Green*ergy* Brazilian Bioethanol verification programme:

GHG Methodology

GHG DOC – 005 v.3 31 January 2011

1. Use of the default value

A default value for sugarcane ethanol of 24 gCO_{2eq}/MJ ethanol can be used as the total for cultivation, processing, transportation and distribution. This is equivalent to 71% GHG savings as compared with the fossil fuel equivalent.

This value is taken from Annex V of Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources. Amendments to the Directive relating to GHG shall be incorporated into the Green*ergy* Brazilian Bioethanol verification programme: GHG Methodology (GHG DOC – 005). If a case arises where the value differs between this document and the Directive, the Directive shall be taken as the reference point.

This default value may be used in lieu of actual values, where there is no land use change.

If there is land use change which is compliant with 'Greenergy bioethanol sustainability criteria for Brazilian sugarcane STD DOC – 002 v.5' I1.1.2, I1.1.3, I1.1.4, I2.2.1, I2.2.2, I2.2.3 and I2.2.4, the default value for cultivation may also be used, but it must be added to the actual value for land use change, as set out below. The results of this calculation shall be used to determine whether the land use is compliant with 'Greenergy bioethanol sustainability criteria for Brazilian sugarcane STD DOC – 002 v.5' I1.1.1.

The following formula is taken directly from the Annex V of Directive 2009/28/EC for calculating GHG emission savings from biofuels and bioliquids:

SAVING = $(E_F – E_B) / E_F$

Where

E_B = total emissions from the biofuel or bioliquid; and

E_F = total emissions from the fossil fuel comparator, which shall be the latest available actual average emissions from the fossil part of petrol and diesel consumed in the Community as reported under Directive 98/70/EC. If no such data are available, the value used shall be 83,8 gCO2eq/MJ.

Where no land use change, E_B = 24 gCO_{2eq}/MJ ethanol

Where there is land use change, the calculation of E_B shall be:

E_B = default value for cultivation (e_{ec})+ default value processing (e_p)+ default value transport and distribution (e_{td})+ actual value for LUC (e_l calculated as per the methodology in Section 2.0)

2. Calculating land use change

2.1 Formula for calculating total GHG emissions

If land use change takes place which is permitted under the 'Green*ergy* bioethanol sustainability criteria for Brazilian sugarcane STD DOC – 002', the following approach shall be used to calculate the GHG emissions.

The following formula is taken directly from the Annex V of Directive 2009/28/EC.

$E = e_{ec} + e_l + e_p + e_{td} + e_u - e_{sca} - e_{ccs} - e_{ccr} - e_{ee}$

Where

E = total emissions from the use of the sugarcane ethanol

e_{ec} = emissions from the cultivation of sugarcane

e_l = annualised emissions from carbon stock changes caused by land-use change

e_p = emissions from processing

e_{td} = emissions from transport and distribution

e_u = emissions from the fuel in use

e_{sca} = emission savings from soil carbon accumulation via improved agricultural management

e_{ccs} = emission saving from carbon capture and geological storage

e_{ccr} = emission saving from carbon capture and replacement

e_{ee}= emission saving from excess electricity from cogeneration

The values used for the calculation shall be as following:

e_{ec}= 14 gCO_{2eq}/MJ ethanol

e_l = where applicable, this shall be calculated as per section 2.2 below.

e_p= 1 gCO_{2eq}/MJ ethanol

e_{td}= 9 gCO_{2eq}/MJ ethanol

$e_{u,}$ e_{sca} $e_{ccr\ and}$ e_{ee} = 0

Units: In this formula, the unit given for emissions, E, is gCO_{2eq}/MJ liquid biomass.

2.2 GHG emissions for land use change e_l

The following section is taken from the COMMISSION DECISION of 10 June 2010 on guidelines for the calculation of land carbon stocks for the purpose of Annex V to Directive 2009/28/EC.

If there is evidence that no land use change has taken place since January 2008, then e_l = 0.

The carbon intensity from the impact of land-use change must be added to the fuel chain carbon default.

Where there is evidence of land use change identified as part of the field verification, a calculation of GHG emissions associated with land use change shall be undertaken using the following formula:

$e_l = (CS_R - CS_A) \times 3.664^1 \times 1/20 \times 1/P - e_B$

where

e_l = annualised greenhouse gas emissions from carbon stock change due to land-use change (measured as mass of CO_2-equivalent per unit biofuel energy);

CS_R = the carbon stock per unit area associated with the reference land use (measured as mass of carbon per unit area, including both soil and vegetation). The reference land use shall be the land use in January 2008 or 20 years before the raw material was obtained, whichever was the later;

CS_A = the carbon stock per unit area associated with the actual land use (measured as mass of carbon per unit area, including both soil and vegetation). In cases where the carbon stock accumulates over more than one year, the value attributed to *CSA* shall be the estimated stock per unit area after 20 years or when the crop reaches maturity, whichever the earlier;

P = the productivity of the crop (measured as biofuel or bioliquid energy per unit area per year);

e_B = bonus of 29 gCO_2eq/MJ biofuel or bioliquid if biomass is obtained from restored degraded land. Note that this cannot be included in the calculation until the EC has published the definition for degraded land.

