Nature-based solutions for climate change adaptation and water pollution in agricultural regions: services supporting the synthesis and dissemination of results

Internal report on D4.1 activities

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1 FAVOURABILITY MAPS and OPPORTUNITY MAPS

1.1 Introduction

This report explains the procedure proposed to develop the favourability and opportunity maps, including all the equations for main and side benefits, as well as cost functions.

All the equations are based on three types of variables:

— c_x	climate
— l_y	landscape
— d_z	design

The list of climate, landscape, and design variables defined for the development of favourability and opportunity maps are summarised in Annex 1.

1.2 SMCA alternatives: NBS type, categories, and sub-categories

A number of SMCA alternatives were defined based on the design variables selected by the multiple linear regressions analysis, and are here presented and discussed. The number of SMCA alternatives could vary during the preparation of the favourability and opportunity maps, if the application of the design, climate and landscape variables leads to an unreliable estimation of removal performance[1].

1.2.1 NBS A

On the basis of the relevant design variables considered in the performance model, NBS A types and categories are defined (**Table 1**) with the following assumptions:

- Favourability maps are built considering only secondary treatments, since information on existing WWTPs for manure is difficult to be gathered at EU scale; NBS tertiary treatments can be considered in the opportunity maps in case additional NBS area is required for more stringent effluent emission standards;
- NBS categories are created considering two main design variables: (i) the use or not of hybrid NBS with a combination of surface flow (SF) and subsurface flow (SSF) wetlands; (ii) greater biodiversity in plant selection of SSF wetlands;

Table 1. NBS A (manure) types, categories, and sub-categories.

NBS Type	NBS category	NBS sub-category	Type of treatment
NBS A1 – wetlands	NBS A1.1 – SF	NBS A1.1.1 – SF only emergent vegetation	Secondary

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[1] If the original dataset was vast enough, unreliable treatment performance would not be obtained, since it was assumed to cover all the possible combinations of the selected variables. However, the n° of samples used for the linear fitting were limited by the amount of sufficiently high quality data gathered from the literature. Therefore, it could happen that a specific set of design, climate, and landscape data was not present in the dataset, extrapolating performance outside those represented by the dataset, which could lead to have an unrealistic removal performance (<0% or >100%). During the process of preparing the favourability and opportunity maps, it is suggested to carry out a series of tests of the selected models with the expected range of the design, landscape, and climate variables at EU scale. If some NBS category or sub-category results unrealistic, the number or NBS categories or sub-categories will be reduced accordingly.

		NBS A1.1.2 – SF mixed vegetation	Secondary
	NBS A1.2 – hybrid SF + SSF	NBS A1.2.1 – SF only emergent vegetation	Secondary
		NBS A1.2.2 – SF mixed vegetation	Secondary

1.2.2 NBS B

On the basis of the relevant design variables considered in the performance model, NBS B types and categories are defined (**Table 2**) with the following assumptions:

- Vegetated drainage ditches (VDDs) and free water surface (FWSs) wetlands are separately considered, due to the different typical aspect ratio of the two NBS solutions;
- Since the use of vegetation other than emergent one has not shown a statistically difference in treatment performance, only emergent vegetation is set for both VDDs and FWSs;
- In order to reduce the number of favourability maps, no substrate is considered, neither for VDDs nor for FWSs; indeed, the use of substrate can be seen as a design variable able to increase the treatment performance (of the total phosphorous) occupying the same NBS area, but increasing the costs; the implication of using a dedicated substrate to enhance TP removal can be investigated in the opportunity maps;
- Since the use of off-line or on-line FWSs does not lead to a statistically significant difference in removal efficiency, no distinction is considered for FWSs in favourability maps;
- Integrated buffer strips (Zak et al. 2018; Zak et al. 2019) have not shown to have a superior performance in comparison to common BSs from statistical analysis, but they allow to implement BSs in common unfavourable conditions (such as the presence of tile drainage); therefore, the NBS categories of integrated buffer strips are here defined

Table 2. NBS B (diffuse pollution) types, categories, and sub-categories.

NBS Type	**NBS category**	**NBS sub-category**
NBS B1 – free water surface wetland (FWS)	no categories	no sub-category
NBS B2 – vegetated drainage ditch (VDD)	no categories	no sub-category
NBS B3 – buffer strip (BS)	NBS B3.1 – BS - R	NBS B3.1.1 – with herbaceous vegetation
		NBS B3.1.2 – without herbaceous vegetation
	NBS B3.2 – BS - G	no sub-category
	NBS B3.3 – BS - Integrated	NBS B3.3.1 – with herbaceous vegetation

		Same performance of BS-R
	NBS B3.3 – BS - Integrated	NBS B3.3.2 – without herbaceous vegetation Same performance of BS-R

1.2.3 NBS C

On the basis of the simplified approach proposed to estimate droughts performance, NBS types and categories are defined. For features see report D2, section 3.1.3.

Table 3. NBS C (droughts) types and categories and set of design parameters.

NBS Type	NBS category	NBS sub-category
NBS C1 – Storage	NBS C1.1 – Storage pond	NBS C1.1.1 – Storage pond (shallow)
		NBS C1.1.2 – Storage pond (deep)
	NBS C1.2 – Pre-treatment pond + Storage pond	NBS C1.2.1 – Pre-treatment pond + Storage pond (shallow)
		NBS C1.2.2 – Pre-treatment pond + Storage pond (deep)
	NBS C1.3 – Pre-treatment wetland + Storage pond	NBS C1.3.1 – Pre-treatment wetland + Storage pond (shallow)
		NBS C1.3.2 – Pre-treatment wetland + Storage pond (deep)
NBS C2 – MAR	NBS C2.1 – Infiltration pond	NBS C2.1 – Infiltration pond (high infiltration)
		NBS C2.2 – Infiltration pond (low infiltration)
	NBS C2.2 – Pre-treatment pond + Infiltration pond	
	NBS C2.3 – Pre-treatment wetland + Infiltration pond	
	NBS C2.4 – Infiltration wooded area	

1.3 SMCA screening: Suitability constraints

1.3.1 NBS A

Two levels of suitability constraints are defined for NBS A:

- Level 1 (mandatory): list of suitability constraints based on literature review and expert-based considerations
- Level 2 (optional): list of suitability constraints set to avoid extrapolation of NBS performance outside the range of landscape and climate conditions of the samples composing the original dataset[2]

Table 4. NBS A (manure) suitability constraints

NBS A category	**Level**	**Landscape**					**Climate**
		Slope	**Floods Directive (2007/60/EC)**	**Soil use**	**Water Table depth**	**Altitude**	**Average annual n of months with T < 6° C**
All NBS A1	1	≤15%	No P3 (Tr≤30 years)	CLC2018 – 131 (Mineral extraction sites) CLC2018 – 2 (Agricultural areas) 100 m from CLC 1 (excluded 131)(1)	≥ 1 m		
	2					≤ 1700 m asl (2)	≤9(3)

(1) Expert-based, due to the wide range reported in literature (3-300 m, Kadlec and Wallace, 2009)
(2) Maximum value of the dataset: 1619 m asl, but known successful experience (on domestic wastewater) up to 2000 m asl (e.g. Garelli shelter, IRIDRA expertise)
(3) Maximum value of the dataset (129 samples). This suitability criterion is set to account for the fact that limitation of TN removal in CWs at low temperatures is well-known (Kadlec and Wallace, 2009)

1.3.2 NBS B

Two levels of suitability constraints are defined for NBS B:

- Level 1 (mandatory): list of suitability constraints based on literature review and expert-based considerations
- Level 2 (optional): list of suitability constraints set to avoid extrapolation of NBS performance outside the range of landscape and climate conditions of the samples composing the original dataset[3]

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[2] Only the most relevant landscape and climate cardinal variables are included in Level 2, unless these variables are already included in the statistical models

[3] Only the most relevant landscape and climate cardinal variables are included in Level 2, unless these variables are already included in the statistical models

Table 5. NBS B (diffuse pollution) suitability constraints from literature and IRIDRA Srl expertise

NBS B category	**Level**	**Landscape**							**Climate**
		Slope	**Floods Directive (2007/60/EC)**	**Soil use**	**Water table depth**	**Phreatic aquifer depth**	**Type of agricultural drainage**	**Altitude**	**Average annual n of months with T < 6° C**
All NBS B	1			CLC2018 – 2 (Agricultural areas)					
NBS B1 FWS	1	≤5% (1)	No P3 (Tr≤30 years)	CLC2018 – 131 (Mineral extraction sites) 100 m from CLC 1 (excluded 131)(2)	≥ 1 m				
	2							≤2000 m asl(3)	
NBS B2 VDD	1		No P3 (Tr≤30 years)						
	2							≤2000 m asl(3)	
NBS B3.1 BS - R	1	≤10%(4)			> 2 m (5)		No tile drainage (6)		
	2							≤1000 m asl(3)	
NBS B3.2 BS - G	1				≤ 2 m(7)	≤ 6 m (8)	No tile drainage (6)		
	2	a) More restrictive: ≤5%(9)						≤1000 m asl(3)	≤8(11)

NBS B category	**Level**	**Landscape**							**Climate**
		Slope	**Floods Directive (2007/60/EC)**	**Soil use**	**Water table depth**	**Phreatic aquifer depth**	**Type of agricultural drainage**	**Altitude**	**Average annual n of months with T < 6° C**
		b) Less restrictive: ≤20%(10)							
NBS B3.3 BS - integrated	1								
	2								

(1) Kadlec and Wallace (2009)

(2) Expert-based, due to the wide range reported in literature (3-300 m, Kadlec and Wallace, 2009)

(3) In agreement with the maximum value of the dataset: 1911 (NBS B1 and B2, 95 samples), 976 (86 BS-R samples), and 996 (120 BS-G samples).

(4) From Zhang et al. (2010) and in agreement with the range of values from the dataset: 3rd quartile (75th percentile) 8.5% (85 BS-G samples); maximum value equal to 18%.

(5) According to Vidon et al. (2019), to avoid the risk that entrapped sediments and pollutants can be remobilised in case of surface flow that occurs when the soil is saturated (e.g. in the case of an extreme rain event).

(6) Vidon et al. (2019), Gold et al. (2001)

(7) From Dosskey and Qiu (2011), and Gumiero et al. (2015) and in agreement with the 3rd quartile (75th percentile) value from the dataset, equal to 2.5 m (120 BS-G samples)

(8) Hill (2019), Gold et al. (2001)

(9) 3rd quartile (75th percentile) value from the dataset (111 BS-G samples)

(10) Maximum value of the dataset (111 BS-G samples).

(11) Maximum value of the dataset (120 BS-G samples). This suitability criterion is set only for BS-G, since literature research highlighted that biological denitrification – of which the temperature dependence is well-known from literature – is the main nitrate removal process for BS-G (Hill 2019)

1.3.3 NBS C

The following suitability constraints are defined for NBS C.

Table 6. NBS C (droughts) suitability constraints from literature review and IRIDRA Srl expertise

NBS C category	Slope	Soil texture	Floods Directive (2007/60/EC)	Soil use	Water Table
All NBS C	≤5%(1)		No P3 (Tr≤30 years)	CLC2018 – 131 (Mineral extraction sites) CLC2018 – 2 (Agricultural areas) (2)	
NBS C1 Storage					≥ 1 m
NBS C2 Infiltration (MAR)		Coarse texture(3): - Sandy loam - Loamy sand - Silt - Sand			≥ h NBS + 3 m(3)

(1) Singhai et al., (2019); Rejani et al., (2017); Kadam et al., (2012); Kumar et al., (2017); Napoli et al., (2014)
(2) Singh et al. (2017); Kumar et al. (2017); Buraihi et al. (2015); Jha et al. (2014) Sallwey et al. (2018)
(3) According to Singh et al. (2017) and Jha et al. (2014)

1.4 SMCA criteria: Objectives

1.4.1 Definition

The next table collects all the objectives (*J*) for each benefit, according to NBS type/category, and whether the objective needs to be estimated for both favourability and opportunity maps. Objectives are calculated on the basis of performance equations (η), which are a function of pixel (*i*), NBS type/category (*p*), and key size variable (*a*). Opportunity maps are also built based on the demand (*D*) for the objective in the specified pixel *i*. The quantification equation and the method to estimate demands are presented in the next sections.

