3 Biomass for energy

3.1 Overview

Biomass is the general name given to organic material from plants and animals. Nature produces biomass in the form of wood and plants, for example. The agricultural industry also produces biomass in forms such as animal feed, crop residues, straw and manure. Biomass may be in an unprocessed form (e.g. tree trunks) or a processed form (furniture or paper). Biomass can be used for a variety of purposes, including agricultural fertilization, manufacturing and energy generation. This model focusses on the use of biomass for energy production purposes. The energy extracted from biomass is known as bio-energy and it may be used as electricity, heat or gas. Biomass-based energy is obtained by the combustion, gasification or fermentation of the biomass. Biomass that people eat is not referred to within the ecosystem service classification system as biomass, but rather as food, and is not included in this sub-model.

At the current stage, five output maps (i.e. actual production from crops, actual production from forests, potential energy production from crops, potential energy production from cultivated grassland, potential energy production from forests) have been produced for the Atlas of Natural Capital for the ecosystem service 'biomass for energy'. Tables 3.1 and 3.2 provide an overview of the input and output maps to model the ecosystem service 'biomass for energy production'. These maps have been produced to show what the capacity of an area is for energy production from biomass (potential maps) given the environmental characteristics and how much is actually being produced in an area (actual production). The potential biomass production maps are included in the model output to provide insight into which areas can potentially provide higher service flows, which can facilitate spatial planning processes.

Table 3.1. Output maps generated for the ecosystem service 'biomass for energy'.

Output map	Unit
Potential energy production from crops	GJ/Ha·yr
Potential energy production from cultivated grassland	GJ/Ha·yr
Potential energy production from forests	GJ/Ha·yr
Actual energy production from crops	GJ/Ha·yr
Actual energy production from forests	GJ/Ha·yr

Table 3.2. Input maps applied to estimate the ecosystem service 'biomass for energy'.

Input	Unit	Short description	Source
Agricultural crop parcels	Land cover types for crops	Crops produced on agricultural fields	RVO 2013
Biophysical suitability crops	Score between 0 and 1	Biophysical suitability for crop production based on soil characteristics and groundwater level.	Natural Capital Model (Remme 2017)
Biophysical suitability grassland	Score between 0 and 1	Biophysical suitability values for grass production based on soil characteristics and groundwater level.	Natural Capital Model (Remme 2017)
Potential wood production	m^3 wood ha^{-1} yr^{-1}	Potential wood production	Natural Capital Model (see Section 2.2.3)
Actual wood production	m^3 wood ha^{-1} yr^{-1}	Actual wood production	NKN (see Section 2.2.2)
Ecosystem unit map	Ecosystem unit classes	Ecosystem unit classes map for the Netherlands in 2013	CBS 2017

3.2 Modelling the ecosystem service

The service biomass for energy production results in five output maps. The modelling of these maps is based on the NARA study conducted by Van Kerckvoorde & Van Reeth (2014) and is the described in the following sections. Figure 3.1 provides a schematic overview of the way input data has been modelled in order to produce the output maps for this ecosystem service.

3.2.1 Potential energy production from crops and cultivated grassland

The potential energy production from crops and permanent cultivated grassland is estimated according to (Function 1 and Function 2, Figure 3.1):

$$\boldsymbol{Potential\ energy\ production = Biophysical\ suitability \times energy\ content}$$

The biophysical suitability maps for crops and permanent grassland form an output from the ecosystem service 'food production' (see Remme, 2017 for technical description). The biophysical suitability maps show the suitability of areas for crop production based on soil characteristics and groundwater level, regardless of the current land use. The energy content for permanent grassland is 111.2 GJ/ha according to the Phyllis database (www.ecn.nl/phyllis). For crops, the energy content is

assumed to be 157.8 GJ/ha based on the average energy content of crops as shown is Table 3.3 (Van Kerckvoorde & Van Reeth 2014).

Table 3.3. Energy content of crops based on Van Kerckvoorde & Van Reeth (2014).