Calculation can either be based on direct measurement of above and below ground carbon or default values for soil and vegetation types. These approaches are set out below.

2.2.1 Calculating carbon stock

For determining the carbon stock per unit area associated with CSR and CSA the following rules shall apply:

(1) The area for which the land carbon stocks are calculated shall for the entire area have similar

(a) biophysical conditions in terms of climate and soil type;

(b) management history in terms of tillage;

(c) input history in terms of carbon input to soil;

(2) The carbon stock of the actual land use, CSA, shall be taken as

– in the case of loss of carbon stock: the estimated equilibrium carbon stock that the land will reach in its new use;

– in the case of carbon stock accumulation: the estimated carbon stock after 20 years or when the crop reaches maturity, whichever the earlier.

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[1] The quotient obtained by dividing the molecular weight of CO_2 (44,010 g/mol) by the molecular weight of carbon (12,011 g/mol) is equal to 3,664.

For the calculation of CS_R and CS_A the following rule shall apply:

$CS_i = (SOC + C_{VEG}) \times A$

where

CS_i = the carbon stock per unit area associated with the land use i (measured as mass of carbon per unit area, including both soil and vegetation);

SOC = soil organic carbon (measured as mass of carbon per hectare),

C_{VEG} = above and below ground vegetation carbon stock (measured as mass of carbon per hectare),

A = factor scaling to the area concerned (measured as hectares per unit area).

2.2.1.1 Calculating soil organic stock

Mineral soils

For the calculation of SOC the following rule may be used:

$SOC = SOC_{ST} \times F_{LU} \times F_{MG} \times F_I$

where

SOC = soil organic carbon (measured as mass of carbon per hectare);

SOC_{ST} = standard soil organic carbon in the 0 - 30 centimetre topsoil layer (measured as mass of carbon per hectare);

F_{LU} = land use factor reflecting the difference in soil organic carbon associated with the type of land use compared to the standard soil organic carbon;

F_{MG} = management factor reflecting the difference in soil organic carbon associated with the principle management practice compared to the standard soil organic carbon;

F_I = input factor reflecting the difference in soil organic carbon associated with different levels of carbon input to soil compared to the standard soil organic carbon.

Values for SOC_{ST}, F_{LU}, F_{MG} and F_I are provided in Annex 1, Table 1- Table 8.

As an alternative to using the formula and values described above, other appropriate methods, including measurements, may be used to determine SOC. As far as such methods are not based on measurements, they shall take into account climate, soil type, land cover, land management and inputs.

Organic soils (histosols)

For determining SOC, appropriate methods shall be used. Such methods shall take into account the entire depth of the organic soil layer as well as climate, land cover and land management and input. Such methods may include measurements.

Where carbon stock affected by soil drainage is concerned, losses of carbon following drainage shall be taken into account by appropriate methods. Such methods may be based on annual losses of carbon following drainage.

2.2.1.2 Above and below ground vegetation carbon stock

Values for C_{VEG} are provided in Annex 1 for the following land use types: cropland, including perennial crops, grassland and forestland (Table 9 – Table 18).

As an alternative to using the values described above for $C_{VEG,}$ for example where land use change includes one of the land uses not covered in the Annex, the following rule shall apply:

$C_{VEG} = C_{BM} + C_{DOM}$

where

C_{VEG} = above and below ground vegetation carbon stock (measured as mass of carbon per hectare);

C_{BM} = above and below ground carbon stock in living biomass (measured as mass of carbon per hectare), calculated as per 'Living biomass' below

C_{DOM} = above and below ground carbon stock in dead organic matter (measured as mass of carbon per hectare), calculated as per 'Dead organic matter' below

For C_{DOM} the value of 0 may be used, except in the case of forest land – excluding forest plantations – having more than 30% canopy cover.