Objective (Criteria)	**Description**	**Type**	**NBS type/category**	**Fav. map**	**Opp. map**
$J_{M,TN}$	Total nitrogen removal	Main	A, B	$J_{M,TN,A}(i,p,a) = \eta_{TN,A}(i,p,a)$	$J_{M,TN,A}(i,p,a) = \eta_{TN,A}(i,p,a)\,\frac{D_{TN,A}(i)}{{D_{TN,A}}^{max}}$ $J_{M,TN,B}(i,p,a) = \eta_{TN,B}(i,p,a)\,\frac{D_{TN,B}(i)}{{D_{TN,B}}^{max}}$
$J_{M,TP}$	total phosphorous removal	Main	A, B	$J_{M,TP,A}(i,p,a) = \eta_{TN,A}(i,p,a)$	$J_{M,TP,A}(i,p,a) = \eta_{TN,A}(i,p,a)\,\frac{D_{TP,A}(i)}{{D_{TP,A}}^{max}}$ $J_{M,TP,B}(i,p,a) = \eta_{TN,B}(i,p,a)\,\frac{D_{TP,B}(i)}{{D_{TP,B}}^{max}}$
$J_{M,drough,1}$	monthly drought response	Main	C1	$J_{M,drough,1}(i,p,a) = V_{drought\ 1,C}\ (i,p,a)$	$J_{M,drough,1}(i,p,a) = \frac{V_{drought\ 1,C}\ (i,p,a)}{D_{drought,1}(i)} \Big/ \max_{i,p}\left[\frac{V_{drought\ 1,C}\ (i,p,a)}{D_{drought,1}(i)}\right]$
$J_{M,drough,2}$	annual drought response	Main	C2	$J_{M,drough,2}(i,p,a) = V_{drought\ 2,C}\ (i,p,a)$	$J_{M,drough,2}(i,p,a) = \frac{V_{drought\ 2,C}\ (i,p,a)}{D_{drought,2}(i)} \Big/ \max_{i,p}\left[\frac{V_{drought\ 2,C}\ (i,p,a)}{D_{drought,2}(i)}\right]$
$J_{S,BOD}$	carbon pollutant removal	Side	A		$J_{M,BOD,A}(i,p,a) = \eta_{BOD,A}(i,p,a)\,\frac{D_{BOD,A}(i)}{{D_{BOD,A}}^{max}}$
$J_{S,TSS}$	solid/sediment removal	Side	A, B, C		$J_{M,TSS,A}(i,p,a) = \eta_{TSS,A}(i,p,a)\,\frac{D_{TSS,A}(i)}{{D_{TSS,A}}^{max}}$ $J_{M,TSS,B}(i,p,a) = \eta_{TSS,B}(i,p,a)\,\frac{D_{TSS,B}(i)}{{D_{TSS,B}}^{max}}$ $J_{M,TSS,C}(i,p,a) = \eta_{TSS,C}(i,p,a)\,\frac{D_{TSS,B}(i)}{{D_{TSS,B}}^{max}}$
$J_{S,pes}$	pesticide removal	Side	B, C		$J_{M,pes,B}(i,p,a) = \eta_{pes,B}(i,p)\,\frac{D_{pes,B}(i)}{{D_{pes,B}}^{max}}$

Objective (Criteria)	**Description**	**Type**	**NBS type/category**	**Fav. map**	**Opp. map**
					$J_{M,pes,C}(i,p,a) = \eta_{pes,C}(i,p,a)\,\frac{D_{pes,B}(i)}{{D_{pes,B}}^{max}}$
$J_{S,TN}$	total nitrogen removal	Side	C		$J_{S,TN,C}(i,p,a) = \eta_{TN,C}(i,p,a)\,\frac{D_{TN,B}(i)}{{D_{TN,B}}^{max}}$
$J_{S,TP}$	total phosphorous removal	Side	C		$J_{S,TP,C}(i,p,a) = \eta_{TP,C}(i,p,a)\,\frac{D_{TP,B}(i)}{{D_{TP,B}}^{max}}$
$J_{S,flood}$	flood mitigation of low intensity rain event	Side	A, B, C		$J_{S,flood}(i,p,a) = \frac{V_{flood}(i)}{D_{flood}(i)}\Big/\max_{i,p}\left[\frac{V_{flood}(i)}{D_{flood}(i)}\right]$
$J_{S,biod}$	biodiversity support	Side	A, B, C		$J_{S,bio}(i,p,a) = v_{wet}(i,a)\,D_{wet}(i) + v_{wood}(i,a)\,D_{wood}(i) + v_{reed}(i,a)\,D_{reed}(i) + v_{pond}(i,a)\,D_{pond}(i)$
$J_{S,CO2}$*	carbon sequestration	Side	A, B, C		$J_{S,CO2}(i,p,a) = \frac{S_{biom,CO2}}{{D_{S,CO2}}^{max}}$
$J_{S,energy}$*	energetic value of the NBS biomass	Side	A, B, C		$J_{S,energy}(i,p,a) = \lambda_{\text{energy}}\,\frac{E_{bio}}{D_{energy}(i)} - \lambda_{\text{biom,tech}} v_{biom,tech}$ with $\lambda_{\text{energy}} = 0.5$ and $\lambda_{\text{biom,tech}} = 0.5$**
$J_{S,nuis}$	nuisance	Side	A, B, C		$J_{S,nui}(i,p) = -v_{wet}(i,p)\,D_{nui}(i)$
$J_{S,social}$	Landscape, amenity, microclimate enhancement, attractiveness	Side	A, B, C		$J_{S,social}(i,p) = v_{social}(i,p)\,\frac{D_{social}(i)}{{D_{social}}^{max}}$
$J_{C,CAPEX}$	CAPEX: Investment cost estimation	Cost	A, B, C		$J_{C,CAPEX(\mathrm{i,p,a})} = -\frac{C_{CAPEX}(i,p,a)}{{D_{CAPEX}}^{max}}$

Objective (Criteria)	**Description**	**Type**	**NBS type/category**	**Fav. map**	**Opp. map**
$J_{C,OPEX}$	OPEX: Operational and Maintenance cost estimation	Cost	A, B, C		$J_{C,OPEX}(i,p,a) = -\frac{C_{OPEX}(i,p,a)}{{D_{OPEX}}^{max}}$

* $J_{S,CO2}$ and $J_{S,energy}$ are mutually exclusive

** Weights for energy value (λ_{energy}) and technical issues related to ash content ($\lambda_{\text{biom,tech}}$) are assumed equally distributed

1.4.2 Main benefit performance

1.4.2.1 Nutrients (total nitrogen and total phosphorous) removal for NBS A

1.4.2.1.1 Quantification

Total nitrogen removal efficiency for NBS A ($\eta_{TN,A}$) is estimated using the selected linear regression model

NBS A	$\eta_{TN,A} = 0.00154\,\frac{c_p}{10} - 0.28044\,l_{ww,mix,rnf} - 0.33049\,l_{poultry} - 0.00019\,d_{HLR} - 0.29820\,d_{pt,tertiary} + 0.24817\,d_{hybrid\ cw} - 0.25072\,d_{v,emer} + 0.75637$
NBS A1.1.1*	$\eta_{TN,A} = 0.00154\,\frac{c_p}{10} - 0.28044\,l_{ww,mix,rnf} - 0.33049\,l_{poultry} + 0.50564$
NBS A1.1.2.*	$\eta_{TN,A} = 0.00154\,\frac{c_p}{10} - 0.28044\,l_{ww,mix,rnf} - 0.33049\,l_{poultry} + 0.75636$
NBS A1.2.1.*	$\eta_{TN,A} = 0.00154\,\frac{c_p}{10} - 0.28044\,l_{ww,mix,rnf} - 0.33049\,l_{poultry} + 0.75381$
NBS A1.2.2.*	$\eta_{TN,A} = 0.00154\,\frac{c_p}{10} - 0.28044\,l_{ww,mix,rnf} - 0.33049\,l_{poultry} + 1.00453^{**}$

* Simplified equations based on the set of selected design variables collected in Annex 2.

** Unreliable estimation of expected removal performance with the selected set of design values for this NBS sub-category, if the manure neither not mixed with rainwater ($l_{ww,mix,rnf} = 0$) nor derived from poultry livestock ($l_{poultry} = 0$)

Where

- c_p average annual precipitation (cardinal, in mm year^{-1})
- $l_{ww,mix,rnf}$ manure mixed with surface runoff (binary, 0 no, 1 yes)
- $l_{poultry}$ poultry manure (binary, 0 no, 1 yes)
- d_{HLR} hydraulic loading rate (cardinal, in m^3 year^{-1} ha^{-1})
- $d_{pt,tertiary}$ NBS for tertiary treatment[4] (binary, 0 no, 1 yes)
- $d_{hybrid\ SSF+SF\ cw}$ hybrid constructed wetland mixing surface and subsurface flow systems[5] (binary, 0 no, 1 yes)

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[4] The linear regression highlighted a significant difference with the variable $d_{pt,nbs,nbs}$, i.e. when the NBS is a tertiary treatment after a primary and a secondary treatment with both NBS. On the other hand, the other variables related to primary and secondary treatment, i.e. $d_{pt,grey,grey}$ (both primary and secondary with grey infrastructure) and $d_{pt,NBS,grey}$(primary with NBS and secondary with grey infrastructure), did not emerge as relevant from the statistical analysis. This discrepancy was not expected and can be attributed to the low number of samples for these variables. Since the significance of $d_{pt,nbs,nbs}$ was positively judged by experts in general terms of tertiary treatments (less concentrated wastewater to be treated is expected to lead to lower removal performance), $d_{pt,nbs,nbs}$ is here used as a *proxy* to represent NBS for tertiary treatment, regardless of whether the primary and secondary stage type is NBS or grey infrastructure.

[5] The linear regression highlighted a significant difference with the variable $d_{fmpm,s}$, i.e. when the NBS treatment chain includes a stage with a porous medium instead of a simple free water surface (FWS) wetland, for instance a subsurface flow system. This was expected, since porous media, and in general subsurface flow wetland systems, are expected to have higher efficiencies in comparison to FWSs. This aspect did not emerge from similar variables, such as all the design variables including the wetland type (HF – horizontal flow, $d_{t,HF}$;

— $d_{v,emer}$ only emergent vegetation (binary, 0 no, 1 yes)

Total phosphorous removal efficiency ($\eta_{TP,A}$) is estimated using the selected linear regression model

NBS A	$\eta_{TP,A} = 0.00008\, d_{HLR} - 0.39422\, d_{pt,tertiary} + 0.36330\, d_A - 0.52466\, d_{v,emer} - 0.07098\, d_{PLR} + 1.16845$
NBS A1.1.1*	$\eta_{TP,A} = 0.58058$
NBS A1.1.2*	$\eta_{TP,A} = 1.10524^{**}$
NBS A1.2.1*	$\eta_{TP,A} = 0.58058$
NBS A1.2.2*	$\eta_{TP,A} = 1.10524^{**}$

* Simplified equations based on the set of selected design variables collected in Annex 2.

** Unreliable estimation of removal performance expected with the selected set of design values.

Where

— d_A NBS area (cardinal, in ha)

— d_{PLR} total phosphorous loading rate (cardinal, in tonTP_P year^{-1} ha^{-1})

1.4.2.1.2 Demand

The demands $D_{TN,A}(i)$ and $D_{TP,A}(i)$ are defined equal to the amounts of pollutants TN and TP generated in pixel i due to manure (in t_{TN}/y and t_{TP}/y).

1.4.2.2 Nutrients (total nitrogen and total phosphorous) removal for NBS B

1.4.2.2.1 Quantification for wetlands (NBS B1) and vegetated drainage ditches (NBS B2)

Due to the poorer fitting of TN removal for NBS B group and the fact that the main target of agricultural diffuse pollution is nitrate removal, the **total nitrogen removal efficiency of vegetated drainage ditches (VDDs, NBS B2) and free water surface wetlands (FWSs, NBS B1)** ($\eta_{TN,B1\,B2}$) is estimated using the selected linear regression model for nitrate removal[6] ($\eta_{NO3,B1\,B2}$) as *"proxy"*

VF – vertical flow, $d_{t,VF}$; hybrid $d_{t,hybr}$), probably due to the low number of full scale experiences which combine FWS + subsurface flow systems. However, in accordance with the expert expectation, $d_{fmpm,s}$ is used here as a *proxy* to represent the enhanced performance of a hybrid wetland that mixes subsurface and surface flow solutions.

[6] The nitrate model used here does not consider the design variable "NBS type vegetated drainage ditch (VDD)". This because the increase in nitrate removal performance of a VDD, in comparison to a free water surface (FWS) wetland, is not justified by the majority of literature, which shows comparable removal efficiencies (e.g. Vymazal et al., 2018). Analysing in detail the dataset used for the model fitting, it's clear that the difference between VDDs and FWSs is affected by a lower number of samples of VDDs and is driven by the single case of Robertson and Merkley (2009), in which, probably, the use of a particular substrate (woodchip – carbon source for denitrification) has boosted the nitrate removal. Since the use of a particular substrate is not the common design approach of a VDD, there is no reason to consider, in terms of favourability map, a greater performance of VDDs in comparison to FWSs.

NBS B1 B2	$\eta_{TN,B1\,B2} = \eta_{NO3,B1\,B2} = -0.04549\, c_{n_{cold}} - 0.09511\, c_{StdDev} - 0.53846\, c_{GAI} - 0.00924\, d_{NO3-N\,LR} + 1.27037$
NBS B1*	$\eta_{TN,B1\,B2} = \eta_{NO3,B1\,B2} = -0.04549\, c_{n_{cold}} - 0.09511\, c_{StdDev} - 0.53846\, c_{GAI} + 1.25485$
NBS B2*	$\eta_{TN,B1\,B2} = \eta_{NO3,B1\,B2} = -0.04549\, c_{n_{cold}} - 0.09511\, c_{StdDev} - 0.53846\, c_{GAI} + 1.25485$

* Simplified equations based on the set of selected design variables collected in Annex 2.

Where

— c_{n_cold} average annual months with mean monthly temperature ≤6°C (cardinal - dimensionless)

— c_{StdDev} temporal uniformity of the precipitation pattern (cardinal - dimensionless), i.e. a *"proxy"* for the standard deviation of the precipitation pattern[7]

— c_{GAI} Global Aridity Index[8] (cardinal - dimensionless)

— $d_{N-NO3\,LR}$ nitrate loading rate (tonNO_3^-_N year^{-1} ha^{-1})

Total phosphorous removal efficiency of VDDs and FWSs ($\eta_{B,TP}$) is estimated using the selected linear regression model

NBS B1 B2	$\eta_{TP,B1\,B2} = -0.00029\, c_{ETo} + 0.00186\, d_{ratio} + 0.72074\, d_{v,emer} + 0.47749\, d_{substr} - 0.08845$
NBS B1*	$\eta_{TP,B1\,B2} = -0.00029\, c_{ETo} + 0.64159$
NBS B2*	$\eta_{TP,B1\,B2} = -0.00029\, c_{ETo} + 0.77179$

* Simplified equations based on the set of selected design variables collected in Annex 2.

Where

— c_{ET0} annual reference evapotranspiration (potential of the reference crop) (cardinal, in mm)

— d_{ratio} NBS aspect ratio (cardinal, length/width)

— $d_{v,emer}$ only emergent vegetation (binary, 0 no, 1 yes)

— d_{substr} use of substrates additional to soil to enhance the performance (e.g. gravel, sand, zeolites, woodchip – binary, 0 no, 1 yes)

1.4.2.2.2 Quantification for buffer strips (NBS B3)

Nutrient removal (both N, main objective $J_{M,B,TN}$, and P, main objective $J_{M,B,TP}$) differs between buffer strips (BSs), depending on whether the target is to intercept nutrients conveyed into sediments within the runoff (also referred to as surface or overland flow,

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[7] The temporal uniformity of the precipitation pattern is calculated as $c_{StdDev} = \frac{\max[T_{mean,m}]-\min[T_{mean,m}]}{\mathrm{mean}[T_{mean,m}]}$, where $T_{mean,m}$ is the mean monthly temperature.

