4 Carbon sequestration

4.1 Overview

Vegetation provides an important climate regulating service by sequestering carbon from the atmosphere and converting it into biomass. Carbon sequestration in biomass decreases the amount of carbon in the atmosphere and therefore helps to mitigate further climate change. The models indicate the potential and actual carbon sequestration in biomass and the avoided monetary damage costs based on carbon sequestration in forests.
Three output maps for the ecosystem service 'carbon sequestration' have been developed for the Atlas of Natural Capital (see Table 4.1). The output map has been produced by combining existing spatial data for the Netherlands with maps developed by RIVM for the Natural Capital Model. Tables 4.1 and 4.2 provide an overview of the input and output maps for the ecosystem service model 'carbon sequestration'.

Table 4.1. Output maps generated for the ecosystem service 'carbon sequestration'.

Output map	Unit	Short description
Potential carbon sequestration in biomass	Ton C ha^{-1} yr^{-1}	The amount of carbon that can potentially be sequestered in biomass.
Actual carbon sequestration in biomass	Ton C ha^{-1} yr^{-1}	The current level of carbon sequestered in woody biomass.
Monetary value carbon sequestration in biomass	€ ha^{-1} yr^{-1}	The monetary value of the current level of carbon sequestered in woody biomass.

Table 4.2. Input maps applied to estimate the ecosystem service 'carbon sequestration'.

Input	Unit	Short description	Source
Biophysical suitability for wood production	Score between 0 and 1	Indicates the biophysical suitability for wood production based on soil characteristics and groundwater table.	Natural Capital Model (see Section 2.2.4)
Potential wood production	m^3 wood ha^{-1} yr^{-1}	Potential wood production	Natural Capital Model (see Section 2.2.3)
Ecosystem unit map	Ecosystem unit classes	Ecosystem unit classes map for the Netherlands in 2013	CBS 2017

4.2 Modelling the ecosystem service

The ecosystem service 'carbon sequestration' results in three output maps. The modelling of these three maps is described in the following sections. Figure 4.1 provides a schematic overview of the way input data has been modelled in order to produce the output maps for the ecosystem service 'carbon sequestration'.

4.2.1 *Monetary value carbon sequestration in biomass*

Carbon sequestration reduces the amount of CO_2 in the atmosphere that could further enhance climate change. The reduction of CO_2 therefore leads to avoided damages. These avoided damages can be monetized, as has been done by Aertsen et al. (2012) in a Flemish study. Aertsen et al. (2012) valued avoided damage costs at €20/ton CO_2 [in 2010 €], which is equivalent to €73.20/ton C (molecular conversion rate of 3.66). This equals €80.98/ton C when converted to 2016 € value. This value is used in this model, but it should be noted that avoided damage costs for carbon vary widely in literature (see, for example, Anthoff & Tol, 2013 and Nordhaus, 2017). The amount of carbon sequestered in a certain forest area is multiplied by the avoided damage costs per ton C to obtain the monetary value for that area, as follows (see also Function 3 in Figure 4.1):

$$\boldsymbol{Monetary\ value\ of\ carbon\ sequestration} \\ = \mathbf{80.98} \times \boldsymbol{Actual\ carbon\ sequestration}$$

This calculation results in the map 'Monetary value carbon sequestration in biomass'.

4.2.2 *Actual carbon sequestration in biomass*

The actual carbon sequestration in biomass is the amount of carbon that is actually sequestered by forests on an annual basis. For this calculation only, forested areas (as delineated by the LCEU map) are used; all other areas are excluded from the calculation. Three LCEU forest types are used for the model: coniferous forests, deciduous forests and mixed forests. To determine the actual carbon sequestration in forests, information is needed on the annual increment of biomass in the forest in a certain location, the carbon density of the forest and the ratio of the total biomass of a tree type (including branches, roots, etc.) compared with the stem. The annual carbon sequestration is calculated as follows (see also Function 2 in Figure 4.1):

$$\boldsymbol{Actual\ carbon\ sequestration} = \boldsymbol{BEF} \times \boldsymbol{C_{density}} \times \boldsymbol{Potential\ wood\ production}$$