Living biomass

For the calculation of C_{BM} the following rule shall apply:

$C_{BM} = C_{AGB} + C_{BGB}$

where

C_{BM} = above and below ground carbon stock in living biomass (measured as mass of carbon per hectare);

C_{AGB} = above ground carbon stock in living biomass (measured as mass of carbon per hectare), calculated as per 'above ground living biomass' below

C_{BGB} = below ground carbon stock in living biomass (measured as mass of carbon per hectare), calculated as per 'below ground living biomass' below

Above ground living biomass

For the calculation of C_{AGB} the following rule shall apply:

$C_{AGB} = B_{AGB} \times C_{FB}$

where

C_{AGB} = above ground carbon stock in living biomass (measured as mass of carbon per hectare);

B_{AGB} = weight of above ground living biomass (measured as mass of dry matter per hectare);

C_{FB} = carbon fraction of dry matter in living biomass (measured as mass of carbon per mass of dry matter).

For cropland, perennial crops and forest plantations the value for B_{AGB} shall be the average weight of the above ground living biomass during the production cycle.

For C_{FB} the value of 0.47 may be used.

Below ground living biomass

For the calculation of C_{BGB} one of the following two rules shall be used:

1) $C_{BGB} = B_{BGB} \times C_{FB}$

where

C_{BGB} = below ground carbon stock in living biomass (measured as mass of carbon per hectare);

B_{BGB} = weight of below ground living biomass (measured as mass of dry matter per hectare);

C_{FB} = carbon fraction of dry matter in living biomass (measured as mass of carbon per mass of dry matter).

For cropland, perennial crops and forest plantations the value for B_{BGB} shall be the average weight of the below ground living biomass during the production cycle.

For C_{FB} the value of 0.47 may be used.

2) $C_{BGB} = C_{AGB} \times R$

where

C_{BGB} = below ground carbon stock in living biomass (measured as mass of carbon per hectare);

C_{AGB} = above ground carbon stock in living biomass (measured as mass of carbon per hectare);

R = ratio of below ground carbon stock in living biomass to above ground carbon stock in living biomass.

Appropriate values for R set out in Annex 1 Tables 2 – Tables 5 may be used.

Dead organic matter

For the calculation of C_{DOM} the following rule shall apply:

$C_{DOM} = C_{DW} + C_{LI}$

where

C_{DOM} = above and below ground carbon stock in dead organic matter (measured as mass of carbon per hectare);

C_{DW} = carbon stock in dead wood pool (measured as mass of carbon per hectare), calculated as per ‘Carbon stock in dead wood pool’ below

C_{LI} = carbon stock in litter (measured as mass of carbon per hectare), calculated as per ‘carbon stock in litter’ below

Carbon stock in dead wood pool

For the calculation of C_{DW} the following rule shall apply:

$C_{DW} = D_{OMDW} \times C_{FDW}$

where

C_{DW} = carbon stock in dead wood pool (measured as mass of carbon per hectare);

D_{OMDW} = weight of dead wood pool (measured as mass of dry matter per hectare);

C_{FDW} = carbon fraction of dry matter in dead wood pool (measured as mass of carbon per mass of dry matter).

For C_{FDW} the value of 0.5 may be used.

Carbon stock in litter

For the calculation of CLI the following rule shall apply:

$C_{LI} = D_{OMLI} \times C_{FLI}$

where

C_{LI} = carbon stock in litter (measured as mass of carbon per hectare);

D_{OMLI} = weight of litter (measured as mass of dry matter per hectare);

C_{FLI} = carbon fraction of dry matter in litter (measured as mass of carbon per mass of dry matter).

For C_{FLI} the value of 0.4 may be used.

2.2.3 Degraded land bonus e_B

The bonus of 29 gCO_2eq/MJ biofuel cannot be included in the calculation until the EC has published a definition. This section of the methodology will be updated at that point.

Annex 1 Values for GHG land use calculations

The following tables are taken from the Commission Decision on guidelines for the calculation of land carbon stocks for the purpose of Annex V of Directive 2009/28/EC

Table 1: SOC_{ST}, standard soil organic carbon in the 0 - 30 centimetre topsoil layer (tonnes of carbon per hectare).

Climate Region	Soil type					
	High activity clay soils	Low activity clay soils	Sandy soils	Spodic soils	Volcanic soils	Wetland soils
Boreal	68	-	10	117	20	146
Cold temperate, dry	50	33	34	-	20	87
Cold temperate, moist	95	85	71	115	130	87
Warm temperate, dry	38	24	19	-	70	88
Warm temperate, moist	88	63	34	-	80	88
Tropical, dry	38	35	31	-	50	86
Tropical, moist	65	47	39	-	70	86
Tropical, wet	44	60	66	-	130	86
Tropical, montane	88	63	34	-	80	86