[8] According to Trabucco and Zomer (2018), the Global Aridity Index is defined as $c_{GAI} = P_{mean,y} / ET0_y$, where $ET0_{mean,y}$ is the annual reference evapotranspiration (potential of the reference crop) (in mm), and $P_{mean,y}$ is the annual mean precipitation (in mm)

BS-R) or those present in groundwater (also referred to as subsurface flow, BS-G). According to Vidon et al. (2019) and as pictured by the suitability constraints (section 1.3.2), the favourable areas for BS-Gs and BS-Rs differ, mainly as a function of water table depth[9]. Therefore, BS-Gs and BS-Rs are considered as two separated and different NBS.

In terms of Nitrogen removal, the statistical analysis does not provide a reliable fitting model, neither for BS-Gs nor for BS-Rs[10]. Therefore, treatment performance for nitrogen removal of BS-Gs and BS-Rs are assumed constant and equal to the 50th percentile of the frequency density function of removal efficiencies from obtained from the dataset. Due to the low performance[11] in terms of P removal of BS-Gs, the effect on phosphorous pollution control of BS-Gs is neglected, in accordance with Vidon et al. (2019). TP removal for BS-Rs ($\eta_{TP,B3.1}$) is estimated using the selected linear regression model

NBS B3	$\eta_{TP,B3.1} = +0.04093\, c_T - 0.00161\, c_p + 1.15638\, c_{GAI} + 0.16350\, l_{CLAY} + 0.02620\, d_w + 0.77568\, d_{v,herb} - 0.18858$
NBS B3.1.1*	$\eta_{TP,B3.1} = +0.04093\, c_T - 0.00161\, c_p + 1.15638\, c_{GAI} + 0.16350\, l_{CLAY} + 0.82290$
NBS B3.1.2*	$\eta_{TP,B3.1} = +0.04093\, c_T - 0.00161\, c_p + 1.15638\, c_{GAI} + 0.16350\, l_{CLAY} + 0.04722$

* Simplified equations based on the set of selected design variables collected in Annex 2.

Where

— c_T	average annual temperature (cardinal, in mm)
— c_p	average annual precipitation (cardinal, in mm year^{-1})
— c_{GAI}	Global Aridity Index (cardinal - dimensionless)
— $l_{CLAY\ pres}$	soil texture with clay[12] (binary, 0 no, 1 yes)
— d_w	BS width (cardinal, in m)
— $d_{v,herb}$	BS with presence of herbaceous vegetation[13] (binary, 0 no, 1 yes)

To sum up, the following performance is set for BS-Gs and BS-Rs, according to the previous hypotheses

Table 7. Summary of nutrient removal performance assumptions for BSs

NBS B3.1	**NBS B3.2**

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[9] Although the trapping efficiency of surface runoff remains a benefit also of BS-Gs, for sake of simplicity the indication of Vidon et al. (2019) is followed, who suggests locating BS-Rs in areas with a low water table in order to avoid the risk of remobilisation of entrapped sediments and pollutants in case of surface flow that occurs when the soil is saturated (e.g. in the case of an extreme rain event).

[10] As discussed in the analysis of the statistical results, this is mainly due to the fact that the majority of the samples of the dataset regards the monitoring of BSs already placed in optimal functioning conditions in terms of landscape variables, as also pointed out by, for instance, Gold et al. (2001) and confirmed by the analysis of the range of landscape variables for the dataset (e.g. slope, water table depth, etc.).

[11] Median (50th percentile) removal efficiency of BS-Gs from the dataset: 15% for PO4^{3}—P (23 samples); 14% for dissolved P (4 samples); 14% for TP (16 samples).

[12] Binary *proxy* to identify the presence of clay, based on the USDA classification. The proxy value is assumed equal to 1 if clay falls within the soil texture classification (i.e. CLAY, SANDY CLAY, SANDY CLAY LOAM, CLAY LOAM, SILTY CLAY, SILTY CLAY LOAM) and equal to 0 if not (i.e. SAND, LOAMY SAND, SANDY LOAM, LOAM, SILT LOAM, SILT)

[13] This design variable means that BSs implement also, but not only, herbaceous vegetation. Therefore, the design value is ranked 1 also in the case of a mix of herbaceous vegetation with other types of vegetation (i.e. Trees or Shrubs)

BS-R **Inside suitability constraint**	**BS-G** **Inside suitability constraint**
$\eta_{TN,B3.1}$ = 70% as TN**	$\eta_{NO3,B3.2}$ = 60% as NO_3^-_N*
$\eta_{TP,B3.1}$ from statistical fitting model f (climate, landscape, design)	$\eta_{TP,B3.2} = 0\%$***

* Median (50th percentile) value from the dataset (111 BS-G samples)
** Median (50th percentile) value from the dataset (52 BS-R samples)
*** Negligible contribution

1.4.2.2.3 Demand

The demands $D_{TN,B}(i)$ and $D_{TN,B}(i)$ are defined equal to the amounts of pollutants TN and TP generated in pixel i due to diffuse pollution (in t_{TN}/y and t_{TP}/y).

1.4.2.3 Drought

1.4.2.3.1 Quantification

The following main objectives are defined for the drought objective:

- $J_{M,drougth,1}$ drought response during dry periods, with the volume available for emergency irrigation during drought periods ($V_{drought\ 1,C}$ cardinal, m^3/month) as an indicator
- $J_{M,drought,2}$ annual drought response to dry periods, with the annual infiltrated volume of intercepted runoff ($V_{drought\ 2,C}$ cardinal, m^3 $year^{-1}$) as an indicator

The volume available for emergency irrigation during drought periods[14] ($V_{drought\ 1,C}$, in m^3) is estimated using the simplified water budget

$$V_{drought\ 1,C} = \left(d_{V,drought} - \max\left[d_{ET,NBS,m}\right]\right) d_{n,NBS\ drought}$$

$$d_{n,NBS\ drought} = \frac{d_{NBS\ area\ ratio,drought}\ l_{A\_pixel\_suit}}{d_A\ d_{NBS,gross}}$$

Where

- $d_{NBS\ area\ ratio}$ NBS area to watershed ratio (cardinal, dimensionless)
- $d_{NBS,gross}$ NBS gross/net area coefficient (cardinal, dimensionless)
- $d_{n,NBS\ drought}$ n° of NBS for drought response in the pixel (cardinal, dimensionless)
- $l_{A\_pixel\_suit}$ suitable area for the NBS within the pixel (cardinal, in m^2), after the suitability constraints criteria
- d_A is the area of the NBS (cardinal, in m^2)
- $d_{V,drought}$ is the volume of the NBS for drought, calculated as

$$d_{A,bottom} = d_{\phi}\left(\sqrt{d_A} - 2\,\frac{d_{h,drought} - d_{h,sed}}{\tan d_{\alpha}}\right)^2$$

---

[14] Infiltration losses of storage ponds are neglected, since storage ponds are assumed to be waterproofed with plastic liners or clay in clay soil textures (negligible monthly volume losses).

$$d_{V,drought} = \frac{\left(d_A + d_{A,bottom} + \sqrt{d_A \cdot d_{A,bottom}}\right) \cdot \left(d_{h,drought} - d_{h,sed}\right)}{3}$$

  - With
    - d_ϕ NBS apparent porosity (cardinal, dimensionless),
    - $d_{h,drought}$ NBS height dedicated to drought response (cardinal, in m)
    - $d_{h,sed}$ NBS height of accumulated sediment (cardinal, in m)
    - d_α NBS side slope (cardinal, in °)
- $d_{ET,NBS,m}$ is the monthly NBS evapotranspiration (cardinal, in m^3 month^{-1}), calculated as

$$d_{ET,NBS,m} = d_A \, d_{k\_p} \, c_{ETo}$$

  - With d_{k_p} as the NBS evapotranspiration loss coefficient (cardinal, dimensionless)

Annual infiltrated volume of intercepted runoff ($V_{drought\ 2,C}$, in m^3) is estimated using the simplified water budget

$$d_{R,y} \geq d_{I,NBS\ MAR,y} \qquad V_{drought\ 2,C} = d_{I,NBS\ MAR,y}$$

$$d_{R,y} < d_{I,NBS\ MAR,y} \qquad V_{drought\ 2,C} = d_{R,y}$$

Where

- $d_{R,y}$ is the runoff volume entering the NBS (cardinal, m^3 year^{-1}), and assuming agriculture as the main land use in the drained catchment, it is calculated as

$d_{R,y} = 0.1\, c_p\, l_{A,NO\ NBS}$	$c_p < 500$ mm year^{-1}
$d_{R,y} = 0.2\, c_p\, l_{A,NO\ NBS}$	500 mm year^{-1} $\leq c_p < 1000$ mm year^{-1}
$d_{R,y} = 0.3\, c_p\, l_{A,NO\ NBS}$	$c_p \geq 1000$ mm year^{-1}

  - With
    - c_p average annual precipitation (cardinal, in mm year^{-1})
    - $l_{A,NO\ NBS}$ area without NBS (cardinal, in m^2)
- $d_{I,NBS\ MAR,y}$ is the annual infiltration capacity of the infiltration NBS (cardinal, m^3/year), design variable

$$d_{I,NBS\ MAR,y} = \frac{d_A\, d_{HLR}}{d_{F\_c}}$$

  - With
    - d_{HLR} hydraulic loading rate (cardinal, in m year^{-1})
    - d_{F_c} clogging factor (cardinal, dimensionless)
    - $d_A = \frac{d_{NBS\ area\ ratio,drought}\, l_{A\_pixel\_suit}}{d_{NBS,gross}}$ NBS area dedicated to MAR

1.4.2.3.2 Demand

Demands in response to drought events are related to crop production **security**.

Food security is assumed to be supported with NBS considering two possibilities (i.e. NBS types):

- accumulating rainwater on the surface for emergency irrigation during prolonged dry periods, i.e. farm ponds (NBS C1), which can cover a water demand on a monthly basis ($D_{drought,1}(i)$)
- accumulating rainwater in the subsurface to balance the annual emergency irrigation, i.e. managed aquifer recharge (NBS C2), which aims to infiltrate a significant amount of rainwater corresponding to the annual water demand ($D_{drought,2}(i)$)

Therefore, demands are defined as follows

- $D_{drought,1}(i)$ average agricultural water demand during the most critical month on pixel i (m^3 month^{-1}), i.e. the month with the highest unbalance between precipitation and evapotranspiration
- $D_{drought,2}(i)$ average annual agricultural water demand on pixel i (m^3 year^{-1}),

1.4.3 Side benefit performance

Evaluation of side-benefits is included only in creating opportunity maps. Therefore, the formulations for side-benefit estimation are reported here.

1.4.3.1 Additional water quality for NBS A

1.4.3.1.1 Quantification

BOD$_5$ removal efficiency ($\eta_{BOD,A}$) is estimated using the selected linear regression model

NBS A	$\eta_{BOD,A} = -0.04177c_T + 0.16764l_{ww,mix,rnf} - 0.00027d_{HLR} + 1.16629$
NBS A1.1.1*	$\eta_{BOD,A} = -0.04177c_T + 0.16764l_{ww,mix,rnf} + 1.16628$
NBS A1.1.2*	$\eta_{BOD,A} = -0.04177c_T + 0.16764l_{ww,mix,rnf} + 1.16628$
NBS A1.2.1*	$\eta_{BOD,A} = -0.04177c_T + 0.16764l_{ww,mix,rnf} + 1.16628$
NBS A1.2.2*	$\eta_{BOD,A} = -0.04177c_T + 0.16764l_{ww,mix,rnf} + 1.16628$

* Simplified equations based on the set of selected design variables collected in Annex 2.

Where

c_T	average annual temperature (cardinal, in °C)
$l_{ww,mix,rnf}$	manure mixed with surface runoff (binary, 0 no, 1 yes)
d_{HLR}	hydraulic loading rate (cardinal, in m^3 year^{-1} ha^{-1})

TSS removal efficiency ($\eta_{TSS,A}$) is estimated using the selected linear regression model

NBS A	$\eta_{TSS,A} = 0.39646 d_{prim,grey} + 0.36227 d_{hybrid\ cw} - 0.07168 l_{ww,mix,rnf} - 0.00038 d_{SLR} + 0.54407$
NBS A1.1.1*	$\eta_{TSS,A} = -0.07168\ l_{ww,mix,rnf} + 0.53761$
NBS A1.1.2*	$\eta_{TSS,A} = -0.07168\ l_{ww,mix,rnf} + 0.53761$
NBS A1.2.1*	$\eta_{TSS,A} = -0.07168\ l_{ww,mix,rnf} + 0.89988*$
NBS A1.2.2*	$\eta_{TSS,A} = -0.07168\ l_{ww,mix,rnf} + 0.89988*$

* Simplified equations based on the set of selected design variables collected in Annex 2.

Where

— $l_{ww,mix,rnf}$	manure mixed with surface runoff (binary, 0 no, 1 yes)
— $d_{hybrid\ SSF+SF\ cw}$	hybrid constructed wetland mixing surface and subsurface flow systems[15] (binary, 0 no, 1 yes)
— $d_{prim,grey}$	primary treatment with grey infrastructure
— d_{SLR}	solid loading rate (cardinal, in tonTSS year^{-1} ha^{-1})

1.4.3.1.2 Demand

The demands $D_{BOD,A}(i)$ and $D_{TSS,A}(i)$ are defined equal to the amounts of pollutants BOD$_5$ and TSS generated in pixel i due to manure (in t$_{BOD}$/y and t$_{TSS}$/y).

1.4.3.2 Additional water quality NBS B

1.4.3.2.1 Quantification

Pesticide removal efficiencies (η_{pes}) **for NBS** are estimated as a function of the pesticide organic carbon sorption coefficient (l_{KOC}) and of the NBS sub-category p, as defined in **Table 8**

Table 8. Summary of pesticide removal performance for buffer strips, $\eta_{B,pes,buffer}(p, K_{OC})$, assumed for NBS B3. Median values from literature review

l_{KOC} (ml g^{-1})	NBS B1 Wetlands	NBS B2 Vegetated ditches	NBS B3.1 BS - Rs	NBS B3.2 BS - Gs

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[15] The linear regression highlighted a significant difference with the variable $d_{fmpm,s}$, i.e. when the NBS treatment chain includes a stage with a porous medium instead of a simple free water surface (FWS) wetland, for instance a subsurface flow system. This was expected, since porous media, and in general subsurface flow wetland systems, are expected to have higher efficiencies in comparison to FWSs. This aspect did not emerge from similar variables, such as all the design variables including the wetland type (HF – horizontal flow, $d_{t,HF}$; VF – vertical flow, $d_{t,VF}$; hybrid $d_{t,hybr}$), probably due to the low number of full scale experiences which combine FWS + subsurface flow systems. However, in accordance with the expert expectation, $d_{fmpm,s}$ is used here as a *proxy* to represent the enhanced performance of a hybrid wetland which mixes subsurface and surface flow solutions.

