Towards a carbon balance for forests in Suriname

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Towards a carbon balance for forests in Suriname

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Abstract

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Currently Suriname is developing systems for Monitoring, Reporting and Verification (MRV) for Reducing Emissions from Deforestation and Forest Degradation (REDD). The goal of the study reported in this report is to support the development of an adequate MRV system for forest carbon in Suriname, with a focus on quantification of monitoring and reporting carbon stocks from field sampling. Based on available existing field data, allometric functions and expansion factors aboveground biomass and carbon stocks are assessed for a number of forest types. Using the data from a long-term logging experiment at the CELOS-Kabo site changes in carbon stocks were quantified over time and under different intensities of selective logging. A review of carbon budget estimates across the Amazon were used to put the results for Suriname in a broader perspective. Finally an overview of methods to quantify and monitor forest carbon stocks at different scales are presented and discussed

Keywords: Abovegound biomass, Forest carbon stocks, Tropical Forest, Suriname, REDD+

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Summary

As a result of the discussions within the UNFCCC on Reducing Emissions from Deforestation and forest Degradation (REDD+), many tropical countries are preparing methods and systems to monitor and report carbon emissions from deforestation and forest management. The details for the financial mechanism to compensate countries for reducing deforestation are still under discussion. Yet the fact that there will be a financial compensation mechanism will inevitably call for transparent and robust systems for Monitoring, Reporting and Verification (MRV).

In support to the development of a MRV system for forests in Suriname this report focusses on the quantification of aboveground biomass (AGB) and carbon stocks based on existing field sampling and existing local information on biomass expansion factors. In Chapter 2 existing field data is evaluated and used to assess aboveground carbon stocks in living biomass for a number of different forest types in Suriname. Aboveground biomass and carbon stocks are much higher if estimated with local biomass expansion factors than if estimated using global allometric equations for tropical forests. The average aboveground biomass of mixed high forest on white sand at the CELOS Kabo site was 460 tonnes ha^{-1} using a local biomass equation and only 391 if a global equation was applied to the same plot data.

Results from the permanent plots at the CELOS Kabo site that were selectively logged and had undergone different levels of refinement treatments indicate that 21 years after logging and application of silvicultural treatments AGB is still considerably lower in managed forest compared to the primary forests (Figure 2.2). Of the different management intensities, the lowest (small losses) and highest (high loss, quicker re-growth) harvest intensities without silviculture showed the best performance in terms of recovery of AGB.

The results for the plots with available data in Suriname appear to be consistent with results from other studies across the Amazon basin and Guiana Shield. Results on AGB based on a large scale forest inventory in Suriname, however, were found to be higher than for a similar large scale forest inventory in Guyana. A comparison of stand tables in these two inventories from the 1970's showed that the forest in Suriname on average harbours more bigger trees than the forest in Guyana. Therefore it is plausible that forests in Suriname show higher aboveground biomass. Applying biomass and carbon data from neighbouring countries, therefore, should only be done cautiously if no other data are available.

In Chapter 3 an overview of different methods to quantify and monitor forest carbon stocks at national scales is provided. These methods range from monitoring permanent sample plots in which biomass is assessed to methods measuring actual carbon fluxes like eddy correlation measurements, flux measurements from aircraft and large scale boundary layer budgets and atmospheric inversion modelling. For any national scale assessment it will be necessary to get accurate biomass stocks for different forest areas. To reduce uncertainty of these carbon stock estimates a stratification of the total forest area into nine areas with similar characteristics is proposed.

1 Introduction

Deforestation is the second largest contributor of worldwide carbon emissions. In many tropical countries there is high pressure on forests for agricultural expansion and wood production. At the same time, reducing deforestation and forest degradation is considered to be a relatively cheap carbon emission mitigation option compared to more advanced technological solutions to reduce emissions from fossil fuel use. Therefore, reducing deforestation and forest degradation and promoting forest conservation and sustainable forest management have gained increased attention in international discussions on climate change.

All countries that signed the United Nations Framework Convention on Climate Change (UNFCCC), including Suriname, are obligatory to prepare National Communications reporting greenhouse gas emissions and mitigation actions. Additionally countries that have an emission reduction target also need to prepare a national greenhouse gas balance. Most industrialised countries currently have such obligation, but so far most developing countries like Suriname don't have this obligation yet. These countries, however, have the possibility to be included as host countries for afforestation and reforestation projects to compensate for emissions.

Currently the National Communications are not tied to a specific time frame or updating frequency. The quantification of reported emission and mitigation is often based on Tier 1 default values as outlined in the IPCC good practice guidance for Land Use, Land-Use Change and Forestry (LULUCF) reporting (IPCC 2003, 2006). The first national communication of Suriname in 2005 showed that the LULUCF sector is the second largest sector with regard to GHG emissions. The net result of emissions from deforestation and forest re-growth was estimated to account for 1477 Gg yearly.

Reducing Emissions from Deforestation and forest Degradation
The past years the UNFCCC discussed ways how Reducing Emissions from Deforestation and forest Degradation (REDD) in developing countries could contribute to climate change mitigation. Since the 2007 Conference of the Parties (COP-13) the Bali Action Plan has set the path for the negotiations on REDD to be included in the successor to the Kyoto Protocol or any agreement under the UNFCCC climate treaty. In 2009 at the COP-15 in Copenhagen, parties further agreed to not only include reduced emissions from deforestation and degradation reductions, but also conservation of forest carbon stocks, sustainable management of forests and enhancements of carbon stocks as mitigation options under an UNFCCC REDD-plus mechanism.

Monitoring, reporting and verification
In addition to important discussions on a financing mechanism for REDD-plus related mitigation and who will be beneficiaries, a key component of the Bali Action Plan is the notion that mitigation actions and commitments need transparent and robust systems for monitoring, reporting and verification (MRV) (Winkler 2008). The need for an adequate MRV system is due to its role in accountability and trust-building, which will be essential for any agreement that includes a financial compensation mechanism. Adequate MRV systems also will have an important facilitative role in availability and exchange of data and experience (Fransen 2009).

The implementation of the Bali Action Plan also means that Nationally Appropriate Mitigation Actions (NAMAs) will need to be developed, and these need to be subject to MRV and thus need to be quantifiable. For the LULUCF sector, NAMAs are likely to relate to REDD-plus activities, and may operate on any scale from local to national.

The full details of REDD-plus implementation are still a matter of inter-governmental negotiation, but it is clear that the goal is a compensation package to be provided to countries with substantial areas of tropical mixed forest. Such compensation should be sufficient to encourage and allow implementation of both effective monitoring and reporting of forest carbon stock as well as policies to effectively protect and sustainably manage those forests. Whatever financing system is ultimately agreed on, it will be essential to have a national network to monitor initial forest biomass and biomass changes over time. This inevitably means that at the national level a movement is required from qualitative assessment as reported in infrequent National Communications to the UNFCCC, to a MRV system for quantification of mitigation efforts related to REDD-plus (Winkler 2008) at higher Tier levels. Several initiatives have sought to provide guidance on quantification of REDD and have developed good practice guidance - like the REDD Sourcebook (GOFC-GOLD 2010), which is mainly based on the IPCC good practice guidance for LULUCF reporting (IPCC 2003, 2006).

Most tropical countries, including Suriname, do not currently have operational an adequate national systems to monitor, report and verify carbon and other greenhouse gas emissions from the LULUCF sector that meet the anticipated MRV standards that will undoubtedly be required under any REDD-plus mechanism. Therefore, development of such national MRV systems and building the capacity needed to implement them is an important first step towards successful implementation of REDD-plus policies.

This study

The goal of this study is to support the development and implementation of an adequate MRV system for forest carbon in Suriname. The focus will be on the quantification of carbon stocks from field sampling. Based on an evaluation and analysis of existing field data and local information on biomass expansion factors we assessed aboveground carbon stocks in living biomass a number of important combinations of forest and soil types (Chapter 2). Based on plot data from a long-term logging experiment at the CELOS - Kabo site we also quantified changes in carbon stocks over time for a limited number of plots and the effect of selective logging under different harvest intensities (Chapter 2). A review of carbon budget estimates (carbon stocks and carbon uptake) including information of the Large-Scale Biosphere Atmosphere (LBA) studies in the Amazon in which Alterra participates, will put the results for Suriname in a broader perspective.