Table 2: Factors for cropland

Climate region	Land use (F_{LU})	Management (F_{MG})	Input (F_I)	F_{LU}	F_{MG}	F_I
Temperate/Boreal, dry	Cultivated	Full-tillage	Low	0.8	1	0.95
			Medium	0.8	1	1
			High with manure	0.8	1	1.37
			High without manure	0.8	1	1.04
		Reduced tillage	Low	0.8	1.02	0.95
			Medium	0.8	1.02	1
			High with manure	0.8	1.02	1.37
			High without manure	0.8	1.02	1.04
		No till	Low	0.8	1.1	0.95
			Medium	0.8	1.1	1
			High with manure	0.8	1.1	1.37
			High without manure	0.8	1.1	1.04
Temperate/Boreal, moist/wet	Cultivated	Full-tillage	Low	0.69	1	0.92
			Medium	0.69	1	1
			High with manure	0.69	1	1.44
			High without manure	0.69	1	1.11
		Reduced tillage	Low	0.69	1.08	0.92
			Medium	0.69	1.08	1
			High with manure	0.69	1.08	1.44
			High without manure	0.69	1.08	1.11
		No till	Low	0.69	1.15	0.92
			Medium	0.69	1.15	1
			High with manure	0.69	1.15	1.44
			High without manure	0.69	1.15	1.11
Tropical, dry	Cultivated	Full-tillage	Low	0.58	1	0.95
			Medium	0.58	1	1
			High with manure	0.58	1	1.37
			High without manure	0.58	1	1.04
		Reduced tillage	Low	0.58	1.09	0.95
			Medium	0.58	1.09	1
			High with manure	0.58	1.09	1.37
			High without manure	0.58	1.09	1.04
		No till	Low	0.58	1.17	0.95
			Medium	0.58	1.17	1
			High with manure	0.58	1.17	1.37
			High without manure	0.58	1.17	1.04
Tropical, moist/wet	Cultivated	Full-tillage	Low	0.48	1	0.92
			Medium	0.48	1	1
			High with manure	0.48	1	1.44
			High without manure	0.48	1	1.11
		Reduced tillage	Low	0.48	1.15	0.92
			Medium	0.48	1.15	1
			High with manure	0.48	1.15	1.44
			High without manure	0.48	1.15	1.11
		No till	Low	0.48	1.22	0.92
			Medium	0.48	1.22	1
			High with manure	0.48	1.22	1.44
			High without manure	0.48	1.22	1.11
Tropical Montane	Cultivated	Full-tillage	Low	0.64	1	0.94
			Medium	0.64	1	1
			High with manure	0.64	1	1.41
			High without manure	0.64	1	1.08
		Reduced tillage	Low	0.64	1.09	0.94
			Medium	0.64	1.09	1
			High with manure	0.64	1.09	1.41
			High without manure	0.64	1.09	1.08
		No till	Low	0.64	1.16	0.94
			Medium	0.64	1.16	1
			High with manure	0.64	1.16	1.41
			High without manure	0.64	1.16	1.08

Table 3 provides guidance for selecting appropriate values from Tables 2 and 4.

Table 3: Guidance on management and input for cropland and perennial crops

Management / Input	Guidance
Full-tillage	Substantial soil disturbance with full inversion and/or frequent (within year) tillage operations. At planting time, little (e.g. <30%) of the surface is covered by residues.
Reduced tillage	Primary and/or secondary tillage but with reduced soil disturbance (usually shallow and without full soil inversion) and normally leaves surface with >30% coverage by residues at planting.
No till	Direct seeding without primary tillage, with only minimal soil disturbance in the seeding zone. Herbicides are typically used for weed control.
Low	Low residue return occurs when there is due to removal of residues (via collection or burning), frequent bare-fallowing, production of crops yielding low residues (e.g. vegetables, tobacco, cotton), no mineral fertilization or nitrogen-fixing crops.
Medium	Representative for annual cropping with cereals where all crop residues are returned to the field. If residues are removed then supplemental organic matter (e.g. manure) is added. Also requires mineral fertilization or nitrogen-fixing crop in rotation.
High with manure	Represents significantly higher carbon input over medium carbon input cropping systems due to an additional practice of regular addition of animal manure.
High without manure	Represents significantly greater crop residue inputs over medium carbon input cropping systems due to additional practices, such as production of high residue yielding crops, use of green manures, cover crops, improved vegetated fallows, irrigation, frequent use of perennial grasses in annual crop rotations, but without manure applied (see row above).