			Runoff removal	**Groundwater removal**
l_{KOC} < 100	$\eta_{pes,B1} = 42\%$	$\eta_{pes,B2} = 42\%*$	$\eta_{pes,B3.1} = 70\%$	$\eta_{pes,B3.2} = 45\%$
100 < l_{KOC} < 1000	$\eta_{pes,B1} = 61\%$	$\eta_{pes,B2} = 81\%$	$\eta_{pes,B3.1} = 81\%$	$\eta_{pes,B3.2} = 43\%*$
l_{KOC} > 1000	$\eta_{pes,B1} = 84\%$	$\eta_{pes,B2} = 84\%$	$\eta_{pes,B3.1} = 83\%$	$\eta_{pes,B3.2} = 41\%$

* Interpolation between l_{KOC} < 100 and l_{KOC} > 1000

The organic carbon sorption coefficient (K_{OC}) is intended here as a landscape variable, l_{KOC}, since it can change according to different pesticide uses across Europe. It is suggested to select, as a "proxy" for pesticide removal, the most used pesticide across the region, i.e. only one target pesticide and one l_{KOC} per pixel i. **Table 9** reports a list of the pesticides used in Europe, to orientate the selection of l_{KOC}.

Table 9. List of the most common pesticides used in Europe and their organic carbon sorption coefficients

Compound	**Pesticide subtype**	**Substance group**	l_{KOC} **(ml g^{-1})**
Chlorpyrifos	Insecticide	Organophosphate	9930
Azinphos-methyl	Insecticide	Organophosphate	882
Atrazine	Herbicide	Triazine	93
Metolachlor	Herbicide	Chloroacetamide	120
Fenpropimorph	Fungicide	Morpholine	2401
Metalaxyl	Fungicide	Phenylamide	163

Total Suspended Solids (TSS) removal efficiency ($\eta_{TSS,B3}$), is assumed constant, equal to the 50th percentile of the dataset, and function only of the NBS sub-category p according to the values reported in **Table 10**.

Table 10. Summary of TSS removal performance assumptions for NBS B

NBS B1 and B2 **Wetlands and VDDs**	**NBS B3.1** **BS-Rs** **Runoff removal**	**NBS B3.2** **BS - Gs** **Groundwater removal**
$\eta_{TSS,B1\,B2} = 71\%*$	$\eta_{TSS,B3.1} = 89\%**$	$\eta_{TSS,B3.2} = 0\%$

* Median (50th percentile) value from the dataset (14 samples)
** Median (50th percentile) value from the dataset (28 samples)

1.4.3.2.2 Demand

The demands $D_{pes,B}(i)$ and $D_{TSS,B}(i)$ are defined equal to the amounts of pesticide and TSS pollutant generated in pixel i due to diffuse pollution (in t_{pes}/y and t_{TSS}/y).

1.4.3.3 Additional water quality NBS C

1.4.3.3.1 Quantification

The following side benefits, J_S, are defined to build the opportunity maps for the NBS C issue:

— $\eta_{TSS,C}$	TSS removal as efficiency (from 0 – 0% – to 1 – 100%)
— $\eta_{TN,C}$	total nitrogen removal as efficiency (from 0 – 0% – to 1 – 100%)
— $\eta_{TP,C}$	total phosphorous removal as efficiency (from 0 – 0% – to 1 – 100%)
— $\eta_{pes,C}$	pesticide removal as efficiency (from 0 – 0% – to 1 – 100%)

Total Suspended Solids removal efficiency ($\eta_{TSS,C}$) is assumed constant for all the NBS C sub-categories p and equal to

$$\eta_{A,TSS} = 59\%^{16}$$

Removal efficiencies of total nitrogen, total phosphorous, and pesticides ($\eta_{TN,C}$, $\eta_{TP,C}$, $\eta_{pes,C}$) are considered only for NBS C sub-categories including a wetland as pre-treatment, i.e. NBS C1.3 and NBS C2.3. The estimation follows the same methodologies described for NBS B, section 1.3.1, considering only the area of the pre-treatment wetlands as effective for TN, TP, and pesticide removal. The area of the pre-treatment wetland is calculated as follows

$$d_{A,pre} = \frac{d_{NBS\ area\ ratio,pre}\ l_{A\_pixel\_suit}}{d_{NBS,gross}}$$

1.4.3.3.2 Demand

The demands are the same as for diffuse pollution.

1.4.3.4 Flood for low intensity rain events

1.4.3.4.1 Quantification

The flood performance of NBS is estimated calculating the retaining volume V_{flood}

$$V_{flood} = d_A\ d_{h,f}$$

Where:

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[16] Equal to the sediment trapping efficiency of a farm pond from literature analysis. Median (50th percentile) value from the dataset (21 samples)

— d_A is the area of NBS (cardinal, in m^2)

— $d_{h,f}$ is the height for additional volume for flood mitigation (cardinal, in m)

1.4.3.4.2 Demand

The demand for flood mitigation, $D_{flood}(i)$, is the runoff volume at pixel level, calculated as follows

$$D_{flood}(i) = d_{R,Tr\,1}$$

Where:

— $d_{R,Tr\,1}$ is the runoff volume entering the NBS (cardinal, m^3 event^{-1}), and assuming agriculture as the main land use in the drained catchment, it is calculated as

$d_{R,y} = 0.1\, c_{p,Tr\,1}\; l_{A,NO\ NBS}$	$c_p < 500$ mm year^{-1}
$d_{R,y} = 0.2\, c_{p,Tr\,1}\; l_{A,NO\ NBS}$	500 mm year^{-1} $\leq c_p < 1000$ mm year^{-1}
$d_{R,y} = 0.3\, c_{p,Tr\,1}\; l_{A,NO\ NBS}$	$c_p \geq 1000$ mm year^{-1}

- With
  - $c_{p,Tr\,1}$ precipitation, the mean maximum daily rainfall depth (cardinal, in mm event^{-1})
  - c_p average annual precipitation (cardinal, in mm year^{-1})
  - $l_{A,NO\ NBS}$ area without NBS (cardinal, in m^2)

1.4.3.5 Biodiversity support

1.4.3.5.1 Quantification

A value function is defined for biodiversity support as a function of each **created habitat**:

— Wetland (NBS B1, NBS C1.3, and NBS C2.3)

- Wetland biodiversity support A: ability to provide habitat for plants, insects, amphibians and reptiles
- Wetland biodiversity support B: ease of colonization of the habitat by amphibians and reptiles
- Wetland biodiversity support C: ability to provide habitat for birds

— Wooded (NBS B3, NBS C2.4)

— Reed (NBS A1)

— Pond (NBS C1, C2.1, C2.2, C2.3)

The value function for the **biodiversity benefit for the wetland habitat**, v_{wet}, is calculated as follows

$$v_{wet} = v_{wet,A}(d_A) + v_{wet,B}(d_A)\, l_{wb} + v_{wet,C}(d_A)$$

Where

— d_A area of the NBS (cardinal, in ha)

- l_{wb} proximity to a water body (binary), defined as follows
    - Distance from the nearest water body less than 500 m 1
    - Distance from the nearest water body greater than 500 m 0
- $v_{w,A}(d_A)$, $v_{w,B}(d_A)$, and $v_{w,C}(d_A)$ are the value functions for the different biodiversity support of wetlands, defined as follows

$$\begin{array}{ll}
d_A < 10\ \text{ha} & v_{wet,A}(d_A) = 0.05\, d_A \\
 & v_{wet,B}(d_A) = 0.03\, d_A \\
 & v_{wet,C}(d_A) = 0.025\,(d_A - 2) \\
d_A \geq 10\ \text{ha} & v_{wet,A}(d_A) = 0.5 \\
 & v_{wet,B}(d_A) = 0.3 \\
 & v_{wet,C}(d_A) = 0.2
\end{array}$$

The **biodiversity benefit for the other habitats**, i.e. wooded (v_{wood}), reeds (v_{reed}), and ponds (v_{pond}) is calculated as follows

$$\begin{array}{ll}
d_A < 10\ \text{ha} & v_{wood} = 0.03\, d_A \\
 & v_{reed} = 0.02\,(d_A - 1) \\
 & v_{pond} = 0.03\, d_A \\
d_A \geq 10\ \text{ha} & v_{wood} = 0.3 \\
 & v_{reed} = 0.2 \\
 & v_{pond} = 0.3
\end{array}$$

The built value functions for the different habitats are graphically represented in **Figure 1**, which shows how the proposed value functions are already normalised between 0 and 1 for all NBS habitats, and, therefore, for all NBS sub-categories p.

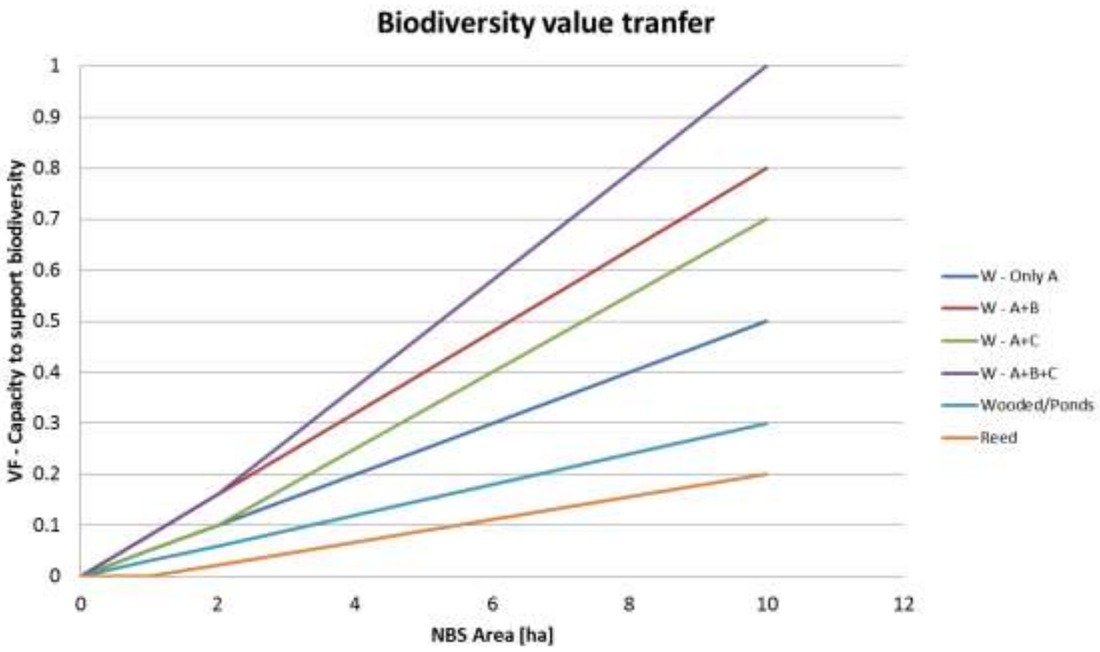

Figure 1. Value functions for each NBS habitat supporting biodiversity – value between 0 and 10 hectares

1.4.3.5.2 Demand

The demands for biodiversity support are differently estimated for each habitat as follows

$$D_{wet}(i) = l_{CLC\ 4.1,50\%}(i)$$

$$D_{wood}(i) = l_{CLC\ 2..4,,50\%}(i)$$

$$D_{reed}(i) = 1$$

$$D_{pond}(i) = l_{CLC\ 4.1,50\%}(i)$$

- $l_{CLC\ 4.1,50\%}(i)$ coverage area of the *Corine Land Cover* (CLC) class 4.1 (inland wetland) on the pixel i ≤50% (binary, 0 no, 1 yes)
- $l_{CLC\ 2.4,50\%}(i)$ coverage area of CLC classes 2.4.2, 2.4.3, and 2.4.4 (Complex cultivation patterns, Land mainly occupied by agriculture, with significant areas of natural vegetation, and Agro-forestry areas) on the pixel i ≤50% (binary, 0 no, 1 yes)

1.4.3.6 Biomass-driven benefits

1.4.3.6.1 Quantification

A couple of side-benefits of the proposed NBS are linked to the provision of ecosystem services related to the production of biomass. Therefore, biomass-driven benefits are defined to build the opportunity maps for all NBS:

- $J_{S,CO2}$ carbon sequestration capacity as mass of CO_2 equivalent (cardinal, in g)
- $J_{S,energy}$ energetic value of the NBS biomass as MJ of energy produced (cardinal, in MJ)

The amount of produced biomass, $d_{biomass}$, is calculated as follows

$$d_{biom} = d_{mean\ biom}\ d_A\ d_{cov}$$

Where

— $d_{mean\ biom}$ above-ground mean biomass production at max growth (cardinal, in $g_{d.w.}/m^2$)

— d_A area of the NBS (cardinal, in m^2)

— d_{cov} biomass coverage coefficient of the NBS (cardinal, dimensionless)

The **carbon sequestration (climate change mitigation)** capacity is calculated considering the CO2e stock, S_{CO2}, as follows

$$S_{biom,CO2} = 1.63\ d_{biom}$$

Where 1.63 is obtained by multiplying the two conversion factors, i.e. 0.44 $g_C/g_{d.w.}$ and 3.7 g_{CO2e}/g_C.

The **energetic value of the NBS biomass**, E_{bio}, in MJ $year^{-1}$, is calculated as follows

$$E_{bio} = \frac{d_{biom}}{d_{biom,y}}\ d_{HHV}$$

Where

— $d_{biom,y}$ age of max. biomass growth (cardinal, in years)

— d_{HHV} high-heating value (cardinal, in MJ $kg_{d.w.}^{-1}$)

Contrarily to biomass for the carbon stock benefit, the energy benefit is calculated for an equal time span for both wetlands and trees, assumed equal to 20 years[17].

The design values that characterizes biomass are summarised in **Table 11**.