In chapter 3 methods to monitor and quantify carbon stocks and carbon fluxes in forests will be introduced. Based on the results on carbon stock estimates from Chapter 2 some possibilities for an MRV system for forest carbon in Suriname are discussed.

2 Assessment of carbon stocks based on existing data for forests in Suriname

2.1 Introduction

The total carbon stock in forests is distributed over different carbon pools. The main carbon pools in tropical forests are the living aboveground biomass (AGB) of trees in stems, branches and leaves, belowground biomass (roots), soil organic matter, necro-mass (standing and lying dead wood), litter and vegetation in the understorey. In forests on mineral soils, aboveground biomass typically represents the largest carbon pool (>50% of total). This is also the most directly impacted pool by deforestation and degradation. With the majority of the forest in Suriname on mineral soils, quantification of the aboveground biomass will probably be the most crucial step in estimating forest carbon stocks and fluxes.

Aboveground biomass of trees in a particular location can be accurately assessed by harvesting, drying and weighing all biomass in a given area. Carbon content typically is 50% of the tree biomass. Since there is relatively little variation between species, this general conversion factor is applied widely. Destructive sampling of biomass is accurate, but also very time-consuming and costly if used for a country level assessment.
A more cost-effective method is to establish robust allometric functions to convert diameter and/or height measurements to tree biomass. Such allometric relations statistically relate the easily measurable diameter at breast height (DBH) to destructive biomass measurements. Although locally elaborated allometric functions may be more accurately relating DBH to biomass and take into account species specific variation between areas, again a large number of trees will need to be harvested. Brown (2002), however, showed that DBH alone explained more than 95% of variation in aboveground biomass and that grouping all species and using generalised functions stratified by forest types therefore is very effective.

In this chapter we will quantify the carbon stocks of forests in Suriname based on existing inventory and plot data. For the CELOS plots at Kabo, next to information on tree diameters in the past also biomass has been assessed by destructive sampling. Resulting allometric biomass equations will be compared with more general allometric functions (see Table 2.1):

- equations without including species specific wood density (Pearson et al. 2005),
- general equations including species specific wood density (Chave et al. 2005),
- local biomass equations (based on destructive measurements of trees close to the Kabo plots) not including species specific differences in wood density (Jonkers 1987) ,
- local biomass equations including species specific differences in wood density (Jonkers 1987).

IPCC (2003) provides good practice guidance for reporting of (changes in) carbon stocks for land use, land-use change and forestry (LULUCF). The default values reported in the tabled provided in this guidance give a rough first estimate for carbon pools and changes thereof at Tier 1 level, but does not include regional variation other than climate related differences. For Suriname the IPCC (2003) report an average growing stock volume of 145 m^3 ha^{-1} and 253 tonnes of aboveground biomass ha^{-1}. Default average annual increment of aboveground biomass in natural forest is estimated at around 2 tonnes dry matter ha^{-1} yr^{-1} for tropical wet (> 2000 mm rainfall yr-1) and tropical moist forests (1000-2000 mm rainfall) in South America.

A review of published carbon stocks and fluxes of Amazon forests put the results also in a more regional perspective (see Chapter 2.4).

Table 2.1. *Biomass regression functions to assess aboveground biomass in tropical forest trees from tree diameters. W: aboveground biomass of a tree (Ws: stem biomass,Wb: branches and Wl: leaves) (kg), D: diameter at breast height of the tree (cm), ρ: tree specific wood density (dry weight per m^3 green volume)*

Reference	Equation	Max DBH
Moist forests		
Pearson et al. (2005)[a]	$W = \exp(-2.289+2.649 \times \mathit{ln}(D-0.021) \times \mathit{ln}(D^2))$	148 cm
Chave et al. (2005)[b]	$W = \rho \times \mathit{exp}(-1.499 + 2.148 \times \mathit{ln}(D) + 0.207 \times \mathit{ln}(D)^2 -0.0281 \times \mathit{ln}(D)^3)$	
Wet forests		
Pearson et al. (2005)[c]	$W = 21.297 - 6.953 \times D + 0.740 \times D^2$	112 cm
Chave et al. (2005)[d]	$W = \rho \times \mathit{exp}(-1.349 + 1.980 \times \mathit{ln}(D) + 0.207 \times \mathit{ln}(D)^2 -0.0281 \times \mathit{ln}(D)^3)$	
Kabo, Suriname		
Jonkers (1987)[e]	$W_s = 1.1184 \times 10^{(-3.4853 + 2.5132 \times \log(D \times 10))}$ $W_b= 1.4428 \times 10^{(-4.8516 + 2.8368 \times \log(D \times 10))}$ $W_l= 1.2602 \times 10^{(-3.7644 + 1.9961 \times \log(D \times 10))}$	
Jonkers (1987)[f]	$W_s = \rho \times (-0.2335 + 0.001125 \times (D)^2)$	

a) update from Brown (1997) wet forest >4000 mm yr-^{1}, b) wet forest >3500 mm yr^{1}, c) based on Brown (1997), moist forest 1500-4000 mm yr^{1}, d) moist forest 1500-3500 mm yr^{1}; e) local functions between diameter and biomass, not including species specific difference in wood density, and f) local biomass function including species specific differences in wood density.

2.2 Existing data and methods

During the past decades a number of forestry experiments using sample plots and forest inventories have been carried out in different areas in Suriname. Although most of these studies were not primarily aimed at quantifying carbon stocks, such data can potentially be used to assess carbon stocks per unit of area. The methods and measurements in most of these plots, however, are limited to higher size classes or only trees of commercial species. Such limitation will most likely result in underestimation of the carbon stocks in the aboveground vegetation.

Available data was evaluated for suitability and data quality (Table 2.2 and Table 2.3). Based on this it was decided to do a more detailed assessment with data from the Kabo 78/5 experiment, and a more general assessment based on the FAO national forest inventory, the plots of Bánki et al. and the plots of Ruysschaert (Table 2.2). Using the Kabo experiment 78/5 data a number of methods to convert tree diameter data to total aboveground biomass and carbon in the plots are explored and compared. These methods include using default biomass estimates from the IPCC good practice guidance for LULUCF (IPCC 2003), published biomass equations (Chave et al. 2005), a biomass equation established for the plot area (Jonkers 1987) and finally using more detailed allometric relations between diameter and volume in combination with species specific wood densities to include variation among species.

Table 2.2. *Overview of forest sample plots and data used to assess carbon stocks in different forest types in Suriname*

Name of plot or inventory	**Sources**	**Census date(s)**	**Data and comments**
Kabo experiment 78/5	Jonkers 1987, Poels 1987, this report	1979 – 1983, 2000 and 2010	See paragraph 2.2.5 below
Kabo experiment 82/2	Poels 1987	1983	Experiment set up within the CELOS forest management system. Allometric data, data on aboveground and belowground biomass are available.
Plots of Bánki et al.	Bánki 2010; Bánki et al. 2003; unpublished data	2007-2008	Biodiversity study with 39 x 1 ha plots across different forest and soil types at Brownsberg, Lely Nassau and Zanderij in Northern Suriname. The DBH of all trees > 10 cm DBH was measured.
Plots of Ruysschaert	Ruysschaert, unpublished data	2008	Biodiversity study including 4 x 1 ha plots of high forest, savanna forest and marsh forest at Brownsweg and Powakka). The DBH of all trees >10 cm DBH was measured.
FAO National forest inventory	de Milde 1974		Stand tables with number of tree per ha divided in 10 cm DBH classes for trees > 15 cm DBH are available. The inventory was carried out over a large area covering Fallawatra, Nassau and Kabalebo. Separate stand tables with all tree species lumped together exist for mixed high dry land forest, creek forest in all three areas and for high savanna forest in Kabalebo.