Crop type	Energy content GJ/ha
potatoes	207.5
rapeseed	95.4
maize (grains)	235.4
linseed	66.3
oil seeds (sunflower)	66.3
other cereals	130.9
maize (silo)	206.3
sugar beets	254.0

3.2.2 *Actual energy production from crops and cultivated grassland*

The actual energy production from crops and cultivated grassland is based on the maps for the potential energy production from crops and grassland and the parcels where these crops are currently being grown for energy production. The map filters out all other parcels that are currently not being used for energy crops. Given the map with agricultural crop parcels, the following crops have been selected as energy crops: miscanthus (elephant grass), linseed, rapeseed, maize for energy and fast-growing trees with short turnover time (e.g. willow coppice). Some crops, such as potatoes and sugar beets, have residual flows that are used for energy production. These are not included in this estimate.

3.2.3 *Potential energy production from forests*

The potential energy production from forests estimates the total annual energy increment of the aboveground biomass, except for the stem wood (stem wood and branches with a diameter > 7 cm). This estimate is based on the potential wood production in which the annual increase in stem wood is estimated for the optimal tree type given the local soil and drainage class. To estimate the potential energy production from forests, the following equation is used (Function 3, Figure 3.1):

$$\boldsymbol{Potential\ energy\ production} = \boldsymbol{Potential\ wood\ production} \times \boldsymbol{Wood\ energy\ content} \times \boldsymbol{Wood\ density} \times \boldsymbol{R2S}$$

Where:

- *Potential wood production* is the potential wood production in m3/ha.year as explained in Section 2.2.3
- *Wood energy content* is the wood energy content of 18 GJ/m³ (Van Kerckvoorde & Van Reeth 2014);
- *Wood density* is the applied average density of wood of 0.5 ton/m^3 (actually it should be 0.47 for coniferous, 0.57 for

deciduous and 0.52 for mixed stem wood according to Van Kerckvoorde & Van Reeth (2014));

- *R2S* is the rest to stem wood ratio, defined as the number of small branches with a diameter < 7 cm and leaves relative to the amount of stem wood. R2S can be estimated using the biomass expansion factor (BEF) as:
  (total wood – stem wood) / stem wood =
  (BEF * stem wood – stem wood) / stem wood= (BEF – 1)
  Given the average above-ground biomass expansion factor of 1.315 (Table 3.4 and Van de Walle et al., 2005), the R2S ratio becomes 0.315.

Table 3.4 Characteristics of coniferous, deciduous and mixed forests, based on characteristics of Dutch tree types.

Forest type	Cover (%)*	Biomass expansion factor (BEF)**	BEF above ground **
Pine	33.6	1.50	1.32
Douglas fir	5.1	1.71	1.28
Larch	4.9	1.75	1.30
Spruce	3.4	1.75	1.29
Other coniferous	0.9	1.75	1.33
Coniferous forest	47.9	1.57	1.31
Beech	4.1	1.67	1.34
Oak	19.5	1.50	1.32
Poplar	3.3	1.50	
Mixed noble	4.5	1.50	1.29
other deciduous	13.3	1.50	1.32
Deciduous forest	44.7	1.52	1.32
Mixed forest	-	-	-

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

3.2.4 *Actual energy production from forests*

The actual energy production from forests is estimated in the same way as the potential energy production from forests using the map with actual wood production in m^3/ha.year from Section 2.2.2, with a correction for the yield loss.
To estimate the actual energy production from forests, the following equation is used (Function 5, Figure 3.1):

$$\boldsymbol{Actual\ energy\ production} = \boldsymbol{Actual\ wood\ production} \times \boldsymbol{wood\ energy\ content} \times \boldsymbol{wood\ density} \times \boldsymbol{R2S\ ratio} \times (\mathbf{1} - \boldsymbol{yield\ loss})$$

Where:

- *Actual wood production* is the actual wood production in m^3/ha.year as explained in Section 2.2.2.
- *Wood energy content* is the wood energy content of 18 GJ/m^3 (Van Kerckvoorde & Van Reeth 2014)
- *Wood density* is the applied average density of wood of 0.5 ton/m^3 (actually it should be 0.47 for coniferous, 0.57 for deciduous and 0.52 for mixed stem wood according to Van Kerckvoorde & Van Reeth (2014))
- *R2S* is the rest to stem wood ratio, defined as the number of small branches with a diameter < 7 cm and leaves relative to the amount of stem wood. R2S can be estimated using the biomass expansion factor (BEF) as:

  (total wood – stem wood) / stem wood =
  (BEF * stem wood – stem wood) / stem wood= (BEF – 1)
- Given the average above-ground biomass expansion factor of 1.315 (Table 3.4 and Van de Walle et al., 2005) the R2S ratio becomes 0.315.
- *R2Yield loss* is a correction factor on the actual energy production for the small branches and leaves that cannot be harvested. A yield loss of 30% is applied.