Table 11. Design values for biomass characterisation

Type of plant	**NBS sub-category**	$d_{biom,y}$ (years)	$d_{mean\ biom}$ ($g_{d.w.}/m^2$)	d_{HHV} ($MJ/kg_{d.w.}$)
Wetland	NBS A NBS B1, B2 NBS C1.3, NBS C2.3	1	1255	18.6
Trees	NBS B3 NBS C2.4	28	15100	18.6

The **technical issues related to ash content** is estimated with a value function ($v_{biom,tech}$), calculated as follows

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[17] These assumptions consider the wetland environment capable of producing biomass for energy demand every year, i.e. that the O&M of reed harvesting in wetlands is carried out every year

Table 12. Value transfer for estimation of technical issues related to ash content; binary, negative orientation

Type of plant	NBS sub-category	$v_{biom,tech}$
Wetland	NBS A NBS B1, B2 NBS C1.3, NBS C2.3	1
Trees	NBS B3 NBS C2.4	0

1.4.3.6.2 Demand

The demand for carbon sequestration is calculated considering the relative maximum value of biomass carbon sequestration across all the pixel i, i.e.

$$D_{S,CO2}{}^{max} = \max_{i,p}[S_{biom,CO2}(i,p)]$$

The demand for energy, $D_{energy}(i)$, is equal to the average energy demand in the representative municipal level, i.e.

$$D_{energy}(i) = \frac{E_{mun,y}}{n_{pix,mun}}$$

Where

— $E_{mun,y}$ is the annual average energetic demand at the municipal level of the municipality including the pixel i (cardinal, in MJ year^{-1})

— $n_{pix,mun}$ is the number of pixels of the municipality including pixel i

1.4.3.7 Prevention of nuisance

1.4.3.7.1 Quantification

The value function for the evaluation of **nuisance** prevention, $v_{nui}(i,p)$, is defined in **Table 13**.

Table 13. NBS set of design parameters for the prevention of nuisance.

NBS type	NBS category	Quantification	
NBS A	NBS A1.1* NBS A1.2*	$v_{nui} = 1.0$ $v_{nui} = 0.5$ $v_{nui} = 0.0$	$l_{urb} < 100\ m$ $100\ m \leq l_{urb} < 500\ m$ $l_{urb} \geq 500\ m$
NBS B	NBS B1	$v_{nui} = 0.2$	
	NBS B2	$v_{nui} = 0.5$	
	NBS B3*	$v_{nui} = 0.8$	
NBS C	NBS C1 NBS C2.1	$v_{nui} = 0.2$	

	NBS C2.2 NBS C2.3	
	NBS C2.4	$v_{nui} = 0.3$

* Wetlands for manure are all considered to have a NBS primary treatment stage, i.e. an anaerobic pond.

** BSs are all considered with wooden species, which are in combination (NBS B3.1.1 and B3.3.1) or not with herbaceous species (NBS B3.1.2, B3.3.2, and B3.2)

Where l_{urb} is the proximity to urban settlements (binary), in m.

1.4.3.7.2 Demand

The demand for nuisance can be interpreted as "request for less nuisance from the NBS" and, therefore, can always be considered needed in potential areas for NBS. Therefore, the demand is

$$D_{nui}(i) = 1$$

1.4.3.8 Landscape, amenity, microclimate enhancement, attractiveness

1.4.3.8.1 Quantification

The **social benefit** (intended as Landscape, amenity, microclimate enhancement, attractiveness) evaluation is done considering the NBS attractiveness with a value function, $v_{social}(i,p)$, defined in **Table 14**

Table 14. NBS set of design parameters for NBS attractiveness.

NBS type	NBS category	Quantification
NBS A	NBS A1.1 NBS A1.1	$v_{social} = 0$
NBS B	NBS B1 NBS B3.3	$v_{social} = 1.0$
	NBS B2	$v_{social} = 0$
	NBS B3.1* NBS B3.2*	$v_{social} = 0.5$
NBS C	NBS C1 NBS C2.1 NBS C2.2 NBS C2.3	$v_{social} = 1.0$
	NBS C2.4	$v_{social} = 0.5$

* BSs are all considered with wooden species, which are in combination (NBS B3.1.1 and B3.3.1) or not with herbaceous species (NBS B3.1.2, B3.3.2, and B3.2)

1.4.3.8.2 Demand

The demand $D_{social}(i)$ is assumed equal to the amount of potential population interested by the NBS, which is defined as the population present in a radius of 2 km from pixel i.

1.4.4 Cost estimation

1.4.4.1 Investment cost estimation (CAPEX)

1.4.4.1.1 Quantification

The **investment cost (CAPEX)**, $C_{CAPEX}(i,p,a)$, has the following form:

$$C_{CAPEX}(i,p,a) = C_{work} + C_{land} + C_{consult}$$

Where:

— C_{work}	working cost
— C_{land}	land acquisition cost
— $C_{consult}$	cost for technical investigation and consultancy

The **working cost**, C_{work}, is calculated as follows:

$$C_{work} = \left(\left(l_{C,exc} + l_{C,emb}\right) d_{V,exc} + l_{C,med}\, d_{V,med} + l_{C,waterpr}\, d_A + l_{C,.pers}\, d_{C,n,h,trees}\, d_A \right) d_{C,c1}\, d_{C,c2}$$

Where

— $l_{C,esx}$	parametric cost for the excavation (cardinal, in € m^{-3})
— $l_{C,emb}$	parametric cost for the earthmoving (cardinal, in € m^{-3})
— $l_{C,med}$	parametric cost for the filling medium (cardinal, in € m^{-3})
— $l_{C,waterpr}$	parametric cost for the waterproofing (cardinal, in € m^{-2})
— $l_{C,pers}$	parametric cost of unskilled personnel (cardinal, in € h^{-1})
— $d_{V,exc}$	excavation volume (cardinal, in m^3)
— $d_{V,med}$	filling medium volume (cardinal, in m^3)
— d_A	area of the NBS (cardinal, in m^2)
— $d_{C,n,h,trees}$	equivalent working hours of unskilled personnel for tree plantation (cardinal, m^{-1})
— $d_{C,c1}$	corrective coefficient for CAPEX (e.g. piping, landscaping), (cardinal, dimensionless)
— $d_{C,c2}$	corrective coefficient for CAPEX of the primary treatments cost (cardinal, dimensionless)

Different elements of the working cost, as well as the value and use of coefficients, vary across the different NBS. The equations and coefficient values are summarised in **Table 16**.

The **land acquisition cost**, C_{land}, is calculated as follows

$$C_{land} = l_{C,land}\ d_{A,land}$$

- $l_{C,land}$ parametric cost for the land acquisition (cardinal, in €/m^2)
- $d_{A,land}$=$d_A\ d_{NBS,gross}$ acquisition area (cardinal, in m^2)

The land acquisition cost is calculated for all the NBS excluding buffer strips. The land acquisition cost of VDDs is calculated considering the land acquisition cost of the excavated area only, i.e. $d_{A,exc} = \ d_L\ d_{W,exc}$. The approach proposed here does not consider the possibility of not acquiring the land and instead offering compensation to land owners for the economic losses due to the implementation of NBS, but this possibility will be considered in the development phases of the favourability and opportunity maps.

The **cost for technical investigation and consultancy**, $C_{consult}$, is calculated as a percentage of the working cost, i.e.

$$C_{consult} = d_{C,consult}\ C_{work}$$

Where $d_{C,consult}$ is the percentage of the working cost that indicates the investment cost for technical investigation and consultancy costs, assumed equal to

- SSF wetlands, SF wetlands, and ponds (NBS A, NBS B1, NBS C) **20%**
- buffer strips and VDDs (NBS B.2 and B.3) **10%**

The methodology proposed here allows to estimate CAPEX according to local working costs with a minimum number of parametric costs. Examples of parametric costs from different European countries are summarised in **Table 15**.

Table 15: Parametric costs for different European countries. All costs are exclusive of VAT

	Unit	PL**	SI**	IT*	BE***
$l_{C,exc}$ – **Excavation**	€/m^3	3.00	5.00	6.00	10.00
$l_{C,emb}$ – **Embankment**	€/m^3	3.00	5.00	6.00	8.00
$l_{C,waterpr}$ – **Waterproofing (including geotextile)**	€/m^2	9.00	15.00	15.00	6.00
$l_{C,med}$ – **Sand** **(range 0.3-2 mm)**	€/m^3	21.00	21.00	42.00	21.00
$l_{C,med}$ – **Gravel**	€/m^3	36.00	15.00	35.00	65.00
$l_{C,pers}$ – **Unskilled personnel**	€/h	N/A	18.00	25.00	32.00

* IRIDRA expertise
** IRIDRA expertise in other international feasibility studies in Europe
*** Global Wetland Technology (GWT) expertise: interview to GWT members

Table 16. Working cost estimation

NBS Type	**NBS category**	C_{work}	$d_{C,c1}$	$d_{C,c2}$	$d_{C,n,h,trees}$	$d_{V,exc}$	$d_{V,med}$
NBS A1	NBS A1.1 – SF	$\left(\left(l_{C,exc} + l_{C,emb}\right) d_{V,exc} + l_{C,waterpr}\, d_A\right) d_{C,c1}\, d_{C,c2}$	$7.46\, {d_A}^{-0.102}$	1.5	-	$d_h\, d_A$	-
	NBS A1.2 – hybrid SF + SSF	$\left(\left(l_{C,exc} + l_{C,emb}\right) d_{V,exc} + l_{C,med}\, d_{V,med} + l_{C,waterpr}\, d_A\right) d_{C,c1}\, d_{C,c2}$	$3.7136\, {d_A}^{-0.088}$	1.4	-	$d_h\, d_A$	$0.5\, d_h\, {d_A}^{*}$
NBS B1 – free water surface wetland (FWS)	no categories	if $l_{CLAY,text} = 0$ $\left(\left(l_{C,exc} + l_{C,emb}\right) d_{V,exc} + l_{C,waterpr}\, d_A\right) d_{C,c1}$ if $l_{CLAY,text} = 1$ $\left(\left(l_{C,exc} + l_{C,emb}\right) d_{V,exc}\right) d_{C,c1}$	$7.46\, {d_A}^{-0.102}$	-	-	$d_h\, d_A$	-
NBS B2 – vegetated drainage ditch (VDD)	no categories	$\left(\left(l_{C,exc} + l_{C,emb}\right) d_{V,exc}\right) d_{C,c1}$	1.7	-	-	$d_h\, d_L\, d_{W,exc}$ with • $d_L = d_A / d_W$	-
NBS B3 – buffer strip (BS)	NBS B3.1 – BS – R NBS B3.2 – BS - G	$l_{pers}\, d_{C,n,h,trees}\, d_A$	-	-	0.04	-	-
	NBS B3.3 – BS - Integrated	$\left(l_{C,exc} + l_{C,emb}\right) d_{V,exc} + l_{pers}\, d_{C,n,h,trees}\, d_A$	-	-	0.04	$d_A\, d_{h,f}$	-
NBS C1 – Storage	NBS C1.1 – Storage pond	if $l_{CLAY,text} = 0$ $\left(\left(l_{C,exc} + l_{C,emb}\right) d_{V,exc} + l_{C,waterpr}\, d_{n,NBS\ drought} d_A\right) d_{C,c1}$ if $l_{CLAY,text} = 1$ $\left(\left(l_{C,exc} + l_{C,emb}\right) d_{V,exc}\right) d_{C,c1}$	$7.819\, {d_A}^{-0.189}$	-	-	$d_{n,NBS\ drought}\left(d_{V,drought} + d_A\, d_{h,f}\right)$ with • $d_{n,NBS\ drought} = \frac{d_{NBS\ area\ ratio,drought}\, l_{A\_pixel\_suit}}{d_A\, d_{NBS,gross}}$ • $d_{V,drought} = d_{\phi}\left(\sqrt{d_A} - 2\frac{d_{h,drought} - d_{h,sed}}{\tan d_{\alpha}}\right)^2$	-
	NBS C1.2 – Pre-treatment pond + Storage pond	if $l_{CLAY,text} = 0$ $\left(\left(l_{C,exc} + l_{C,emb}\right) d_{V,exc} + l_{C,waterpr}\, d_{n,NBS\ drought}\, d_A\right) d_{C,c1}$ if $l_{CLAY,text} = 1$ $\left(\left(l_{C,exc} + l_{C,emb}\right) d_{V,exc}\right) d_{C,c1}$	$7.819\, {d_A}^{-0.189}$	-	-	$d_{n,NBS\ drought}\left(d_{V,drought} + d_A\, d_{h,f} + d_{A,pre}\, d_{h,pre}\right)$ with • $d_{n,NBS\ drought} = \frac{d_{NBS\ area\ ratio,drought}\, l_{A\_pixel\_suit}}{d_A\, d_{NBS,gross}}$ • $d_{V,drought} = d_{\phi}\left(\sqrt{d_A} - 2\frac{d_{h,drought} - d_{h,sed}}{\tan d_{\alpha}}\right)^2$ • $d_{A,pre} = \frac{d_{NBS\ area\ ratio,pre}\, l_{A\_pixel\_suit}}{d_{NBS,gross}}$	-
	NBS C1.3 – Pre-treatment wetland + Storage pond	if $l_{CLAY,text} = 0$ $\left(\left(l_{C,exc} + l_{C,emb}\right) d_{V,exc} + l_{C,waterpr}\, d_{n,NBS\ drought} d_A\right) d_{C,c1}$ if $l_{CLAY,text} = 1$ $\left(\left(l_{C,exc} + l_{C,emb}\right) d_{V,exc}\right) d_{C,c1}$	Pond $7.819\, {d_A}^{-0.189}$ Wetland $7.46\, {d_A}^{-0.102}$	-	-	$d_{n,NBS\ drought}\left(d_{V,drought} + d_A\, d_{h,f} + d_{A,pre}\, d_{h,pre}\right)$ with • $d_{n,NBS\ drought} = \frac{d_{NBS\ area\ ratio,drought}\, l_{A\_pixel\_suit}}{d_A\, d_{NBS,gross}}$	-