Table 2.3. *Plots not included in this preliminary assessments. Reason for rejection are provided in the comments*

Name of plot or inventory	Sources	Census date(s)	Data and comments
Mapane experiment 67/9a and 67/9b	de Graaf et al. 1999; Poels et al. 1998	1967 - 1974, 1976 - 1980 and 1995	The plots at Mapane bridge were established to study different silvicultural treatments aimed at improving recovery of commercial standing stock after selective logging. The plots were established, however in a forest area that was logged before with unknown intensity. This will likely interfere with the results of a carbon assessment. As a result no reliable estimates will be possible for this area.
Mapane experiment 81/29	de Vletter	1981 and 1997/98	
Zanderij 100% inventory	SBB		This inventory was carried out as part of a tree spotter training in a former LBB training centre in Savanna forest near Zanderij. Only large commercial species were included, which makes the data unsuitable to include in the carbon stock assessment.
Brinkheuvel	SBB		Recent inventory of transect of 4 km long and 20 m wide by SBB. Transect was cut in 100 x20 m plots. All species were inventoried, but only individuals > 30 cm

		DBH were included, which would omit a substantial part of the aboveground carbon in living biomass
Cambior inventory	SBB	Plots of 100 x 20 m, probably on white sand savanna Because only trees > 25 cm DBH of commercial species were inventoried data were not used.
Exploration at Century concession	SBB	In same area as the FAO 1974 inventory at Kabalebo

2.2.1 Kabo experiment 78/5

In 1979 a large scale experiment was established to study optimal combinations of silvicultural treatments and exploitation level. This was done at a larger scale than in the earlier plots in the Mapane area. Data are available for the years 1979 t/m 1983 en 2000.

The experiment was set up as a complete factorial design with 3 x 3 randomised blocks, three replicates of nine treatment plots. The experiment included 3 harvesting levels per hectare of 15 m^3, 23 m^3 and 46 m^3 and three levels of silvicultural treatments carried out 1-2 years after logging. In these refinements all trees without commercial potential above a certain diameter limit are removed/killed. The levels applied were 1) no refinement (only logging), 2) refinement with diameter limit of 30 cm and 3) refinement with diameter limit of 20 cm).

The treatment plots were 4 ha each, with the central 2.25 ha (150x150m) as measurement plot. Initially in the measurement plots only all trees > 15 cm DBH of commercial species were measured, while trees > 5 cm of commercial species were measured in subsamples of 6 circular plots measuring 0.075 ha each.

In 1981 also three plots were established in nearby virgin forest without harvesting and treatment. In that same year also 1 ha measurement plots were introduced centrally in the previous 2.25 ha measurement plots. These were subdivided in 100 10x10 m quadrants. In this new measurement plot all trees >15 cm DBH were measured following the guidelines in Synnott (1979), enabling an assessment of carbon stocks in plots with different levels of exploitation and silvicultural treatments and comparison with primary forest. Trees >15 cm DBH have been measured again in the three control plots during 2009/2010.

In 1982 in replications I en II also sapling and seedling plots were established. Seedlings were tallied in sixteen 5x5 m plots that were laid out in a systematic sample in each 1 ha measurement plot. In each 5x5 m sapling plot also a 2x2 m seedling plot was established.

To get total above- and belowground biomass in the forest plots, biomass expension factors (BEF) are used. These expand the tree stem biomass to total above ground biomass on individual level or for the whole stand as a whole. IPCC (2003) gives a BEF of 3.4 from stembiomass to total AGB. Data from an experiment close to the Kabo plots, however, result in a BEF of 1.536 from stem biomass to total AGB and 1.796 to total biomass (de Graaf 1991; phytomass is approximately 480 tonnes ha^{-1}, of which 250 tonnes ha^{-1} in stems, 16 tonnes ha^{-1} in leaves, 118 tonnes ha^{-1} in branches and 65 tonnes ha^{-1} in roots). The function by Jonkers (1987; Table 2.1) gives only AGB for stems. The BEF 1.536 is applied to this stem biomass to get total AGB of trees.

2.2.2 Other plots

The plots of Bánki et al. and of Ruyseart were 1 ha sample plots in which the DBH of all trees > 10 cm DBH were measured. DBH of single trees was converted to AGB using the allometric equations (Table 2.1) that did not need information on wood density (i.e. the generalised equation by Pearson et al. 2005 and the equation of Jonkers 1987 based on the Kabo data). Since these plots are comparable in size and measurements and have been set up across a range of soil and forest types, the results of both plots will be used for an initial comparison of different forest and soil types.

From the detailed FAO inventory (de Milde 1974) across large areas of forest in the forestry belt of Suriname. Stand tables with number of tree per ha divided in 10 cm DBH classes for trees > 15 cm DBH are available. The inventory was carried out over a large area covering Fallawatra, Nassau and Kabalebo. Seperate stand tables with all tree species lumped together exist for mixed high dryland forest, creekforest in all three areas and for high savanna forest in Kabalebo.

2.3 Results

2.3.1 Kabo experiment 78/5

The estimates for aboveground biomass and carbon based on local biomass regression functions not including specific differences in wood density (Table 2.1, Jonkers 1987) were significantly higher than the other estimates (ANCOVA multiple comparisons with Bonferoni adjustments, $p < 0.001$). In contrast the estimates based on the local function that took species specific variation in wood density into consideration (Table 2.1, Jonkers 1987) were significantly lower than the other biomass estimates ($P<0.001$), while the two generalised pan-tropical functions (Table 2.1, Pearson et al. 2005 and Chave et al. 2005) did not differ from each other. The chosen method thus will have an strong effect on the outcome of the carbon assessment.

The allometric function that include wood density in Jonkers (1987) appear to strongly underestimate the aboveground biomass. Reason for this could be that this function is parameterised using average biomass for 10 cm DBH classes related to the DBH of the class middle. Since the diameter distribution of trees in tropical forest is typically is J shaped the average biomass of each size class is probably based on individuals that are slightly smaller than the class middle, resulting in an underestimation of biomass at the class middle.

In the following analysis we subsequently only used the allometric functions that did not need information on wood density. It is recommended to use the general equations as long as there are no detailed representative local allometric functions available. The local functions can be gradually established over time while setting up the MRV system and compared with the general equations.

In comparison to estimates from ter Steege (2001) for aboveground biomass for forests on white sand in Guyana (248 t ha^{-1}), the estimates for the Kabo plots appear to be rather high. Both estimates for Kabo using two different biomass equations, however, are much higher and also the estimates for white sand based on 10 1 ha plots in the Zanderij (Bánki et al. plots) show a much higher aboveground biomass.