Where

- *BEF* is the biomass expansion factor of a forest type. The BEF describes the expansion of the total biomass of a tree (including branches and roots) in relation to the annual increment of the stem biomass.
- $C_{density}$ is the carbon density factor of a forest (ton C/m^3).
- *Potential wood production* is an output map of the wood production model (see Section 2.2.3 for the model description). This map shows the potential wood production that can be acquired in a certain area.

The potential wood production calculation is used as the model and carries the assumption that carbon is maintained in both standing stock, as well as harvested wood. This assumption can be debated, as not all harvested wood may be left intact in the long term. To obtain the BEF and carbon density of the different forest types, data on the characteristics of different tree species was used based on the 6th Dutch Forest Inventory (Schelhaas & Clerkx 2015) and Van de Walle et al. 2005), see Table 4.3 for details. Mixed forests are calculated based on a 50/50 ratio between coniferous and deciduous forests.

Table 4.3. Characteristics of coniferous, deciduous and mixed forests, based on the characteristics of Dutch tree types.

Forest type	Cover (%)*	Biomass expansion factor (BEF)**	BEF above ground **	Wood density (t dry matter/ m^3) **	Carbon content (t C/t dry matter) **	Carbon density (ton C/m^3)
Pine	33.6	1.50	1.32	0.48	0.50	
Douglas fir	5.1	1.71	1.28	0.45	0.50	
Larch	4.9	1.75	1.30	0.47	0.50	
Spruce	3.4	1.75	1.29	0.38	0.50	
Other coniferous	0.9	1.75	1.33	0.40	0.50	
Coniferous forest	47.9	1.57	1.31	0.47	0.50	0.28
Beech	4.1	1.67	1.34	0.56	0.49	
Oak	19.5	1.50	1.32	0.60	0.50	
Poplar	3.3	1.50		0.41	0.50	
Mixed noble	4.5	1.50	1.29	0.59	0.50	
other deciduous	13.3	1.50	1.32	0.55	0.50	
Deciduous forest	44.7	1.52	1.32	0.57	0.50	0.23
Mixed forest	-	-	-	-	-	0.26

*Schelhaas & Clerkx 2015
**Van de Walle et al. 2005

4.2.3 *Potential carbon sequestration in biomass*

Parallel to the actual carbon sequestration, the potential carbon sequestration is also modelled. This calculation eliminates the restriction to calculate only areas that are currently forest and calculates the maximum possible carbon sequestration in the whole of the Netherlands if the most suitable type of forest were to grow in a given location. The calculation uses information from Table 4.3 and is as follows (see also Function 1 in Figure 4.1):

$$\boldsymbol{Potential\ carbon\ sequestration} = \boldsymbol{BEF} \times \boldsymbol{C_{density}} \times \boldsymbol{Suitability\ for\ wood\ production}$$

Where

- *BEF* is the biomass expansion factor of a forest type. The BEF describes the expansion of the total biomass of a tree (including branches and roots) in relation to the annual increment of the stem biomass.
- $C_{density}$ is the carbon density factor of a forest (ton C/m^3).
- *Suitability for wood production* is an output map of the wood production model (see Section 2.2.4 for the model description). This map shows the potential wood production that can be acquired in a certain area.

4.3 Remarks and potential model improvements

- The monetary value of avoided damage costs related to carbon sequestration vary widely in (academic) literature and a more thorough assessment should be done to check whether the current value is the most appropriate.
- RIVM has developed a method to map carbon sequestration based on satellite imagery, which is most suitable to assess past and present carbon sequestration. To predict carbon sequestration based on future changes, the current model is more suitable.