Table 4: Factors for perennial crops, namely multi-annual crops whose stem is usually not annually harvested such as short rotation coppice and oil palm

Climate region	Land use (F_{LU})	Management (F_{MG})	Input (F_I)	F_{LU}	F_{MG}	F_I
Temperate/Boreal, dry	Perennial crop	Full-tillage	Low	1	1	0.95
			Medium	1	1	1
			High with manure	1	1	1.37
			High without manure	1	1	1.04
		Reduced tillage	Low	1	1.02	0.95
			Medium	1	1.02	1
			High with manure	1	1.02	1.37
			High without manure	1	1.02	1.04
		No till	Low	1	1.1	0.95
			Medium	1	1.1	1
			High with manure	1	1.1	1.37
			High without manure	1	1.1	1.04
Temperate/Boreal, moist/wet	Perennial crop	Full-tillage	Low	1	1	0.92
			Medium	1	1	1
			High with manure	1	1	1.44
			High without manure	1	1	1.11
		Reduced tillage	Low	1	1.08	0.92
			Medium	1	1.08	1
			High with manure	1	1.08	1.44
			High without manure	1	1.08	1.11
		No till	Low	1	1.15	0.92
			Medium	1	1.15	1
			High with manure	1	1.15	1.44
			High without manure	1	1.15	1.11
Tropical, dry	Perennial crop	Full-tillage	Low	1	1	0.95
			Medium	1	1	1
			High with manure	1	1	1.37
			High without manure	1	1	1.04
		Reduced tillage	Low	1	1.09	0.95
			Medium	1	1.09	1
			High with manure	1	1.09	1.37
			High without manure	1	1.09	1.04
		No till	Low	1	1.17	0.95
			Medium	1	1.17	1
			High with manure	1	1.17	1.37
			High without manure	1	1.17	1.04
Tropical, moist/wet	Perennial crop	Full-tillage	Low	1	1	0.92
			Medium	1	1	1
			High with manure	1	1	1.44
			High without manure	1	1	1.11
		Reduced tillage	Low	1	1.15	0.92
			Medium	1	1.15	1
			High with manure	1	1.15	1.44
			High without manure	1	1.15	1.11
		No till	Low	1	1.22	0.92
			Medium	1	1.22	1
			High with manure	1	1.22	1.44
			High without manure	1	1.22	1.11
Tropical Montane	Perennial crop	Full-tillage	Low	1	1	0.94
			Medium	1	1	1
			High with manure	1	1	1.41
			High without manure	1	1	1.08
		Reduced tillage	Low	1	1.09	0.94
			Medium	1	1.09	1
			High with manure	1	1.09	1.41
			High without manure	1	1.09	1.08
		No till	Low	1	1.16	0.94
			Medium	1	1.16	1
			High with manure	1	1.16	1.41
			High without manure	1	1.16	1.08

Table 5: Factors for grassland, including savannahs

Climate region	Land Use (F_{LU})	Management (F_{MG})	Input (F_I)	F_{LU}	F_{MG}	F_I
Temperate/Boreal, dry	Grassland	Improved	Medium	1	1.14	1
			High	1	1.14	1.11
		Nominally managed	Medium	1	1	1
		Moderately degraded	Medium	1	0.95	1
		Severely degraded	Medium	1	0.7	1
Temperate/Boreal, moist/wet	Grassland	Improved	Medium	1	1.14	1
			High	1	1.14	1.11
		Nominally managed	Medium	1	1	1
		Moderately degraded	Medium	1	0.95	1
		Severely degraded	Medium	1	0.7	1
Tropical, dry	Grassland	Improved	Medium	1	1.17	1
			High	1	1.17	1.11
		Nominally managed	Medium	1	1	1
		Moderately degraded	Medium	1	0.97	1
		Severely degraded	Medium	1	0.7	1
Tropical, moist/wet	Savannah	Improved	Medium	1	1.17	1
			High	1	1.17	1.11
		Nominally managed	Medium	1	1	1
		Moderately degraded	Medium	1	0.97	1
		Severely degraded	Medium	1	0.7	1
Tropical Montane, dry	Grassland	Improved	Medium	1	1.16	1
			High	1	1.16	1.11
		Nominally managed	Medium	1	1	1
		Moderately degraded	Medium	1	0.96	1
		Severely degraded	Medium	1	0.7	1

Table 6 provides guidance for selecting appropriate values from Table 5.

Table 6: Guidance on management and input for grassland

Management / Input	Guidance
Improved	Represents grassland which is sustainably managed with moderate grazing pressure and that receive at least one improvement (e.g. fertilization, species improvement, irrigation).
Nominally managed	Represents non-degraded and sustainably managed grassland, but without significant management improvements.
Moderately degraded	Represents overgrazed or moderately degraded grassland, with somewhat reduced productivity (relative to the native or nominally managed grassland) and receiving no management inputs.
Severely degraded	Implies major long-term loss of productivity and vegetation cover, due to severe mechanical damage to the vegetation and/or severe soil erosion.
Medium	Applies where no additional management inputs have been used.
High	Applies to improved grassland where one or more additional management inputs/improvements have been used (beyond that is required to be classified as improved grassland).