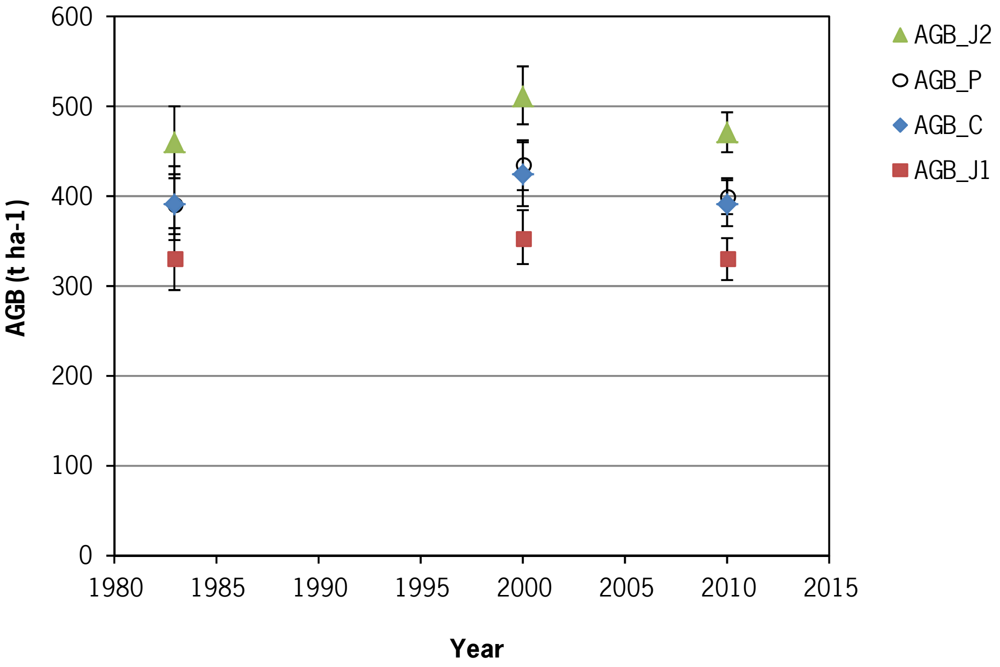

Figure 2.1
Aboveground biomass over time in the three control plots in primary forest in the Kabo experiment. AGB_J2 is based on the allometric function for Kabo without wood density (Jonkers (1987)f in Table 2.1), AGB_P on the general function by Pearson et al. 2005 In Table 2.1, AGB_C on the general function by Chave et al. 2005 and AGB_J1 on the allometric function for Kabo including wood density. In all cases the functions for moist forest were used (Table 2.1).

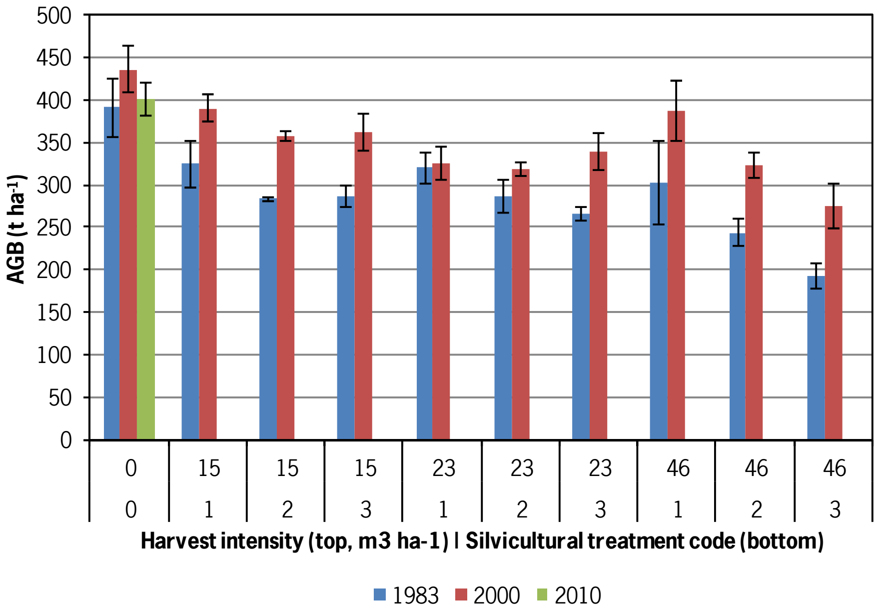

Figure 2.2
Average aboveground biomass (tonnes dry matter ha^{-1}) in plots with different combinations of harvest intensity and silviculture. Harvest intensity is in m^3 ha^{-1}), coding of silviculture 0: control plots, 1: no treatment, only harvesting, 2: refinement with 30 cm limit and 3: refinement with 20 cm limit. Error bars give standard error.

Harvesting and silviculture significantly reduced AGB (Figure 2.2). The results indicate that 21 years after harvesting and application of treatments AGB is still considerably lower in the managed forests compared to the primary forest. Recovery appears to be quicker in forests with higher exploitation levels.

2.3.2 Aboveground biomass estimated for different areas in Suriname

In the comparison of AGB among the different habitat types identified in the studies by Bánki and Ruyscchaert only showed a significant difference between forests on slopes (highest AGB) and Savanna forests (Table 2.4).

Table 2.4.
Overview of Aboveground biomass estimates (AGB, tonnes dry matter ha^{-1}) and related aboveground carbon (AGC, tonnes C ha^{-1}) in different forest areas in Suriname based on 1) allometric function without wood density of Jonkers 1987 (AGB_J and AGC_J) and 2) allometric function of Pearson et al. 2005 (AGB_P and AGC_P.Where possible averages +/- s.e. are given. N gives the number of plots in forest and soil type; st: stand tables over larger areas.

Area	Forest & soil type	Study	n	AGB_J	AGC_J	AGB_P	AGC_P
Kabo	Mixed high forest on white sand	Jonkers, 1987	3	460 ± 40	230	391 ± 34	196
Zanderij	Mixed high forest on brown sand	Bánki et al.	6	408 ± 75	204	346 ± 64	173
Zanderij	Mixed high forest on white sand	Bánki et al.	10	429 ± 114	215	364 ± 98	182
Bauxite plateaus	Lowland	Bánki et al.	7	414 ± 62	207	351 ± 53	176
Bauxite plateaus	Mid slope	Bánki et al.	4	530 ± 52	265	450 ± 44	225
Bauxite plateaus	Plateau	Bánki et al.	10	480 ± 125	240	407 ± 106	204
Bauxite plateaus	Savanna forest	Bánki et al.	2	293 ± 33	147	247 ± 30	124
Brownsweg	Marsh forest	Ruysschaert	1	450	225	381	191
Brownsweg	High forest on slope	Ruysschaert	1	564	282	479	240
Brownsweg	Savanna forest	Ruysschaert	1	308	154	259	130
Brownsweg	High forest flat terrain	Ruysschaert	1	375	188	318	159
Fallawatra	Creek forest	de Milde 1974	st	281	141	239	120
Fallawatra	Mixed high dryland	de Milde 1974	st	340	170	289	145
Kabalebo	Creek forest	de Milde 1974	st	282	141	240	120
Kabalebo	High Savanna	de Milde 1974	st	242	121	205	103
Kabalebo	Mixed high dryland	de Milde 1974	st	326	163	278	139
Nassau	Creek forest	de Milde 1974	st	320	160	272	136
Nassau	Mixed high dryland	de Milde 1974	st	354	177	301	151
All	Creek forest	de Milde 1974	3	294 ± 13	147	250 ± 11	125
All	High Savanna	de Milde 1974	1	242	121	205	103
All	Mixed high dryland	de Milde 1974	3	340 ± 8	170	289 ± 7	145

2.4 Discussion putting results in a regional perspective

2.4.1 Review of carbon budget estimates of Amazon forests

Carbon sequestration by intact ecosystems can be an important component of the carbon budget in compensating emissions from fossil fuel burning and deforestation. Tropical forests have a high potential of carbon uptake, but also present a high risk in emitting carbon, through climate change, disturbance or logging. Their net uptake rate (Net Ecosystem exchange or NEE, see) is in fact a delicate balance between high uptake and high emission rates. Also other ecosystems take up carbon. Young, growing forests and secondary regrowth can be considered carbon sinks. Pasture and agricultural land can also store large quantities of carbon but this depends on management. Savannas and swamps store less carbon above ground, but can store large quantities in their soils.

In all cases, if the net sequestration rate from the atmosphere needs to be quantified, there are two contrasting approaches: on one hand, all components of the ecosystem's carbon budget can be measured separately, such as wood increment, mortality, soil accumulation, or photosynthesis, respiration and soil emissions. The advantage of such an approach is that the results are highly localized and the ecosystem is well understood. The disadvantage is that it is not easy to come to a well-weighted, statistically significant result. On the other hand, the net exchange of the whole ecosystem can be quantified, as were it enclosed in a large virtual gas-exchange chamber. The advantage is that no components of the ecosystem are missed, but the disadvantage is that the system is treated as a black box. Furthermore, as we will see, it is not trivial to guarantee that the virtual chamber is really closed.