NBS Type	**NBS category**	$\boldsymbol{C_{work}}$	$\boldsymbol{d_{C,c1}}$	$\boldsymbol{d_{C,c2}}$	$\boldsymbol{d_{C,n,h,trees}}$	$\boldsymbol{d_{V,exc}}$	$\boldsymbol{d_{V,med}}$
						• $d_{V,drought} = d_\phi \left(\sqrt{d_A} - 2\,\frac{d_{h,drought}-d_{h,sed}}{\tan d_\alpha}\right)^2$ • $d_{A,pre} = \frac{d_{NBS\ area\ ratio,pre}\ l_{A\_pixel\_suit}}{d_{NBS,gross}}$	
NBS C2 – MAR	NBS C2.1 – Infiltration pond	$\left(\left(l_{C,exc} + l_{C,emb}\right) d_{V,exc}\right) d_{C,c1}$	Pond $7.819\ d_A{}^{-0.189}$	-	-	$d_A\left(d_{h,MAR} + d_{h,f}\right)$ with • $d_A = \frac{d_{NBS\ area\ ratio,drought}\ l_{A\_pixel\_suit}}{d_{NBS,gross}}$	-
	NBS C2.2 – Pre-treatment pond + Infiltration pond	Pre treatment if $l_{CLAY,text} = 0$ $\left(\left(l_{C,exc} + l_{C,emb}\right) d_{V,exc,pre} + l_{C,waterpr}\ d_A\right) d_{C,c1}$ if $l_{CLAY,text} = 1$ $\left(\left(l_{C,exc} + l_{C,emb}\right) d_{V,exc,pre}\right) d_{C,c1}$ Infiltration basin $\left(\left(l_{C,exc} + l_{C,emb}\right) d_{V,exc,MAR}\right) d_{C,c1}$	Pond $7.819\ d_A{}^{-0.189}$ Wetland $7.46\ d_A{}^{-0.102}$	-	-	$d_{V,exc,pre} = d_{A,pre}\left(d_{h,pre} + d_{h,f}\right)$ $d_{V,exc,MAR} = d_A\left(d_{h,MAR} + d_{h,f}\right)$ with • $d_A = \frac{d_{NBS\ area\ ratio,drought}\ l_{A\_pixel\_suit}}{d_{NBS,gross}}$ • $d_{A,pre} = \frac{d_{NBS\ area\ ratio,pre}\ l_{A\_pixel\_suit}}{d_{NBS,gross}}$	-
	NBS C2.3 – Pre-treatment wetland + Infiltration pond	Pre treatment if $l_{CLAY,text} = 0$ $\left(\left(l_{C,exc} + l_{C,emb}\right) d_{V,exc,pre} + l_{C,waterpr}\ d_A\right) d_{C,c1}$ if $l_{CLAY,text} = 1$ $\left(\left(l_{C,exc} + l_{C,emb}\right) d_{V,exc,pre}\right) d_{C,c1}$ Infiltration basin $\left(\left(l_{C,exc} + l_{C,emb}\right) d_{V,exc}, MAR\right) d_{C,c1}$	Pond $7.819\ d_A{}^{-0.189}$ Wetland $7.46\ d_A{}^{-0.102}$	-	-	$d_{V,exc,pre} = d_{A,pre}\left(d_{h,pre} + d_{h,f}\right)$ $d_{V,exc,MAR} = d_A\left(d_{h,MAR} + d_{h,f}\right)$ with • $d_A = \frac{d_{NBS\ area\ ratio,drought}\ l_{A\_pixel\_suit}}{d_{NBS,gross}}$ • $d_{A,pre} = \frac{d_{NBS\ area\ ratio,pre}\ l_{A\_pixel\_suit}}{d_{NBS,gross}}$	-
	NBS C2.4 – Infiltration wooded area	$\left(\left(l_{C,exc} + l_{C,emb}\right) d_{V,exc}\right) d_{C,c1} + l_{pers}\ d_{C,n,h,trees}\ d_A$	Pond $7.819\ d_A{}^{-0.189}$	-	0.04	$d_A\left(d_{h,MAR} + d_{h,f}\right)$ with • $d_A = \frac{d_{NBS\ area\ ratio,drought}\ l_{A\_pixel\_suit}}{d_{NBS,gross}}$	-

* Hybrid wetlands are assumed, for sake of simplicity, to be divided into 50% subsurface flow and 50% surface flow constructed wetlands

1.4.4.1.2 Demand

The demand for CAPEX can be interpreted as "minimization of investment costs" and is calculated considering the relative maximum value of CAPEX across all the pixel i, i.e.

$$D_{CAPEX}{}^{max} = \max_{i,p}[C_{CAPEX}(i,p)]$$

1.4.4.2 Operational and maintenance costs (OPEX)

1.4.4.2.1 Quantification

The operational and maintenance costs, C_{OPEX}, are calculated with an equation that has the following form:

$$C_{OPEX}(i,p,a) = l_{C,pers}\, d_{C,n,h,OPEX}\, d_{C,c3}\, d_{C,c4}$$

Where

- l_{pers} parametric cost of personnel (cardinal, in €/h)
- $d_{C,nOPEX} = \left(d_{C,n,h,pers} + d_{C,n,h,rg}\right)d_A$ number of annual personnel working hours for OPEX (cardinal, in hours), with
    - $d_{C,n,h,rg}$ equivalent unskilled personnel working hours for reed and green maintenance (cardinal, m^{-1})
    - $d_{C,n,h,pers}$ parametric number of annual personnel working hours for the checking (cardinal, m^{-1})
- $d_{C,c3}$ corrective coefficient for NBS OPEX
- $d_{C,c4}$ corrective coefficient for the primary treatments OPEX

Different elements of the operational and maintenance costs, as well as the value and use of coefficients, vary across the different NBS. The equations and coefficient values are summarised in **Table 17**.

Table 17. OPEX estimation

NBS Type	**NBS category**	**NBS sub-category**	C_{OPEX}	$d_{C,c3}$	$d_{C,c4}$	$d_{C,n,h,pers}$ **(m^{-2} y^{-1})**	$d_{C,n,h,rg}$ **(m^{-2} y^{-1})**
NBS A1	NBS A1.1 – SF		$l_{C,pers}\ d_{C,n,h,OPEX}\ d_{C,c3}\ d_{C,c4}$	$1.06\ d_A{}^{0.046}$	1.9	$12.016 d_A{}^{-0.758}$	0.07
	NBS A1.2 – hybrid SF + SSF		$l_{C,pers}\ d_{C,n,h,OPEX}\ d_{C,c3}\ d_{C,c4}$	$1.17\ d_A{}^{0.0024}$	1.8	$12.016 d_A{}^{-0.758}$	0.09
NBS B1 – free water surface wetland (FWS)	no categories		$l_{C,pers}\ d_{C,n,h,OPEX}\ d_{C,c3}$	$1.06\ d_A{}^{0.046}$	-	$12.016 d_A{}^{-0.758}$	0.07
NBS B2 – vegetated drainage ditch (VDD)	no categories		$l_{C,pers}\ d_{C,n,h,OPEX}\ d_{C,c3}$	1.5	-	$12.016 d_A{}^{-0.758}$	0.07
NBS B3 – buffer strip (BS)	NBS B3.1 – BS – R NBS B3.2 – BS – G NBS B3.3 – BS - Integrated		$l_{C,pers}\ d_{C,n,h,OPEX}\ d_{C,c3}$	1.6	-	0.01	-
NBS C1 – Storage	NBS C1.1 – Storage pond		$l_{C,pers}\ d_{C,n,h,OPEX}\ d_{C,c3}$	$0.332\ d_A{}^{02637}$	-	$12.016 d_A{}^{-0.758}$	-
	NBS C1.2 – Pre-treatment pond + Storage pond		$l_{C,pers}\ d_{C,n,h,OPEX}\ d_{C,c3}$	$0.332\ d_A{}^{02637}$	-	$12.016 d_A{}^{-0.758}$	-

NBS Type	**NBS category**	**NBS sub-category**	C_{OPEX}	$d_{C,c3}$	$d_{C,c4}$	$d_{C,n,h,pers}$ **(m^{-2} y^{-1})**	$d_{C,n,h,rg}$ **(m^{-2} y^{-1})**
	NBS C1.3 – Pre-treatment wetland + Storage pond		$l_{C,pers}\ d_{C,n,h,OPEX}\ d_{C,c3}$	Pond $0.332\ d_A^{02637}$ Wetland $1.06\ d_A^{0.046}$	-	$12.016 d_A^{-0.758}$	Only wetland 0.07
NBS C2 – MAR	NBS C2.1 – Infiltration pond	NBS C2.1 – Infiltration pond (high infiltration)	$l_{C,pers}\ d_{C,n,h,OPEX}\ d_{C,c3}$	$0.332\ d_A^{02637}$	1.9*	$12.016 d_A^{-0.758}$	-
		NBS C2.2 – Infiltration pond (low infiltration)	$l_{C,pers}\ d_{C,n,h,OPEX}\ d_{C,c3}$	$0.332\ d_A^{02637}$	-	$12.016 d_A^{-0.758}$	-
	NBS C2.2 – Pre-treatment pond + Infiltration pond		$l_{C,pers}\ d_{C,n,h,OPEX}\ d_{C,c3}$	$0.332\ d_A^{02637}$	-	$12.016 d_A^{-0.758}$	-
	NBS C2.3 – Pre-treatment wetland + Infiltration pond		$l_{C,pers}\ d_{C,n,h,OPEX}\ d_{C,c3}$	Pond $0.332\ d_A^{02637}$ Wetland $1.06\ d_A^{0.046}$	-	$12.016 d_A^{-0.758}$	Only wetland 0.07
	NBS C2.4 –		$l_{C,pers}\ d_{C,n,h,OPEX}\ d_{C,c3}$	$0.332\ d_A^{02637}$	-	$12.016 d_A^{-0.758}$	-

NBS Type	**NBS category**	**NBS sub-category**	C_{OPEX}	$d_{C,c3}$	$d_{C,c4}$	$d_{C,n,h,pers}$ **(m^{-2} y^{-1})**	$d_{C,n,h,rg}$ **(m^{-2} y^{-1})**
	Infiltration wooded area						

* The need for annual sediment emptying of the MAR basin is considered as an extra cost equal to that of the primary treatment for SF wetlands

1.4.4.2.2 Demand

The demand for OPEX can be interpreted as "minimization of O&M costs" and is calculated considering the relative maximum value of OPEX across all the pixel i, i.e.

$$D_{OPEX}{}^{max} = \max_{i,p}[C_{OPEX}(i,p)]$$

1.5 Ecosystem service monetization

The *k*-th ecosystem service is monetized with the following value transfer formulation

$$M_{ES}(i,p,a,k) = M_{ES}^{SS}(k) \cdot \frac{l_{GDP,2018}(i)}{GDP_{year\ of\ VT}(k)} \cdot d_{\$/€}$$

where:

- $M_{ES}^{SS}(k)$ is the monetization of the *k*-th ecosystem service in the study site, to be transferred in the *i*-th pixel
- $GDP_{year\ of\ VT}(k)$ is the Gross Domestic Product (GDP) per capita based on the Purchasing Power Parity (PPP) of the country of the study site in the year of the value transfer estimation for the *k*-th ecosystem service
- $l_{GDP,2018}(i)$ is the GDP per capita based on the Purchasing Power Parity (PPP) of the country of the *i*-th pixel in 2018 (landscape cardinal variable)
- $d_{\$/€}$ is the Dollar to Euro exchange rate in 2018, equal to 0.87097 €/$[18]

The parameters needed for value transfer are summarised in **Table 18** and **Table 19**.

Table 18. Gross Domestic Product (GDP) per capita based on the Purchasing Power Parity (PPP) of the country in 2018 for EU countries (current international $).

Country Name	Country Code	$l_{GDP,2018}(i)$ [$]
Austria	AUT	56871.2114
Belgium	BEL	52249.5735
Cyprus	CYP	39737.3252
Czech Republic	CZE	40389.3576
Germany	DEU	54456.9293
Denmark	DNK	57218.4064
Spain	ESP	40482.589
Estonia	EST	36358.0278
Finland	FIN	49373.184
France	FRA	46605.1863
Greece	GRC	30354.349
Croatia	HRV	28038.6854
Hungary	HUN	31578.7598
Ireland	IRL	84459.6516
Italy	ITA	42816.203
Lithuania	LTU	35831.8628
Luxembourg	LUX	116786.48

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[18] https://it.exchange-rates.org/Rate/USD/EUR/31-12-2018

Latvia	LVA	30644.6083
Malta	MLT	43555.2051
Netherlands	NLD	57565.1976
Poland	POL	31834.4091
Portugal	PRT	34340.7133
Romania	ROU	29213.8415
Serbia	SRB	17563.1654
Slovak Republic	SVK	32574.8231
Slovenia	SVN	38749.252
Sweden	SWE	53746.7992

Source: World Development Indicators (https://data.worldbank.org/indicator/NY.GDP.PCAP.PP.CD, Access 14th December 2020)

Table 19. Value transfer parameters for the ecosystem services monetization

		Study site			$M_{ES}^{SS}(k)$												**Unit**
					NBS A		**NBS B**					**NBS C**					
		Country	**Year VT**	$GDP_{year\ of\ VT}(k)$	**A1.1 SF**	**A1.2 hybrid SF + SSF**	**B1 FWS**	**B2 VDD**	**B3.1 BS-R**	**B3.2 BS-G**	**B3.3 int. BS**	**C1.1 Stor. Pond** **C1.2 Pre-treat. pond + Stor. pond**	**C1.3 Pre-treat. wet. + Stor. pond**	**C2.1 MAR Infiltr. pond** **C2.2 Pre-treat. pond + Infiltr. pond**	**C2.3 MAR Pre-treat. wet. + Infiltr. pond**	**C2.4 MAR infiltr. Wood**	
WATER SUPPLY	↑	Spain	2004	26119.79								4396	4396	4396	4396	4396	$/ha/yr
		Poland	2013	24719.25								807	807	807	807	807	$/ha/yr
		Spain	2004	26119.79						5470							$/ha/yr
NATURAL HABITAT and BIODIVERSITY SUPPORT	↑	Spain	2004	26119.79	286	179	321	179									$/ha/yr
		UK	2007	35600.01					29	29	32					29	$/ha/yr
WATER QUALITY	↑	Germany	2001	28380.38	4111	4111	4111	4111					4111		4111		$/ha/yr
		Spain	2004	26119.79	2121	2121	2121	2121					2121		2121		$/ha/yr
		US	1998	32853.68					59	107	107						$/ha/yr
CARBON SEQUESTRATION	↑	US	2008	48382.56	140	140	140	100					140		140		$/ha/yr
		UK	2007	35600.01					1974	1974	1974					1974	$/ha/yr
FLOOD RISK	↑	Denmark	2000	28662.09	83		133	83				133	133	133	133		$/ha/yr
		Spain	2004	26119.79							222						$/ha/yr
NUISANCE (ODOURS, RUMORS, OBSTACLES TO COMMON FARMING PRACTICES)	↓	Belgium	2008	37883.33	4720	4720	2622	2622				2622	2622	2622	2622		$/house/yr
		Belgium	2008	37883.33													$/house/yr
RECREATION and TOURISM	↑	Spain	2004	26119.79			4003	2224				2224	2224	2224	2224		$/ha/yr
		Denmark	2000	28662.09			5										$/person/visit
		Spain	2007	32438.17			3										$/person/visit
		Spain	2004	26119.79					3901	3901	3901					2167	$/ha/yr
VISUAL IMPACT/AMENITY and AESTHETIC	↑	Spain	2004	26119.79			2252	1408				1408	1408	1408	1408		$/ha/yr
		UK	2007	35600.01						1606						1147	$/ha/yr
AWARENESS/EDUCATION	↑	Greece	2003	23870.16			9										$/person/visit
		Canada	1983	46723.32						10						7	$/person/visit