3.3 References

- CBS 2017. Ecosystem Unit map, 2013. Available at https://www.cbs.nl/en-gb/background/2017/12/ecosystem-unit-map
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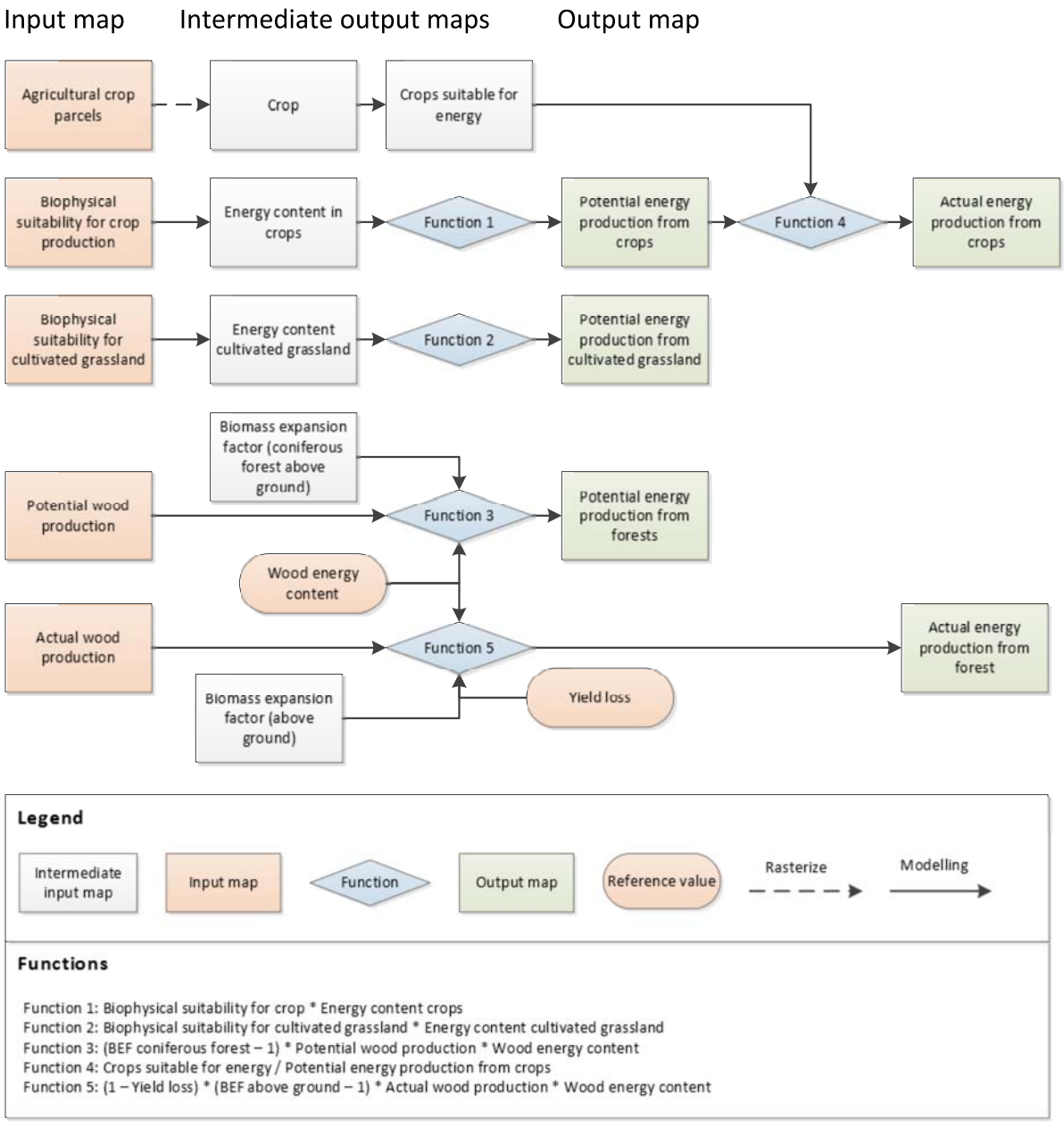

Figure 3.2 Schematic overview of 'biomass for energy' model