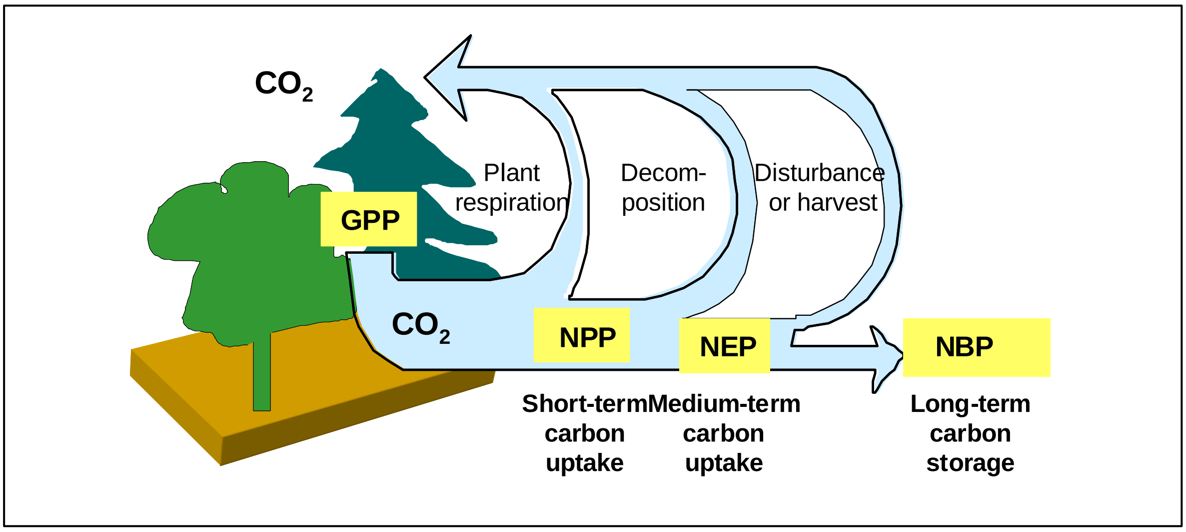

Figure 2.3
Ecosystem processes contribution to carbon uptake and carbon emissions. The balance between these processes determined the Net Ecosystem Exchange of CO2 and carbon storage of the forest system. GPP: Gross Primary Productivity (i.e. photosynthesis), NPP: Net Primary Production, NEP: Net Ecosystem Production and NBP: Net Biome Production.

Both approaches have been explored in the Amazon, mainly within the Brazilian part, in the scope of the 'Large-scale Biosphere-Atmosphere experiment in Amazonia' (LBA). In the following we will show results of several methods, mainly focusing on the bulk ecosystem approaches, but also review results of plot-scale components-based methods. We will also assess the significance of results obtained for the Brazilian Amazon for the Surinamese case.

Eddy correlation

Eddy correlation is a bulk ecosystem approach. The basic principle is that the 'flux', i.e. the vertical net transport, of CO2 to or from the land surface (including the ecosystem on it) is measured directly, with high time resolution, for areas of typically several hectares up to square kilometres at once. The measurement principle is based on monitoring the turbulent air movement and concentrations within the air. Typically, this is done from a tower, extending above the ecosystem and equipped with sensitive meteorological equipment, but it can also be done from mobile equipment and even from a dedicated low-flying aircraft. The method yields time records with a half-hourly to hourly resolution, but has been applied in several cases for up to ten years continuously now. So, the method gives both long-term budgets of carbon and insight into physiological response of the ecosystem's carbon budget to environmental variation. Therefore, the method is especially suitable to assess the sensitivity of ecosystems to environmental change.

Sites in the Amazon

The Eddy correlation method has been applied at several sites in the Brazilian Amazon, continuously since roughly 1999, and before that during shorter periods (see map in Figure 2.4. The most elaborate data sets are from a forest north of Manaus ('Cuieraas reserve' or 'ZF2', 'C14' and 'K34' tower sites), a forest in central Rondonia (SW Amazonia, the 'Reserva Biológica do Jaru, or Rebio Jaru, or simply 'Jaru'). Since about 2001, the tower sites in the Floresta Nacional ('Flona') Tapajós, near Santarem, and a tower in Eastern Amazonia, inland from Belem, have functioned. Additional, but less frequent data, have been collected in Savannas near Brasilia, transitional forest in Mato Grosso, very wet and forest on sandy soils in NW Brazil, near São Gabriel da Cachoeira, in Seasonally inundated transitional forest of Tocantins (Bananal), as well as in several deforests sites under pasture management.

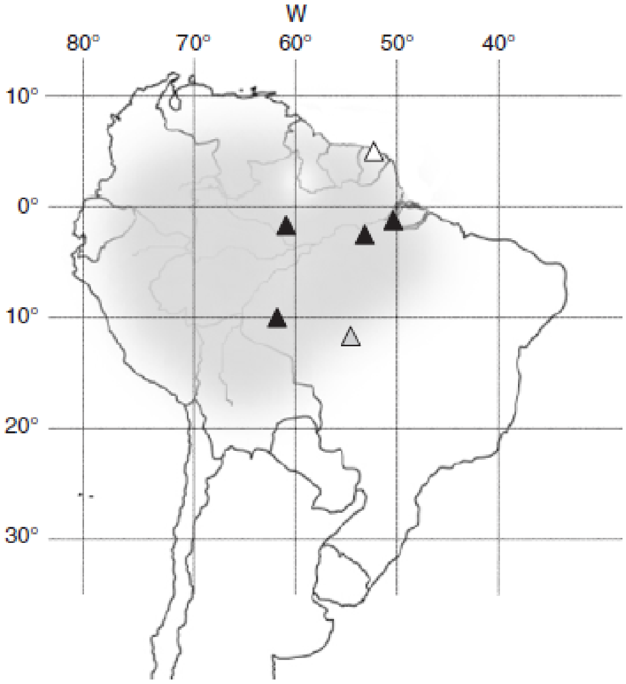

Figure 2.4.

Location of the main neo-tropical rain forest sites with flux tower measurements. The white triangle represents the site in French Guiana. Source: Bonal et al. (2008)

These towers together give a reasonable cover of Mid-to Eastern Amazon carbon exchange, except for the river marginal flooded forests, and also except for the Western Amazonian forests of Peru and Ecuador. So far, no tower data exist for those but plans are to establish these soon.

Results

Traditionally, tropical rain forests have been considered 'climax' ecosystems, that is, they were assumed fully developed and, on average, not increasing any more in biomass and carbon. However, the first direct eddy correlation measurements in an undisturbed south-west Amazon forest showed that these forests were accumulating carbon at a rate of about one tonne per hectare, per year (Grace et al. 1995). The explanation offered was that the rise of CO2 concentrations in the atmosphere acts as fertilizer. Subsequent studies, in several sites, showed a similar phenomenon, with uptake rates being even higher: Malhi et al. (1998) and Carswell et al. (2002) reported rates of 5 TC ha^{-1} y^{-1}, for Central and Eastern Amazonia, respectively, while Araújo et al. (2002) reported even higher rates also for central Amazonia. The latter study, as well as Kruijt et al. (2004) also showed high uncertainty in these measurements, mainly related to poor performance of the methodology at night. The only exception so far using direct flux measurements was shown by Saleska et al. (2003), for a site near Santarem, state of Para, where the forest was reported to be carbon-neutral or even emit carbon at a modest rate. This site was reported to be more disturbed than the others, with much coarse litter present. Taken together, these results point at high spatial variability. They highlight the fact that even 'pristine' tropical forests are never in equilibrium, but always either recently disturbed by tree fall or climatic effects, and emitting carbon, or restoring from disturbance, and absorbing carbon.

One recent result deserves special attention, as it is based upon a tower site in French Guiana. Bonal et al. (2008) report on the first two years of measurements. They deem it too early to come with definite numbers for net carbon storage, but as shown in the Figure 2.5 (Bonal et al. 2008) net fluxes (NEE) are mostly negative (implying uptake) and average around -0.5 gCm^{-2} d^{-1}), which would add up to about 1.7 Tonnes per hectare per year, with high uncertainty. More significantly, the study shows that uptake mainly takes place in the dry season, when soils are dry and emitting little carbon dioxide.