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ANNEX 1: List of descriptor variables used for performance estimation

Variable	**Category**	**Type**	**Description**	**Unit**
c_p	climate	Cardinal	Average annual precipitation	mm y^{-1}
$c_{n_{cold}}$	climate	Cardinal	Average annual month with mean monthly temperature ≤6°C	dimensionless
c_{StdDev}	climate	Cardinal	Temporal uniformity of precipitation pattern, i.e. a *"proxy"* for the standard deviation of the precipitation pattern $$c_{StdDev} = \frac{\max[T_{mean,m}] - \min[T_{mean,m}]}{\mathrm{mean}[T_{mean,m}]}$$ where $T_{mean,m}$ are the mean monthly temperature	dimensionless
c_{GAI}	climate	Cardinal	Global Aridity Index $$\mathrm{c_{GAI}} = {}^{\mathrm{P_{mean,y}}}\!/_{\mathrm{ET0_{,y}}}$$	dimensionless
c_{ET0}	climate	Cardinal	Annual reference evapotranspiration (potential of the reference crop)	mm y^{-1}
c_T	climate	Cardinal	Average annual temperature	°C
$c_{p,Tr\,1}$	climate	Cardinal	precipitation = mean maximum daily rainfall depth	mm event^{-1}
$l_{ww,mix,rnf}$	landscape	Binary	Manure mixed with surface runoff	0 no 1 yes
$l_{poultry}$	landscape	Binary	Poultry manure	0 no 1 yes
$l_{A\_pixel\_suit}$	landscape	Cardinal	Suitable area for NBS within the pixel after the suitability constraints criteria	m^2
l_S	landscape	Cardinal	Retention value $$l_S = \frac{25400}{l_{CN}} - 254$$	mm y^{-1}
l_{CN}	landscape	Cardinal	Curve number	dimensionless
$l_{CLAY,pres}$	landscape	Binary	Presence of clay according to soil texture	0 no • sand • loamy sand • sandy loam • loam

Variable	Category	Type	Description	Unit
				• silt loam • silt 1 yes • clay • sandy clay • sandy clay loam • clay loam • silty clay • silty clay loam
$l_{CLAY,text}$	landscape	Binary	Clay soil according to soil texture	0 no • sand • loamy sand • sandy loam • loam • silt loam • silt • sandy clay • sandy clay loam • clay loam • silty clay • silty clay loam 1 yes • clay
$l_{A,NO\ NBS}$	landscape	Cardinal	Area without NBS	m^2
l_{wb}	landscape	Binary	proximity to a water body	0: Distance from the nearest water body greater than 500 m 1: Distance from the nearest water body less than 500 m
l_{KOC}	landscape	Cardinal	pesticide solubility in water K_{OC} for the target pesticide in the region	ml g^{-1}
$l_{CLC\ 4.1,50\%}$	landscape	Binary	coverage area of the Corine Land Cover CLC class 4.1 (inland wetland) on the pixel i ≤50%	0 no 1 yes
$l_{CLC\ 2.4,50\%}$	landscape	Binary	coverage area of CLC classes 2.4.2, 2.4.3, and 2.4.4 (Complex cultivation patterns, Land mainly occupied by agriculture, with	0 no 1 yes

Variable	Category	Type	Description	Unit
			significant areas of natural vegetation, and Agro-forestry areas) on the pixel i ≤50%	
l_{urb}	landscape	Binary	proximity to urban settlements	0: Distance from the nearest urban settlement greater than 100 m 1: Distance from the nearest urban settlement less than 100 m
$l_{C,exc}$	landscape	Cardinal	parametric cost for the excavation	€ m^{-3}
$l_{C,emb}$	landscape	Cardinal	parametric cost for the embankment (earthmoving)	€ m^{-3}
$l_{C,med}$	landscape	Cardinal	parametric cost for the filling medium	€ m^{-3}
$l_{C,waterpr}$	landscape	Cardinal	parametric cost for the waterproofing (including geotextile)	€ m^{-2}
$l_{C,land}$	landscape	Cardinal	parametric cost for the land acquisition	€ m^{-2}
$l_{C,pers}$	landscape	Cardinal	parametric cost of unskilled personnel	€ h^{-1}
d_q	design	Cardinal	Hydraulic loading rate	m^3 y^{-1} ha^{-1}
$d_{pt,tertiary}$	design	Binary	NBS for tertiary treatment	0 no 1 yes
$d_{hybrid\ SSF+SF\ cw}$	design	Binary	Hybrid constructed wetland mixing surface and subsurface flow systems	0 no 1 yes
$d_{prim,grey}$	design	Binary	Primary treatment with grey infrastructure	0 no 1 yes
$d_{v,emer}$	design	Binary	Only emergent vegetation	0 no 1 yes
d_{ratio}	design	Cardinal	NBS aspect ratio (cardinal, length/width)	dimensionless
d_{substr}	design	Binary	Use of substrates additional to soil to enhance the performance (e.g. gravel, sand, zeolites, woodchip)	0 no 1 yes
d_w	design	Cardinal	Buffer strip width	m
$d_{v,herb}$	design	Binary	Buffer strip with presence of herbaceous vegetation	0 no 1 yes
$d_{V,drought}$	design	Cardinal	Volume of the NBS for drought response	m^3

Variable	Category	Type	Description	Unit
			$$d_{V,drought} = d_{\phi}\left(\sqrt{d_A} - 2\frac{d_{h,drought} - d_{h,sed}}{\tan d_{\alpha}}\right)^2$$	
d_{ϕ}	design	Cardinal	NBS apparent porosity	dimensionless
d_A	design	Cardinal	NBS surface area	ha or m^2
$d_{A,bottom}$	design	Cardinal	NBS bottom surface area	m^2
$d_{A,pre}$	design	Cardinal	NBS area dedicated to the pre-treatment stage of harvested rainwater for drought response	m^2
$d_{A,MAR}$	design	Cardinal	NBS area dedicated to MAR	m^2
d_h	design	Cardinal	NBS height	m
d_L	design	Cardinal	NBS length	m
d_W	design	Cardinal	NBS width	m
$d_{W,exc}$	design	Cardinal	NBS width of excavation	m
$d_{A,exc}$	design	Cardinal	NBS area of excavation	m^2
$d_{h,drought}$	design	Cardinal	NBS height dedicated to drought response	m
$d_{h,pre}$	design	Cardinal	NBS height dedicated to the pre-treatment stage of harvested rainwater for drought response	m
$d_{h,sed}$	design	Cardinal	NBS height of accumulated sediment	m
$d_{h,f}$	design	Cardinal	height for additional volume for flood mitigation	m
$d_{h,MAR}$			NBS height dedicated to MAR	m
d_{α}	design	Cardinal	NBS side slope	°
$d_{NBS\ area\ ratio,drought}$	design	Cardinal	NBS area to watershed ratio for drought response	dimensionless
$d_{NBS\ area\ ratio,pre}$	design	Cardinal	NBS area to watershed ratio for pre-treatment	dimensionless
$d_{NBS,gross}$	design	Cardinal	NBS gross/net area coefficient	dimensionless
$d_{ET,NBS,m}$	design	Cardinal	Monthly NBS evapotranspiration	m^3 $month^{-1}$
d_{k_p}	design	Cardinal	NBS evapotranspiration loss coefficient	dimensionless
$d_{R,y}$	design	Cardinal	Runoff volume entering the NBS $$d_{R,y} = \frac{\left(c_p - 0.2\,l_S\right)^2}{\left(c_p + 0.8\,l_S\right)}\,l_{A,NO\ NBS}$$	m^3 $year^{-1}$
$d_{I,NBS\ MAR,y}$	design	Cardinal	yearly infiltration capacity of the infiltration NBS $$d_{I,NBS\ MAR,y} = \frac{d_{NBS\ area\ ratio}\ l_{A\_pixel\_suit}\ d_{HLR}}{d_{NBS,gross}\ d_{F\_c}}$$	m^3 $year^{-1}$
d_{F_c}	design	Cardinal	clogging factor	dimensionless
d_{HLR}	design	Cardinal	hydraulic loading rate	m^3 $year^{-1}$ ha^{-1} for NBS A

Variable	Category	Type	Description	Unit
				m year^{-1} for NBS C
$d_{n,NBS\ drought}$	design	Cardinal	n° of NBS for drought response in the pixel	dimensionless
d_{PLR}	design	Cardinal	Total phosphorous loading rate	ton_P y^{-1} ha^{-1}
d_{SLR}	design	Cardinal	Solid loading rate	ton_TSS y^{-1} ha^{-1}
$d_{N-NO3\ LR}$	design	Cardinal	Nitrate loading rate	tonNO_3^-_N year^{-1} ha^{-1}
$d_{R,Tr\ 1}$	design	Cardinal	Runoff volume entering the NBS $d_{R,y} = \frac{\left(c_{p,Tr\ 1} - 0.2\ l_S\right)^2}{\left(c_{p,Tr\ 1} + 0.8\ l_S\right)}\ l_{A,NO\ NBS}$	m^3 event^{-1}
d_{biom}	design	Cardinal	Amount of produced biomass	$g_{d.w.}$
$d_{mean\ biom}$	design	Cardinal	above-ground mean biomass production at max growth	$g_{d.w.}$/m^2
d_{cov}	design	Cardinal	plant coverage coefficient of the NBS	dimensionless
$d_{biom,y}$	design	Cardinal	age of max. biomass growth	years
d_{HHV}	design	Cardinal	high-heating value	MJ/$kg_{d.w}$
$d_{V,exc}$	design	Cardinal	excavation volume	m^3
$d_{V,exc,pre}$	design	Cardinal	excavation volume for pre-treatment	m^3
$d_{V,exc,MAR}$	design	Cardinal	excavation volume dedicated to MAR	m^3
$d_{V,med}$	design	Cardinal	filling medium volume	m^3
d_A	design	Cardinal	NBS area	m^2
$d_{A,land}$	design	Cardinal	acquisition area	m^2
$d_{C,consult}$	design	Cardinal	percentage of the working costs that indicates the technical investigation and consultancy costs	%
$d_{C,c1}$	design	Cardinal	corrective coefficient for NBS CAPEX	dimensionless
$d_{C,c2}$	design	Cardinal	corrective coefficient for CAPEX of the primary treatments	dimensionless
$d_{C,c3}$	design	Cardinal	corrective coefficient for NBS OPEX	
$d_{C,c4}$	design	Cardinal	corrective coefficient for OPEX of the primary treatments	
$d_{C,n,h,trees}$	design	Cardinal	equivalent unskilled personnel working hours for trees plantation	m^{-2}
$d_{C,n,h,rg}$	design	Cardinal	equivalent unskilled personnel working hours for reed and green maintenance	m^{-2} y^{-1}
$d_{C,n,h,pers}$	design	Cardinal	parametric number of annual personnel working hours for the checking	m^{-2} y^{-1}

ANNEX 2: Definition of design variable for favourability and opportunity maps

Table 20. Set of design parameters for each NBS type, categories, and sub-category

NBS Type	**NBS category**	**NBS sub-category**	**Design parameters**
NBS A1 – wetland	NBS A1.1 – SF	NBS A1.1.1 – SF only emergent vegetation	— $d_{HLR} = 35\ \mathrm{m^3 y^{-1} ha^{-1}} 1000^{-1}$ (a) (variable a – only favourability maps) — $d_{pt,tertiary} = 0$ — $d_{hybrid\ SSF+SF\ cw} = 0$ — $d_{v,emer} = 1$ — $d_A = 0.08\ \mathrm{ha}$ (b) (variable a – only favourability maps) — $d_{PLR} = 1.3\ \mathrm{tonP\ y^{-1} ha^{-1}}$ (c) — $d_{cov} = 0.7$ — $d_h = 0.3\ \mathrm{m}$ (p) — $d_{h,f} = 0.0\ \mathrm{m}$ — $d_{SLR} = 17\ \mathrm{tonTSS\ y^{-1} ha^{-1}}$ (u) — $d_{prim,grey} = 0$
		NBS A1.1.2 – SF mixed vegetation	— $d_{HLR} = 35\ \mathrm{m^3 y^{-1} ha^{-1}} 1000^{-1}$ (a) (variable a – only favourability maps) — $d_{pt,tertiary} = 0$ — $d_{hybrid\ SSF+SF\ cw} = 0$ — $d_{v,emer} = 0$ — $d_A = 0.08\ \mathrm{ha}$ (b) (variable a – only favourability maps) — $d_{PLR} = 1.3\ \mathrm{tonP\ y^{-1} ha^{-1}}$ (c) — $d_{cov} = 0.7$ — $d_h = 0.3\ \mathrm{m}$ (p) — $d_{h,f} = 0.0\ \mathrm{m}$

