torreblanca, Moro Marsh, and Pego-Oliva Marsh, Year 2023* [in Spanish], Naturaleza Pastoreada/Fundación Global Nature. Fuentes de Nava, Palencia.

Millenium Ecosystem Assessment. 2005. Ecosystems and Human Well-being (Vol. 5). Washington DC (US-DC): Island Press.

Ministry for Ecological Transition and Demographic Challenge, undated. *Treatment Systems. Evaluation and Material Recycling. 1.2 Biological Treatments* [in Spanish].
www.miteco.gob.es/es/calidad-y-evaluacion-ambiental/temas/prevencion-y-gestion-residuos/flujos/domesticos/gestion/sistema-tratamiento/tratamientos-biologicos-compostaje.html#:~:text=El%20compostaje%20es%20un%20proceso,puede%20utilizar%20como%20enmienda%20org%C3%A1nica.

Ministry for Ecological Transition and Demographic Challenge, 2022. *Information on the Carbon Dioxide Absorption Projects Section. Carbon Footprint Register, Offsets and Carbon Dioxide Absorption Projects* [in Spanish]. March.
www.miteco.gob.es/content/dam/miteco/es/cambio-climatico/temas/mitigacion-politicas-y-medidas/documentoapoyopa_tcm30-479077.pdf

Ministry for Ecological Transition and Demographic Challenge, Climate Change Office, 2023. *Carbon footprint registry, offsetting and carbon dioxide absorption projects. Emission factors* [in Spanish].
www.miteco.gob.es/content/dam/miteco/es/cambio-climatico/temas/mitigacion-politicas-y-medidas/factoresemision_tcm30-479095.pdf.

Mitsch W.J., Bernal B., Nahlik A.M., Mander U., Zhang L., Anderson C.J., Jørgernsen S.E., Brix H., 2013. *Wetlands, Carbon, and ClimateCchange*. Landscape Ecology. 28(4): pp. 583-597.
www.doi.org/10.1007/s10980-012-9758-8

Monrós J. S., Neto J. M., Arcos F., Vera, P., Belda, E. J., 2018. *The Reed Bunting in Spain and Portugal. Breeding Population in 2015 and Census Method* [in Spanish]. Universitat de València-Universitat Politécnica de València-SEO/BirdLife, Madrid.

Morant D., Picazo A., Rochera C., Santamans A.C., Miralles-Lorenzo J., Camacho A., 2020a. *Influence of the Conservation Status on Carbon Balances of Semiarid Coastal Mediterranean Wetlands*. Inland Waters. 10(4): pp. 453-467.
www.doi.org/10.1080/20442041.2020.1772033

Morant D., Picazo A., Rochera C., Santamans A.C., Miralles-Lorenzo J., Camacho-Santamans A., Ibañez C., Martínez-Eixarch M., Camacho A., 2020b. *Carbon Metabolic Rates and GHG Emissions in Different Wetland Types of the Ebro Delta*. PLoS ONE. 15(4): e0231713. www.doi.org/10.1371/journal.pone.0231713
www.doi.org/10.1371/journal.pone.0231713

Palomino D., 2016. Yellow Wagtail Motacilla flava. In: *Enciclopedia Virtual de los Vertebrados Españoles* [in Spanish]. Salvador, A., Morales, M. B. (Eds.). Museo Nacional de Ciencias Naturales, Madrid
www.vertebradosibericos.org

Reeves P.N., Champion, P.D., 2004. *Effects of Livestock Grazing on Wetlands: Literature Review*. Client report HAM2004-059. National Institute of Water & Atmospheric Research Ltd. Hamilton, New Zealand..

Schmidt M. H., Lefebvre G., Poulin B., Tscharntke, T., 2005. *Reed Cutting Affects Arthropod Communities, Potentially Reducing Food for Passerine Birds*. Biological Conservation, 121: pp. 157-166.

Schäfer W., Väisänen J., Pihala M. 2002. *Technique of Green Mulch Spreading*. Agrifood Research, Finland, Agriculture Engineering Research (Vakola). Vakolan tutkimusselostus. Report no. 79: p. 165.

Tanner, C.C., 1992. A *Review of Cattle Grazing Effects on Lake Margin Vegetation with Observations from Dune Lakes in Northland, New Zealand*. New Zealand Natural Sciences 19: pp. 1-14.

Thesiger W., 1964. The Marsh Arabs. Penguin Books, Harmondsworth, Middlesex, England. EN: Kobbing J.F, Thevs N, Zerbe S, 2013. *The Utilisation of Reed* (Phragmites Australis): A Review. Mires and Peat. Vol 13 (2013/2014). Article 01, pp. 1-14.
www.mires-and-peat.net/, ISSN 1819-754X

Tolhurst S., 1997. *Investigation into the use of Domestic Herbivores fFor Fen Grazing Management.* Adocument for discussion. Broads Authority, English Nature and the Norfolk Wildlife Trust.

Vellinga Th.V., Blonk H., Marinussen M., van Zeist W.J., de Boer I.J.M., Starmans D., 2013. *Methodology used in Feedprint: A tool quantifying greenhouse gas emissions of feed production and utilization*. Wageningen UR Livestock Research. Report 674. ISSN 1570 - 8616.

Vera P., 2020. *Reed bunting* Emberiza schoeniclus [in Spanish]. In: Enciclopedia Virtual de los Vertebrados Españoles. López, P., Martín, J., Barba, E. (Eds.). Museo Nacional de Ciencias Naturales, Madrid.
www.vertebradosibericos.org

Voslamber B., Vulink J. T., 2010. *Experimental Manipulation of Water Table and Grazing Pressure as a Tool for Developing and Maintaining Habitat Diversity for Waterbirds*. Ardea, 98(3), 329-338..
www.doi.org/10.5253/078.098.0307.

"Wetlands

NATURAL ALLIES AGAINST CLIMATE CHANGE"

WITH A CONTRIBUTION FROM THE FUNDING INSTRUMENT OF THE EUROPEAN UNION

Follow us at #Wetlands4Climate

www.wetlands4climate.eu
info@wetlands4climate.eu

Partners

FUNDACIÓN GLOBAL NATURE

EFE: VERDE efeverde.com

Universitat de València ICBiBE Institut Universitari Cavanilles de Biodiversitat i Biologia Evolutiva

València Clima i Energia

With the support of

Gobierno de España. Vicepresidencia Tercera del Gobierno. Ministerio para la Transición Ecológica y el Reto Demográfico

Co-sponsors

AJUNTAMENT DE VALÈNCIA. CONSERVACIÓ D'ÀREES NATURALS I DEVESA-ALBUFERA

GENERALITAT VALENCIANA. Conselleria d'Agricultura, Desenvolupament Rural, Emergència Climàtica i Transició Ecològica

AJUNTAMENT DE TORREBLANCA