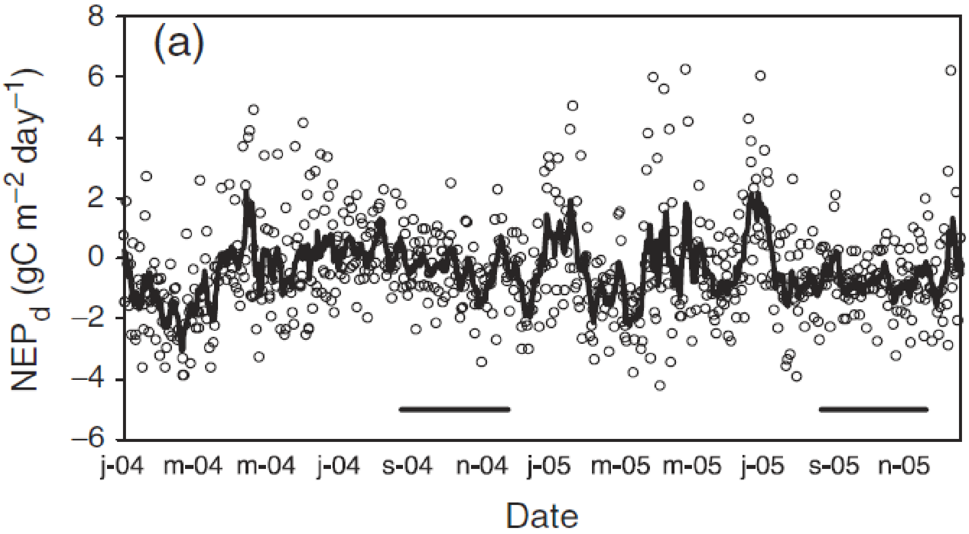

Figure 2.5

Seasonal variations (2004–2005) in (a) daily net ecosystem productivity (NEP$_d$, gCm^2 day^1). Source: Bonal et al. (2008).

Ometto et al. (2005) present an overview of LBA tower results thus far, which shows strong variation among the sites (Figure 2.6). As argued, the very high uptake rates shown are likely to be biased. The emission rates are likely to be caused by recent strong disturbance. Taking all data together, however, leads most researchers to estimating the uptake rate of average, undisturbed 'Terra Firme' Amazon forest at about 1 Tonne per hectare per year, or within a range of similar magnitude. Forests with past disturbance can remain sources of carbon to the atmosphere for quite a long time. The measurement methodology needs to be improved, however, to deal with the night-time leak problems and some other issues before we can use it to give more definite carbon budget estimates. It has become clear that Eddy correlation methods are most suited to understand and predict environmental responses and sensitivity to change. At the same time, model predictions such as those by Cox et al (2000) have highlighted that is also this sensitivity to change (in climate or land management) that is most relevant to understand. After all, carbon reporting to UNFCCC will also have to be on the basis of changes rather than on existing conditions.

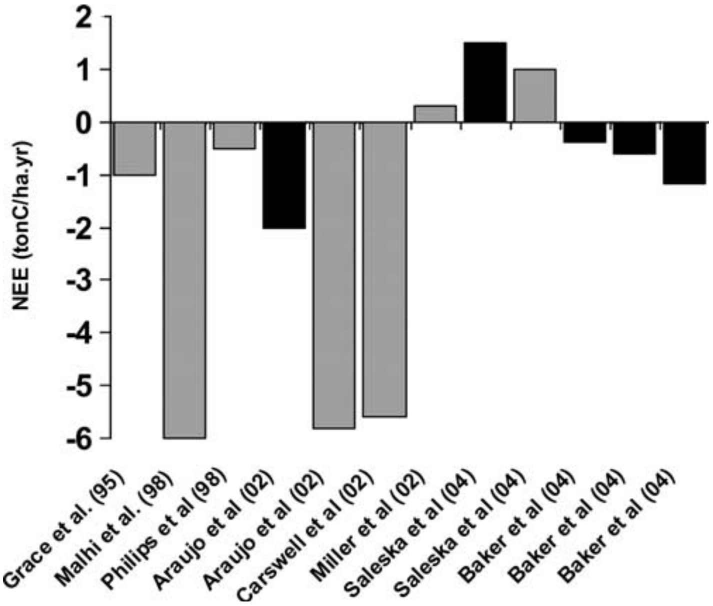

Figure 2.6
Estimates of net ecosystem exchange (NEE, tonne C ha^{-1} yr^{-1}) obtained by eddy covariance technique (grey bars) and by aboveground biomass estimates (black bars). Source: Ometto et al. (2005).

Biomass inventories
The biomass in various forest types in Guyana as described by ter Steege (2001) can be used as a very coarse comparison for the situation in Suriname. Forests on lateritic soils are estimated to contain about 286 tonnes C ha^{-1} in above-and below ground components, dead and alive, together. Malhi et al. (2006) showed biomass being highest in the moderately seasonal, slow growing forests of central Amazonia and the Guianas (up to 350 tonnes dry weight ha^{-1}) and declining to 200-250 tonnes dry weight ha^{-1} at the western, southern and eastern margins of the Amazon. Including dead biomass and belowground biomass would increase these values by approximately 10% and 21%, respectively, giving an estimate for the Guianas of about 470 tonnes ha^{-1}, which would be equivalent to about 235 tonnes C ha^{-1} at 50% carbon content in biomass. This is comparable to the estimate by ter Steege (2001).

Other lines of evidence come from an Amazon-wide effort to re-establish and recensus the many forestry inventory plots across the region, as well as implement new ones, using standard methodologies, where needed (RAINFOR, Malhi et al. 2006). Although these plots only provide data on dynamics of above ground biomass, and sometimes necromass, and not of roots and SOM, the paired censuses in many more sites than the direct eddy-correlation provide rich and independent data on the magnitude and spatial variation of above-ground carbon dynamics. Malhi et al. (2006) showed a gradient in biomass accumulation from east (0.5 tonnes C $ha^{-1}yr^{-1}$) to west (1.5 tonnes C $ha^{-1}yr^{-1}$). Also, turn-over and species richness appeared higher in the western Amazon than in the east. The gradient was most strongly correlated with nutrient availability, but also (inversely) with the length of the dry season. Chambers et al. (2004) performed a detailed study of all flux components in an Amazon forest near Manaus, Brazil. Their conclusion was that net carbon uptake was small.

It can be questioned to what extent these biomass plots are representative for the Amazon forests. It is likely that research plots, also with the direct eddy correlation studies, are situated preferentially in well-developed places, such that recently disturbed areas are underrepresented. It is possible that, if these areas would be sampled representatively, the estimated sink strengths would vanish. Summarising, the uncertainty and variability analyses done on both direct flux studies and inventories highlight the importance of accounting for the disturbance history.

Another aspect of tropical forest carbon storage is whether the soils can and do ultimately store the carbon produced in the biomass. Chambers et al. (2001) argue from a theoretical point of view that Amazon forests can at best accumulate 1 tonne of carbon per hectare and per year.

Recently, Malhi et al. (2009) made a comparison of bottom-up (components) and top-down (eddy correlation flux) for the three major LBA sites Manaus, Tapajós and Caxiuanã. The conclusion was that these two approaches match well, increasing the trust in both methods. Also, these data confirmed that phosphorus limitation is an important factor in the primary productivity of these forests, as one of the sites holding more P was significantly more productive, with higher carbon use efficiency (ratio of net to gross primary productivity). Net Ecosystem productivity, however, was not elevated as also respiratory losses are higher in such conditions.