NBS Type	NBS category	NBS sub-category	Design parameters
			— $d_{SLR} = 17\ \text{tonTSS}\ \text{y}^{-1}\text{ha}^{-1}$ (u) — $d_{prim,grey} = 0$
	NBS A1.2 – hybrid SF + SSF	NBS A1.2.1 – SF only emergent vegetation	— $d_{HLR} = 35\ \text{m}^3\text{y}^{-1}\text{ha}^{-1}1000^{-1}$ (a) (variable a – only favourability maps) — $d_{pt,tertiary} = 0$ — $d_{hybrid\ SSF+SF\ cw} = 1$ — $d_{v,emer} = 1$ — $d_A = 0.08\ \text{ha}$ (b) (variable a – only favourability maps) — $d_{PLR} = 1.3\ \text{tonP}\ \text{y}^{-1}\text{ha}^{-1}$(c) — $d_{cov} = 0.85$(m) — $d_h = 0.6\ \text{m}$ (p) — $d_{h,f} = 0.0\ \text{m}$ — $d_{SLR} = 17\ \text{tonTSS}\ \text{y}^{-1}\text{ha}^{-1}$ (u) — $d_{prim,grey} = 0$
		NBS A1.2.2 – SF mixed vegetation	— $d_{HLR} = 35\ \text{m}^3\text{y}^{-1}\text{ha}^{-1}1000^{-1}$ (a) (variable a – only favourability maps) — $d_{pt,tertiary} = 0$ — $d_{hybrid\ SSF+SF\ cw} = 1$ — $d_{v,emer} = 0$ — $d_A = 0.08\ \text{ha}$ (b) — $d_{PLR} = 1.3\ \text{tonP}\ \text{y}^{-1}\text{ha}^{-1}$ (c) — $d_{cov} = 0.85$(m) — $d_h = 0.6\ \text{m}$ (p) — $d_{h,f} = 0.0\ \text{m}$ — $d_{SLR} = 17\ \text{tonTSS}\ \text{y}^{-1}\text{ha}^{-1}$ (u) — $d_{prim,grey} = 0$

NBS Type	NBS category	NBS sub-category	Design parameters
NBS B1 – free water surface wetland (FWS)	no categories	no sub-category	— $d_{ratio} = 5$ (d) — $d_{v,emer} = 1$ — $d_{substr} = 0$ — $d_{NO3-N\,LR} = 1.68\,\mathrm{tonNO_3^- - N\,y^{-1}ha^{-1}}$ (e) (variable a – only favourability maps) — $d_{cov} = 0.7$ — $d_h = 0.3\,\mathrm{m}$ (q) — $d_{h,f} = 1.0\,\mathrm{m}$
NBS B2 – vegetated drainage ditch (VDD)	no categories	no sub-category	— $d_{ratio} = 75$ (f) — $d_{v,emer} = 1$ — $d_{substr} = 0$ — $d_{NO3-N\,LR} = 1.68\,\mathrm{tonNO_3^- - N\,y^{-1}ha^{-1}}$ (e) (variable a – only favourability maps) — $d_{cov} = 0.7$ — $d_h = 0.5\,\mathrm{m}$ (r) — $d_W = 2.7\,\mathrm{m}$ (s) — $d_{W,exc} = 1.0\,\mathrm{m}$ (t) — $d_{h,f} = 0.0\,\mathrm{m}$
NBS B3 – buffer strip (BS)	NBS B3.1 – BS - R	NBS B3.1.1 – with herbaceous vegetation	— $d_w = 9\,\mathrm{m}$ (g) (variable a – only favourability maps) — $d_{v,herb} = 1$ — $d_{h,f} = 0.0\,\mathrm{m}$
		NBS B3.1.2 – without herbaceous vegetation	— $d_w = 9\,\mathrm{m}$ (g) (variable a – only favourability maps) — $d_{v,herb} = 0$ — $d_{cov} = 1$ — $d_{h,f} = 0.0\,\mathrm{m}$

NBS Type	**NBS category**	**NBS sub-category**	**Design parameters**
	NBS B3.2 – BS - G	no sub-category	— No need to define design parameters for favourability maps — $d_{cov} = 1.0$ — $d_{h,f} = 0.0\ \mathrm{m}$
	NBS B3.3 – BS - Integrated	NBS B3.3.1 – with herbaceous vegetation Same performance of BS-R	— $d_w = 9\ \mathrm{m}$ (g) (variable a – only favourability maps) — $d_{v,herb} = 1$ — $d_{cov} = 0.85$(n) — $d_{h,f} = 1.0\ \mathrm{m}$
	NBS B3.3 – BS - Integrated	NBS B3.3.2 – without herbaceous vegetation Same performance of BS-R	— $d_w = 9\ \mathrm{m}$ (g) (variable a – only favourability maps) — $d_{v,herb} = 0$ — $d_{cov} = 0.85$(n) — $d_{h,f} = 1.0\ \mathrm{m}$
NBS C1 – Storage	NBS C1.1 – Storage pond	NBS C1.1.1 – Storage pond (shallow)	— $d_{\phi} = 1$ — $d_A = 700\ \mathrm{m}^{2}$(h) (variable a – only favourability maps) — $d_{h,drought} = 2.5\ \mathrm{m}$ — $d_{h,sed} = 0.3\ \mathrm{m}$ (i) — $d_{\alpha} = 45°$ — $d_{k\_p} = 0.6$ — $d_{NBS\ area\ ratio,drought} = 4\%$ (j) — $d_{NBS\ area\ ratio,pre} = 0\%$ — $d_{NBS,gross} = 2$ — $d_{h,f} = 1.0\ \mathrm{m}$

NBS Type	NBS category	NBS sub-category	Design parameters
		NBS C1.1.2 – Storage pond (deep)	— $d_{\phi} = 1$ — $d_A = 700\ \mathrm{m}^2$(h) (variable a – only favourability maps) — $d_{h,drought} = 5\ \mathrm{m}$ — $d_{h,sed} = 0.3\ \mathrm{m}$ (i) — $d_{\alpha} = 45°$ — $d_{k\_p} = 0.6$ — $d_{NBS\ area\ ratio,drought} = 4\%$ (j) — $d_{NBS\ area\ ratio,pre} = 0\%$ — $d_{NBS,gross} = 2$ — $d_{h,f} = 1.0\ \mathrm{m}$
	NBS C1.2 – Pre-treatment pond + Storage pond	NBS C1.2.1 – Pre-treatment pond + Storage pond (shallow)	— $d_{\phi} = 1$ — $d_A = 700\ \mathrm{m}^2$(h) (variable a – only favourability maps) — $d_{h,drought} = 2.5\ \mathrm{m}$ — $d_{h,sed} = 0\ \mathrm{m}$ — $d_{\alpha} = 45°$ — $d_{k\_p} = 0.6$ — $d_{NBS\ area\ ratio,drought} = 3.5\%$ (k) — $d_{NBS\ area\ ratio,pre} = 0.5\%$ (k) — $d_{h,pre} = 1.0\ \mathrm{m}$ (k) — $d_{NBS,gross} = 2$ — $d_{h,f} = 1.0\ \mathrm{m}$
		NBS C1.2.2 – Pre-treatment pond + Storage pond (deep)	— $d_{\phi} = 1$ — $d_A = 700\ \mathrm{m}^2$(h) (variable a – only favourability maps)

NBS Type	NBS category	NBS sub-category	Design parameters
			— $d_{h,drought} = 5\ \mathrm{m}$ — $d_{h,sed} = 0\ \mathrm{m}$ — $d_{\alpha} = 45°$ — $d_{k\_p} = 0.6$ — $d_{NBS\ area\ ratio,drought} = 3.5\%$ (k) — $d_{NBS\ area\ ratio,pre} = 0.5\%$ (k) — $d_{h,pre} = 1.0\ \mathrm{m}$ (k) — $d_{NBS,gross} = 2$ — $d_{h,f} = 1.0\ \mathrm{m}$
	NBS C1.3 – Pre-treatment wetland + Storage pond	NBS C1.3.1 – Pre-treatment wetland + Storage pond (shallow)	— $d_{\phi} = 1$ — $d_A = 700\ \mathrm{m}^{2}$(h) (variable α – only favourability maps) — $d_{h,drought} = 2.5\ \mathrm{m}$ — $d_{h,sed} = 0\ \mathrm{m}$ — $d_{\alpha} = 45°$ — $d_{k\_p} = 0.6$ — $d_{NBS\ area\ ratio,drought} = 3\%$ (l) — $d_{NBS\ area\ ratio,pre} = 1.0\%$ (l) — $d_{h,pre} = 0.5\ \mathrm{m}$ (l) — $d_{NBS,gross} = 2$ — $d_{cov} = 0.7$(o) — $d_{h,f} = 1.0\ \mathrm{m}$
		NBS C1.3.2 – Pre-treatment wetland + Storage pond (deep)	— $d_{\phi} = 1$ — $d_A = 700\ \mathrm{m}^{2}$(h) (variable α – only favourability maps)

NBS Type	NBS category	NBS sub-category	Design parameters
			— $d_{h,drought} = 5\ \mathrm{m}$ c — $d_{h,sed} = 0\ \mathrm{m}$ — $d_{\alpha} = 45°$ — $d_{k\_p} = 0.6$ — $d_{NBS\ area\ ratio,drought} = 3\%$ (l) — $d_{NBS\ area\ ratio,pre} = 1\%$ (l) — $d_{h,pre} = 0.5\ \mathrm{m}$ (l) — $d_{NBS,gross} = 2$ — $d_{cov} = 0.7$(o) — $d_{h,f} = 1.0\ \mathrm{m}$
NBS C2 – MAR	NBS C2.1 – Infiltration pond	NBS C2.1 – Infiltration pond (high infiltration)	— $d_{NBS\ area\ ratio,drought} = 4\%$ (j) (variable a – only favourability maps) — $d_{NBS\ area\ ratio,pre} = 0\%$ — d_{HLR} ○ 30 m year^{-1}-sandy loam ○ 100 m year^{-1}-loamy sand and silt ○ 300 m year^{-1}-sand — d_{F_c}=1 — $d_{NBS,gross} = 2$ — $d_{h,f} = 1.0\ \mathrm{m}$ — $d_{h,MAR} = 1.0\ \mathrm{m}$
		NBS C2.2 – Infiltration pond (low infiltration)	— $d_{NBS\ area\ ratio,drought} = 4\%$(j) (variable a – only favourability maps) — $d_{NBS\ area\ ratio,pre} = 0\%$ — d_{HLR}

NBS Type	NBS category	NBS sub-category	Design parameters
			○ 30 m year^{-1}-sandy loam ○ 100 m year^{-1}-loamy sand and silt ○ 300 m year^{-1}-sand — d_{F_c}=10 — $d_{NBS,gross} = 2$ — $d_{h,f} = 1.0$ m — $d_{h,MAR} = 1.0$ m
	NBS C2.2 – Pre-treatment pond + Infiltration pond		— $d_{NBS\ area\ ratio,drought} = 3.5\%$ (k) (variable a – only favourability maps) — $d_{NBS\ area\ ratio,pre} = 0.5\%$ (k) — $d_{h,pre} = 1.0$ m (k) — d_{HLR} ○ 30 m year^{-1}-sandy loam ○ 100 m year^{-1}-loamy sand and silt ○ 300 m year^{-1}-sand — d_{F_c}=1 — $d_{NBS,gross} = 2$ — $d_{h,f} = 1.0$ m — $d_{h,MAR} = 1.0$ m
	NBS C2.3 – Pre-treatment wetland + Infiltration pond		— $d_{NBS\ area\ ratio,drought} = 3\%$ (l) (variable a – only favourability maps) — $d_{NBS\ area\ ratio,pre} = 1.0\%$ (l) — $d_{h,pre} = 0.5$ m (l) — d_{HLR} ○ 30 m year^{-1}-sandy loam

NBS Type	NBS category	NBS sub-category	Design parameters
			○ 100 m year^{-1}-loamy sand and silt ○ 300 m year^{-1}-sand — d_{F_c}=1 — $d_{NBS,gross} = 2$ — $d_{cov} = 0.7^{(o)}$ — $d_{h,f} = 1.0$ m — $d_{h,MAR} = 1.0$ m
	NBS C2.4 – Infiltration wooded area		— $d_{NBS\ area\ ratio,drought} = 4\%$ (j) (variable a – only favourability maps) — $d_{NBS\ area\ ratio,pre} = 0.0\%$ — d_{HLR} ○ 30 m year^{-1}-sandy loam ○ 100 m year^{-1}-loamy sand and silt ○ 300 m year^{-1}-sand — d_{F_c}=10 — $d_{NBS,gross} = 2$ — $d_{cov} = 1.0$ — $d_{h,f} = 1.0$ m — $d_{h,MAR} = 1.0$ m

(a) Median (50th percentile) value from the dataset (37 samples)
(b) Median (50th percentile) value from the dataset (113 samples)
(c) Median (50th percentile) value from the dataset (34 samples)
(d) Median (50th percentile) value from the dataset (67 FWS samples)
(e) Median (50th percentile) value from the dataset (42 samples)
(f) Median (50th percentile) value from the dataset (28 VDD samples)
(g) Median (50th percentile) value from the dataset (93 BS-R samples)
(h) Median (50th percentile) value from the dataset (61 samples)
(i) Median (50th percentile) value from the dataset (7 samples) – after 20 years
(j) Median (50th percentile) value from the dataset (13 samples)

(k) Median (50th percentile) value from the dataset (13 samples) minus 0.5% (about 1/10 of the total available area) for the pre-treatment pond. The forebay inlet for TSS sedimentation varies between 10 to 45% of the surface area (Kadlec and Wallace, 2009)

(l) Median (50th percentile) value from the dataset (13 samples) minus 1.0% (1/4 of the total available area) for the pre-treatment wetland. The forebay inlet for TSS sedimentation varies between 10 to 45% of the surface area (Kadlec and Wallace, 2009)

(m) Average value between surface (0.7) and subsurface (1.0)

(n) Average value between surface wetland (0.7) and wood (1.0)

(o) To be applied only on the wetland area

(p) Median (50th percentile) for SFs and 3rd quartile (75th percentile) value from the dataset (96 samples), since SSF wetland systems are usually deeper than SF ones (Kadlec and Wallace, 2009)

(q) Median (50th percentile) value from the dataset (73 samples)

(r) Median (50th percentile) value from the dataset (22 samples)

(s) Median (50th percentile) value from the dataset (28 samples)

(t) Assuming 1 meter of excavation to enlarge the ditch, in order to maintain the hydraulic efficiency after the plantation (assuming the ditches unplanted)

(u) Median (50th percentile) value from the dataset (22 samples)