Table 7: Factors for forest land having at least 10% canopy cover

Climate region	Land use (F_{LU})	Management (F_{MG})	Input (F_I)	F_{LU}	F_{MG}	F_I
All	Native forest (non degraded)	n/a*	n/a	1		
All	Managed forest	All	All	1	1	1
Tropical, moist/dry	Shifting cultivation-shortened fallow	n/a	n/a	0.64		
	Shifting cultivation- mature fallow	n/a	n/a	0.8		
Temperate/Boreal, moist/dry	Shifting cultivation-shortened fallow	n/a	n/a	1		
	Shifting cultivation- mature fallow	n/a	n/a	1		

* n/a = not applicable; in these cases F_{MG} and F_I shall not apply and for the calculation of SOC the following rule may be used: $SOC = SOC_{ST} \times F_{LU}$

Table 8 provides guidance for selecting appropriate values from Table 7.

Table 8: Guidance on land use for forest land

Land use	Guidance
Native forest (non degraded)	Represents native or long-term, non-degraded and sustainably managed forest.
Shifting cultivation	Permanent shifting cultivation, where tropical forest or woodland is cleared for planting of annual crops for a short time (e.g. 3-5 years) period and then abandoned to regrowth.
Mature fallow	Represents situations where the forest vegetation recovers to a mature or near mature state prior to being cleared again for cropland use.
Shortened fallow	Represents situations where the forest vegetation recovery is not attained prior to re-clearing.

Table 9: Vegetation values for cropland (general)

Climate region	C_{VEG} (tonnes carbon/hectare)
All	0

Table 10: Vegetation values for sugar cane (specific)

Domain	Climate region	Ecological zone	Continent	C_{VEG} (tonnes carbon per hectare)
Tropical	Tropical dry	Tropical dry forest	Africa	4.2
			Asia (continental, insular)	4
		Tropical scrubland	Asia (continental, insular)	4
	Tropical moist	Tropical moist deciduous forest	Africa	4.2
			Central and South America	5
	Tropical wet	Tropical rain forest	Asia (continental, insular)	4
			Central and South America	5
Subtropical	Warm temperate dry	Subtropical steppe	North America	4.8
	Warm temperate moist	Subtropical humid forest	Central and South America	5
			North America	4.8

Table 11: Vegetation values for perennial crops (general)

Climate region	C_{VEG} (tonnes carbon per hectare)
Temperate (all moisture regimes)	43.2
Tropical, dry	6.2
Tropical, moist	14.4
Tropical, wet	34.3

Table 12: Vegetation values for specific perennial crops

Climate region	Crop type	C_{VEG} (tonnes carbon per hectare)
All	Coconuts	75
	Jatropha	17.5
	Jojoba	2.4
	Oil palm	60

Table 13: Vegetation values for grassland - excluding scrubland (general)

Climate region	C_{VEG} (tonnes carbon per hectare)
Boreal – Dry & Wet	4.3
Cool Temperate – Dry	3.3
Cool Temperate –Wet	6.8
Warm Temperate – Dry	3.1
Warm Temperate –Wet	6.8
Tropical – Dry	4.4
Tropical - Moist & Wet	8.1

Table 14: Vegetation values for miscanthus (specific)

Domain	Climate region	Ecological zone	Continent	C_{VEG} (tonnes carbon per hectare)
Subtropical	Warm temperate dry	Subtropical dry forest	Europe	10
			North America	14.9
		Subtropical steppe	North America	14.9

Table 15: Vegetation values for scrubland, namely land with vegetation composed largely of woody plants lower than 5 meter not having clear physiognomic aspects of trees.

Domain	Continent	C_{VEG} (tonnes carbon per hectare)
Tropical	Africa	46
	North and South America	53
	Asia (continental)	39
	Asia (insular)	46
	Australia	46
Subtropical	Africa	43
	North and South America	50
	Asia (continental)	37
	Europe	37
	Asia (insular)	43
Temperate	Global	7.4

Table 16: Vegetation values for forest land - excluding forest plantations - having between 10% and 30% canopy cover,