Difference between soils, climate and forests of Suriname and of the (Brazilian) Amazon
Most direct carbon flux measurements are from the Brazilian Amazon, as shown above. The Suriname forests share much of the climatic conditions and of the floristic composition with the Amazon. Also, measured variability in carbon exchange between various tropical forests is not very large, at least not larger than the uncertainty. Nevertheless, the biometrics-based work in the RAINFOR projects (Malhi et al. 2006) shows that carbon exchange does depend on climate (seasonality) and soil fertility. We have to be careful in applying Brazilian data to Suriname too uncritically. First of all, the climate in Suriname exhibits a bimodal seasonality. This bimodality is only matched in the far eastern Amazon, which would imply that the climatically most suitable proxy would be the Caxiuanã tower site. In terms of soils, Surinam's interior is located on the Guiana shield, with granitic, Precambrian bedrock. This is similar to the bedrock in Central and NW Amazonia, but there this is usually overlain by more recent Cenozoic clay sediments. The exact differences in soils and fertility needs to be verified. Third, in terms of floristic composition, the Suriname forests seem more species-rich, with relatively more big trees and epiphytes. Malhi et al. (2006) also report higher mean basal area and higher biomass for the Guianas, mainly based upon data from French Guiana. Following the RAINFOR analogy, forests on richer soils have lower biomass but higher turnover rates. High turnover does not necessarily lead to higher NEE, but NPP is certainly higher and global relationships of NPP and NEE do suggest a tendency of higher NEE where NPP is higher (Luyssaert et al. 2008). Concluding, much still needs to be specified further but if proxies are to be used for assessing carbon fluxes of Suriname forest, we may tentatively assume that the data from Central and SW Amazonia (Manaus, Jaru) show higher uptake and biomass. While the sites in Caxiuanã (Eastern Amazon) and French Guiana would be most comparable, those are sites with the shortest data records.

Temporal variability
When assessing the carbon budgets of the forests of Surinam, not only the overall mean stocks and sequestration rates are of interest. Especially variability between years (' interannual variability') is important, as this information is needed to assess the significance of reported changes in uptake rates. It is of course even more interesting to understand variation related to global change, because this can help to assess the consequences of various scenarios as well as the permanence of sequestered carbon in these forests.

The effect of water stress on Amazon forests has been a focus of research in recent years. The multi-year data sets contain rich information on fluxes over dry and wet seasons. The response of the carbon exchange to seasonality appears to vary between sites and regions in the Amazon. In the Southwest, with pronounced seasonality, net carbon uptake (NEE) is clearly reduced in the dry season. In Central Amazonia, with weak seasonality, NEE does not vary significantly with rainfall. But more to the East, in the Tapajós forests, NEE is anti-correlated with rainfall, even though the seasonality is fairly strong (Araújo et al. 2002; Keller et al. 2004; Saleska et al. 2003). More specifically, it appears that the latter forests have a peak in productivity towards the end of the dry season. These phenomena are tentatively explained through a combination of leaf area being high and productive in the moist sunny, dry, season, with deep roots accessing water, and litter decomposition (the return flow of carbon to the atmosphere) being reduced when soils are dry. The in-phase seasonality in the southwest could be related to the very shallow soils and rooting there.

The lack of seasonality or reversed seasonality does not have to imply that the Amazon forests are insensitive to drought. To assess this sensitivity, research has to look into interannual variability and trends. The variability between years has been poorly researched so far. The consequences of the very dry year 2005 has been studied in several publications. Conclusions are contradictory, however. Saleska et al. (2007) show that basin-wide forests have been 'greener' than in normal years, while Phillips et al. (2009) show significant biomass has been lost during that year where drought was most severe.

Long-term model simulations suggest that as a result of climate change (warming and droughting) the Amazon may lose most of its biomass and carbon, turning the biome into a savanna region (Cox et al. 2000; Oyama and Nobre 2004). The question is how relevant this is for the assessment of carbon budgets for UNFCCC reporting purposes. On one hand, if these studies are correct, this implies a limit to permanence and climate mitigation value of carbon in tropical rain forest – it might be better to invest into avoided fossil fuel burning that in avoided deforestation. On the other hand, the predictions may well be an exaggeration and on the shorter term what counts in annual rates of carbon sequestration. If single dry years have little effect this is relevant knowledge because many models would predict lower sequestration rates. It is important to further assess the effect of annual- to prolonged droughts on rain forest carbon budgets.

Management

The primary effect of logging or deforestation in forests is the loss of biomass and hence emission of carbon to the atmosphere. Land-use change does, however, also lead to changed carbon uptake properties of the land surface. Loss of vegetation leads to loss of photosynthetic uptake and, initially, high emissions from decomposing organic material (root and litter) that remained in and on the soil. Usually, in the tropics, logging leads to disturbed forest with big gaps, and clearance is followed by pasture or agricultural use.

Therefore we need to assess the effect of land use change not only on biomass but also on subsequent carbon dynamics. Tropical grasslands have been reported to be able to store large quantities of organic material in their soils (Amézquita et al. 2005). Usually pastures in the Amazon are planted with *Brachiaria* grass, which is a highly productive C4 species. From the few data sets available, it is not obvious, however, that this also leads to high net carbon uptake. Conflicting results exist where pastures are sometimes sources of carbon, sometimes sinks and of these sometimes larger sinks than forests (Grace et al. 2006; Sakai et al. 2004; Wilsey et al. 2002). None of these studies, however, cover sufficiently long observation periods to really say something about the carbon budgets of pasture relative to forests.

For logged-over forests there have been attempts to measure the carbon exchange but there are no firm results due to the complexity of measuring fluxes over chaotic, fragmented forest remains (Miller et al. 2007). All that can be said is that the forests in the Tapajós area of LBA appear strongly disturbed in the recent past, and that at the same time measurements of NEE were substantially lower than those over more pristine forest (Keller et al. 2004; Malhi et al. 2009).

Secondary re-growth vegetation can have very high productivity, given that over 20-30 years, secondary forest can reach heights and densities comparable to primary forest. Boerboom et al (1987) illustrated that the rate of regrowth decreases with the intensity and scale of land use after clear felling. There should be several studies of biomass increase in secondary forest (not shown here), but Eddy correlation flux data in secondary vegetation are not available as yet, to our knowledge. In 2008, a new observation tower was set up in a secondary forest in Central Amazonia, but results are not available yet.

It is somewhat surprising that data on land use type following deforestation in the Amazon are so poorly available. It is clear that this needs to be corrected in the near future. Meanwhile, it is important to realize that for managed vegetation, including forests, pastures and agriculture, measuring only surface-atmosphere exchange of carbon or biomass changes in not enough. For example, highly productive pasture grass is eaten and carried off the land by cattle. The carbon budget here is strongly affected by the life cycle of the biomass, including harvest, burning, manuring, cattle respiration and meat production. Any experiment on managed vegetation needs to account for these.

Other GHG fluxes

Emissions of methane and N2O can be potentially important in tropical systems. Methane is emitted in wet, anoxic environments while N2O emissions are generally associated with fertilized agriculture. Methane emissions are only a small part of the carbon balance, but methane is 40 times more effective as a greenhouse gas than CO2.

Apart from swamps and rice fields (see below), artificial lakes and hydropower reservoirs should be accounted for. An obvious candidate in Suriname is lake Brokopondo. Sinha et al. (2007) estimate very preliminary methane emissions from an area near to and including this lake, as about 4 x 1011 molecules $cm^{-2}s^{-1}$, which is of similar magnitude as those estimated for boreal wetlands and within two order of magnitude of estimates from the Brazilian Amazon (e.g., Miller et al, 2007 Miller et al. 2007).

Recently there have been claims from satellite-based atmospheric methane measurements that Amazon forest may be emitting large amounts of methane (Frankenberg et al. 2005), supposedly through hitherto not detected emissions from live plants. These claims have been corrected (Frankenberg et al. 2008), however, and new work is now under way using aircraft and flux tower data to better specify the exact role of upland tropical rain forests in methane budgets. It has to be considered that these forests can also act as a sink for methane, enhancing its oxidation in their soils.