4.4 References

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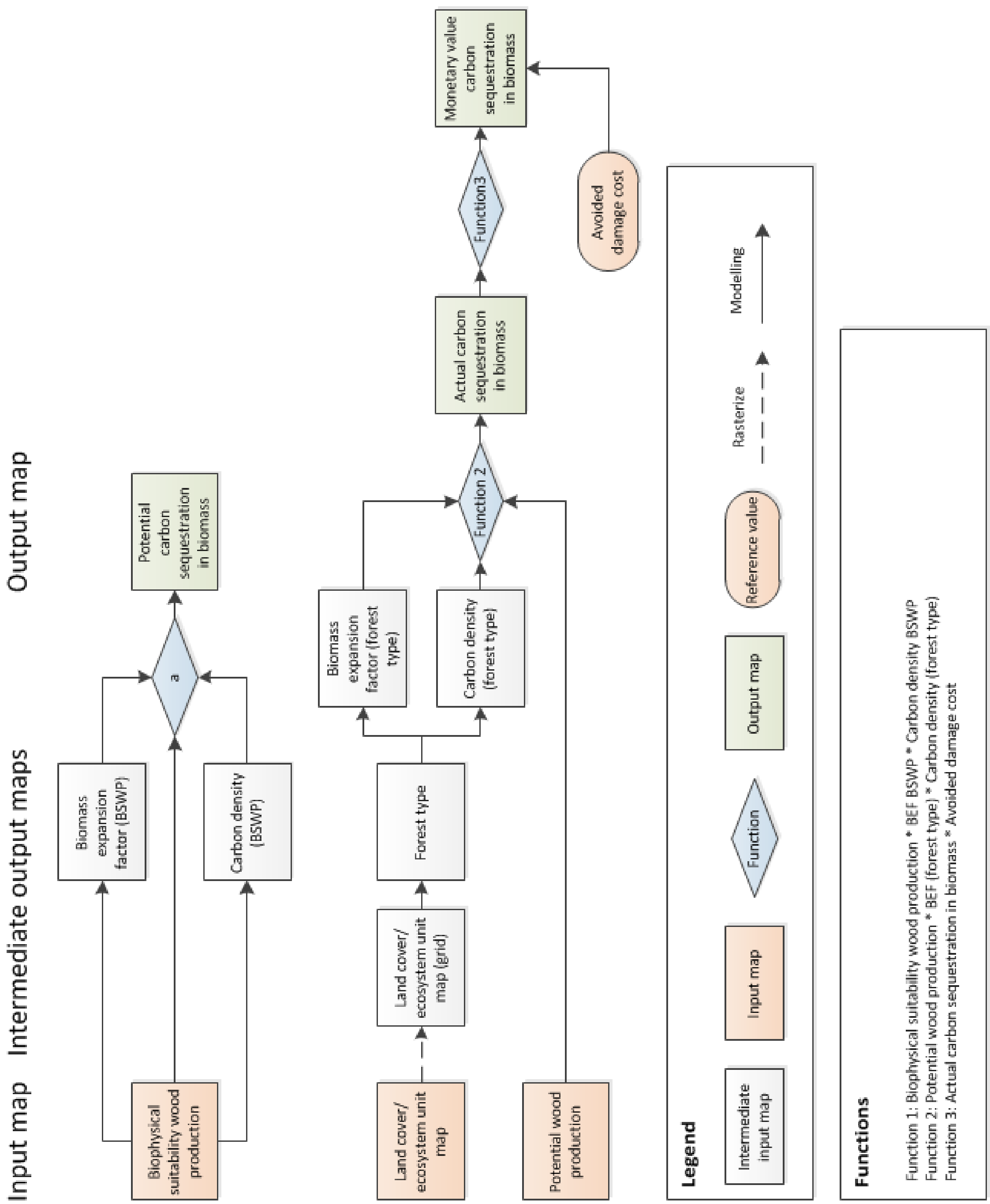

Figure 4.1 Schematic overview of the ‘carbon sequestration’ model.