Domain	Ecological zone	Continent	C_{VEG} (tonnes carbon per hectare)	*R*
Tropical	Tropical rain forest	Africa	40	0.37
		North and South America	39	0.37
		Asia (continental)	36	0.37
		Asia (insular)	45	0.37
	Tropical moist forest	Africa	30	0.24
		North and South America	26	0.24
		Asia (continental)	21	0.24
		Asia (insular)	34	0.24
	Tropical dry forest	Africa	14	0.28
		North and South America	25	0.28
		Asia (continental)	16	0.28
		Asia (insular)	19	0.28
	Tropical mountain systems	Africa	13	0.24
		North and South America	17	0.24
		Asia (continental)	16	0.24
		Asia (insular)	26	0.28
Subtropical	Subtropical humid forest	North and South America	26	0.28
		Asia (continental)	22	0.28
		Asia (insular)	35	0.28
	Subtropical dry forest	Africa	17	0.28
		North and South America	26	0.32
		Asia (continental)	16	0.32
		Asia (insular)	20	0.32
	Subtropical steppe	Africa	9	0.32
		North and South America	10	0.32
		Asia (continental)	7	0.32
		Asia (insular)	9	0.32
Temperate	Temperate oceanic forest	Europe	14	0.27
		North America	79	0.27
		New Zealand	43	0.27
		South America	21	0.27
	Temperate continental forest	Asia, Europe (≤ 20 y)	2	0.27
		Asia, Europe (>20 y)	14	0.27
		North and South America (≤ 20 y)	7	0.27
		North and South America (>20 y)	16	0.27
	Temperate mountain systems	Asia, Europe (≤ 20 y)	12	0.27
		Asia, Europe (>20 y)	16	0.27
		North and South America (≤ 20 y)	6	0.27
		North and South America (>20 y)	6	0.27
Boreal	Boreal coniferous forest	Asia, Europe, North America	12	0.24
	Boreal tundra woodland	Asia, Europe, North America (≤ 20 y)	0	0.24
		Asia, Europe, North America (>20 y)	2	0.24
	Boreal mountain systems	Asia, Europe, North America (≤ 20 y)	2	0.24
		Asia, Europe, North America (>20 y)	6	0.24

Table 17: Vegetation values for forest land - excluding forest plantations - having more than 30% canopy cover

Domain	Ecological zone	Continent	C_{VEG} (tonnes carbon per hectare)
Tropical	Tropical rain forest	Africa	204
		North and South America	198
		Asia (continental)	185
		Asia (insular)	230
	Tropical moist deciduous forest	Africa	156
		North and South America	133
		Asia (continental)	110
		Asia (insular)	174
	Tropical dry forest	Africa	77
		North and South America	131
		Asia (continental)	83
		Asia (insular)	101
	Tropical mountain systems	Africa	77
		North and South America	94
		Asia (continental)	88
		Asia (insular)	130
Subtropical	Subtropical humid forest	North and South America	132
		Asia (continental)	109
		Asia (insular)	173
	Subtropical dry forest	Africa	88
		North and South America	130
		Asia (continental)	82
		Asia (insular)	100
	Subtropical steppe	Africa	46
		North and South America	53
		Asia (continental)	41
		Asia (insular)	47
Temperate	Temperate oceanic forest	Europe	84
		North America	406
		New Zealand	227
		South America	120
	Temperate continental forest	Asia, Europe (≤ 20 y)	27
		Asia, Europe (>20 y)	87
		North and South America (≤ 20 y)	51
		North and South America (>20 y)	93
	Temperate mountain systems	Asia, Europe (≤ 20 y)	75
		Asia, Europe (>20 y)	93
		North and South America (≤ 20 y)	45
		North and South America (>20 y)	93
Boreal	Boreal coniferous forest	Asia, Europe, North America	53
	Boreal tundra woodland	Asia, Europe, North America (≤ 20 y)	26
		Asia, Europe, North America (>20 y)	35
	Boreal mountain systems	Asia, Europe, North America (≤ 20 y)	32
		Asia, Europe, North America (>20 y)	53

Table 18: Vegetation values for forest plantations

Domain	Ecological zone	Continent	C_{VEG} (tonnes carbon per hectare)	R
Tropical	Tropical rain forest	Africa broadleaf >20 y	87	0.24
		Africa broadleaf ≤ 20 y	29	0.24
		Africa Pinus sp. >20 y	58	0.24
		Africa Pinus sp. ≤ 20 y	17	0.24
		Americas Eucalyptus sp.	58	0.24
		Americas Pinus sp.	87	0.24
		Americas Tectona grandis	70	0.24
		Americas other broadleaf	44	0.24
		Asia broadleaf	64	0.24
		Asia other	38	0.24
	Tropical moist deciduous forest	Africa broadleaf >20 y	44	0.24
		Africa broadleaf ≤ 20 y	23	0.24
		Africa Pinus sp. >20 y	35	0.24
		Africa Pinus sp. ≤ 20 y	12	0.24
		Americas Eucalyptus sp.	26	0.24
		Americas Pinus sp.	79	0.24
		Americas Tectona grandis	35	0.24
		Americas other broadleaf	29	0.24
		Asia broadleaf	52	0.24
		Asia other	29	0.24
	Tropical dry forest	Africa broadleaf >20 y	21	0.28
		Africa broadleaf ≤ 20 y	9	0.28
		Africa Pinus sp. >20 y	18	0.28
		Africa Pinus sp. ≤ 20 y	6	0.28
		Americas Eucalyptus sp.	27	0.28
		Americas Pinus sp.	33	0.28
		Americas Tectona grandis	27	0.28
		Americas other broadleaf	18	0.28
		Asia broadleaf	27	0.28
		Asia other	18	0.28
	Tropical shrubland	Africa broadleaf	6	0.27
		Africa Pinus sp. >20 y	6	0.27
		Africa Pinus sp. ≤ 20 y	4	0.27
		Americas Eucalyptus sp.	18	0.27
		Americas Pinus sp.	18	0.27
		Americas Tectona grandis	15	0.27
		Americas other broadleaf	9	0.27
		Asia broadleaf	12	0.27
		Asia other	9	0.27
	Tropical mountain systems	Africa broadleaf >20 y	31	0.24
		Africa broadleaf ≤ 20 y	20	0.24
		Africa Pinus sp. >20 y	19	0.24
		Africa Pinus sp. ≤ 20 y	7	0.24
		Americas Eucalyptus sp.	22	0.24
		Americas Pinus sp.	29	0.24
		Americas Tectona grandis	23	0.24
		Americas other broadleaf	16	0.24
		Asia broadleaf	28	0.24
		Asia other	15	0.24
Subtropical	Subtropical humid forest	Americas Eucalyptus sp.	42	0.28
		Americas Pinus sp.	81	0.28
		Americas Tectona grandis	36	0.28
		Americas other broadleaf	30	0.28
		Asia broadleaf	54	0.28
		Asia other	30	0.28
	Subtropical dry	Africa broadleaf >20 y	21	0.28

Subtropical	Subtropical humid forest	Americas Eucalyptus sp.	42	0.28
		Americas Pinus sp.	81	0.28
		Americas Tectona grandis	36	0.28
		Americas other broadleaf	30	0.28
		Asia broadleaf	54	0.28
		Asia other	30	0.28
	Subtropical dry forest	Africa broadleaf >20 y	21	0.28
		Africa broadleaf ≤ 20 y	9	0.32
		Africa Pinus sp. >20 y	19	0.32
		Africa Pinus sp. ≤ 20 y	6	0.32
		Americas Eucalyptus sp.	34	0.32
		Americas Pinus sp.	34	0.32
		Americas Tectona grandis	28	0.32
		Americas other broadleaf	19	0.32
		Asia broadleaf	28	0.32
		Asia other	19	0.32
	Subtropical steppe	Africa broadleaf	6	0.32
		Africa Pinus sp. >20 y	6	0.32
		Africa Pinus sp. ≤ 20 y	5	0.32
		Americas Eucalyptus sp.	19	0.32
		Americas Pinus sp.	19	0.32
		Americas Tectona grandis	16	0.32
		Americas other broadleaf	9	0.32
		Asia broadleaf >20 y	25	0.32
		Asia broadleaf ≤ 20 y	3	0.32
		Asia coniferous >20 y	6	0.32
		Asia coniferous ≤ 20 y	34	0.32
	Subtropical mountain systems	Africa broadleaf >20 y	31	0.24
		Africa broadleaf ≤ 20 y	20	0.24
		Africa Pinus sp. >20 y	19	0.24
		Africa Pinus sp. ≤ 20 y	7	0.24
		Americas Eucalyptus sp.	22	0.24
		Americas Pinus sp.	34	0.24
		Americas Tectona grandis	23	0.24
		Americas other broadleaf	16	0.24
		Asia broadleaf	28	0.24
		Asia other	15	0.24
Temperate	Temperate oceanic forest	Asia, Europe, broadleaf >20 y	60	0.27
		Asia, Europe, broadleaf ≤ 20 y	9	0.27
		Asia, Europe, coniferous >20 y	60	0.27
		Asia, Europe, coniferous ≤ 20 y	12	0.27
		North America	52	0.27
		New Zealand	75	0.27
		South America	31	0.27
	Temperate continental forest and mountain systems	Asia, Europe, broadleaf >20 y	60	0.27
		Asia, Europe, broadleaf ≤ 20 y	4	0.27
		Asia, Europe, coniferous >20 y	52	0.27
		Asia, Europe, coniferous ≤ 20 y	7	0.27
		North America	52	0.27
		South America	31	0.27
Boreal	Boreal coniferous forest and mountain systems	Asia, Europe >20 y	12	0.24
		Asia, Europe ≤ 20 y	1	0.24
		North America	13	0.24
	Boreal tundra woodland	Asia, Europe >20 y	7	0.24
		Asia, Europe ≤ 20 y	1	0.24
		North America	7	0.24