Savannas

Data on carbon stocks and carbon uptake in savannas are relatively scarce, but recently Grace et al. (2006) published an extensive review. Their general conclusion is that savannas can be quite productive, but although the capacity to store carbon underground is often expected to be high, the overall productivity of savannas is lower than tropical rain forests. Below ground there seem to be important differences between the Central Brazilian Cerrado and the Savannas in the north of South America, where the former have more carbon in both live biomass and soil organic matter. The estimated carbon content in live biomass of 5-10 tonnes C ha^{-1} above ground and a similar amount below ground seems an appropriate first estimate. The amount of soil organic matter SOM varies more than one order of magnitude between all savannas. The only relevant estimate for this study is from the Lamto area, where the carbon content was low, only 18 tonnes ha^{-1}. As this is a wet savanna type, on gley soils, usually associated with peat formation, this seems very low. For annual NPP Grace et al. (2006) mention between 3.5 and 6.5 tonnes C $ha^{-1}y^{-1}$ for these savannas. They also mention that these are likely to be underestimates because below-ground productivity is usually poorly estimated. At the same time it needs to be realized that NPP is not the same as NEP, and hence that the NEP of savannas is likely to be low, especially for those ecosystems that have not recently been disturbed or been subject to fire.

Flux measurement studies similar to those in tropical rain forest exist, but are so far either not applicable to the Surinamese situation (e.g., Brazilian Cerrado sites, dry African sites), or not yet producing publications (measurements in the Ilha do Bananal, S.E. Amazon, Brazil, run by the University of São Paulo).

Other forest types

Other forest types mentioned in ter Steege (2001) are reasonably comparable to Suriname. Values mentioned are, for soils with impeded drainage (swamps) between 400 and 650 tonnes C ha^{-1}, because of the peat layer present. Forests on alluvial soils, near rivers, are estimated at 374 tonnes C ha^{-1}.

Ecosecurities (2002) present an attempt to summarise the biomass contents of forests of the Guianas. They cite a report from Suriname (Tjon 1996), estimating less well-studied forest types such as swamp forests, savanna and creek forests. Estimating below-ground carbon at a similar amount as above-ground biomass, the estimate for ‘high’ swamp forests total carbon is only 140 tonnes C ha^{-1}. It is likely, however, that ter Steege (2001) is correct in assuming organic peat layers, leading to the much higher estimates.

The Ecosecurities (2002) study mentions for ‘creek’ forest, which is likely to be similar to the ‘alluvial clay’ forests from ter Steege (2001), also to contain about 140 tonnes C ha^{-1} for total carbon. Again, this is much lower than ter Steege’s estimate. In this case, probably the Ecosecurities estimate is closer, because ter Steege refers to a forest with high numbers of large *Mora excelsa* trees.

Malhi et al. (2004) report on two seasonally inundated and swamp plots, which have an NPP of about 4 tonnes ha^{-1}y^{-1}, which is at the high end of productivity in Amazon forests and comparable to the estimates for savannas by Grace et al. (2006). However, these plots are in Peru in the more fertile western Amazon. Because of high turn-over rates net ecosystem carbon productivity is expected to be still modest.

Methane emissions from swamps

It is important to account for the fact that waterlogged ecosystems, such as swamps and flooded forests, will emit Methane gas from their often anoxic soils along with the absorption of carbon dioxide. Methane emissions are only a small part of the carbon balance, but since methane is 40 times more effective as a greenhouse gas than CO2, care should be taken to claim benefits from carbon sequestration by inundated forests and savannas. This is not to say that draining them would positively affect the greenhouse gas balance because methane emissions would be reduced. In reality, emissions from drained, decomposing peat and organic soils usually have a larger impact in terms of global warming than the methane emissions from undisturbed swamp.

Application of data from other countries for carbon stock assessments in Suriname

To accelerate carbon stock inventories in Suriname it is tempting to include data from neighbouring countries (i.e. Guyana and French Guiana) with more or less similar forest types as found in Suriname. Species composition shows some overlap, but still the floristic composition can be clearly separated between the countries across the Guyana Shield (Bánki 2010). Estimated of AGB for different forest types in Guyana (ter Steege 2001) that were based on similar forest inventory data as de Milde (1974) ranged between 223 and 256 t ha^{-1} (excl. Savanna), which is lower than the Forest Inventory in Suriname (excl. Savanna) of 294 to 340 t ha^{-1} or 250 to 289 t ha^{-1}, depending on method used (Table 2.4, de Milde 1974). Comparison of the stand tables shows that forests in Suriname tend to have more trees in the bigger size classes, which could explain the higher biomass. Since the FAO Forest Inventories were based on large areas in both countries it is plausible that forests in Suriname on average will show higher above ground biomass. Therefore the application of biomass and carbon stock data from other countries should only be done cautiously if no other data are available.

3 Towards a monitoring, reporting and verification system in Suriname

3.1 Overview of methods to quantify and monitor forest carbon stocks at national scale

MRV systems will require remote sensing to asses gross changes in forest area (deforestation and afforestation) and area and level of forest degradation. To address issues of leakage and permanence of carbon stocks wall-to-wall information will be needed (Baker et al. 2010). Additionally, field sampling of carbon stocks and changes thereof under encountered circumstances and land-use practices will be needed for calibration. MRV systems thus will need to combine remote sensing with accurate ground data from forest inventories. To design schemes for field sampling and monitoring it is necessary to get an indication of carbon stocks and variation within and between different forest types and regions. Subsequent sampling then should focus on the forest types with the highest carbons stocks, with the largest variation (or uncertainty), the largest extent and/or those experiencing largest changes as a result of human activities.

Uncertainties, principle of conservativeness and reliable minimum estimates
To ensure the credibility of REDD-plus as an mitigation instrument in the context of the UNFCCC the assessments need to be accurate, precise and transparent. Both the assessment of activity data (i.e. deforestation area, change in area of forest degradation) and carbon stock changes (emission factors), however, are subject to a certain level of uncertainty evolving from the applied estimation and sampling methodologies. The Subsidiary Body for Scientific and Technological Advice (SBSTA) in its 28th concerning methodological issues for REDD implementation stated that forest carbon assessments should ensure that reductions in emissions or increases in removals are not overestimated (UNFCCC 2008). Also according IPCC (2003, 2006) it is good practice to be conservative in reporting emission reductions or carbon sequestration and to overestimate rather than underestimate emissions.

Two major error types contribute to the uncertainty of the estimation of activity data and emission factors: sampling and non-sampling errors (Köhl et al. 2009; Köhl et al. 2011). Sampling errors are the result from using a subset to infer carbon stocks for larger areas, which is controlled by the design of the sampling scheme and the sample size. Non-sampling errors include other sources of errors that are related to the measurements and estimations, like classification errors, measurement errors, calculation errors, etc. The IPCC Good Practice Guidance for LULUCF reporting (IPCC 2003) suggests that the 95% confidence interval can be used to quantify the uncertainty of the estimates, but Köhl et al. (2009; 2011) argue that this confidence interval is only related to the sampling errors and propose to implement a more detailed error budget.

Also the concept of using a Reliable Minimum Estimate (RME) as suggested by the IPCC Good Practice Guidance (IPCC 2003) fits in the guidelines of reporting conservative estimates. This RME, originally developed for soils, is the difference between the lower bound of the error interval for carbon emissions for the baseline or reference period and the upper bound of the error interval at the assessment period (Köhl et al. 2009, Figure 3.1). Figure 3.1 clearly illustrates the effect of only using the 95% confidence interval which only gives the sampling error, or of using the total error. Although there are currently not yet specific requirements for implementation of the conservativeness principle it will undoubtedly be part of MRV requirements and RME appears to be a good way to account for sampling and non-sampling uncertainty. Yet for a country like

Suriname, maintaining a high forest cover and relatively low deforestation rates application of the RME could potentially result in a need to report net increase of emissions (i.e. in case the upper bound of the error interval is higher than the lower bound of the error interval for the reference period).

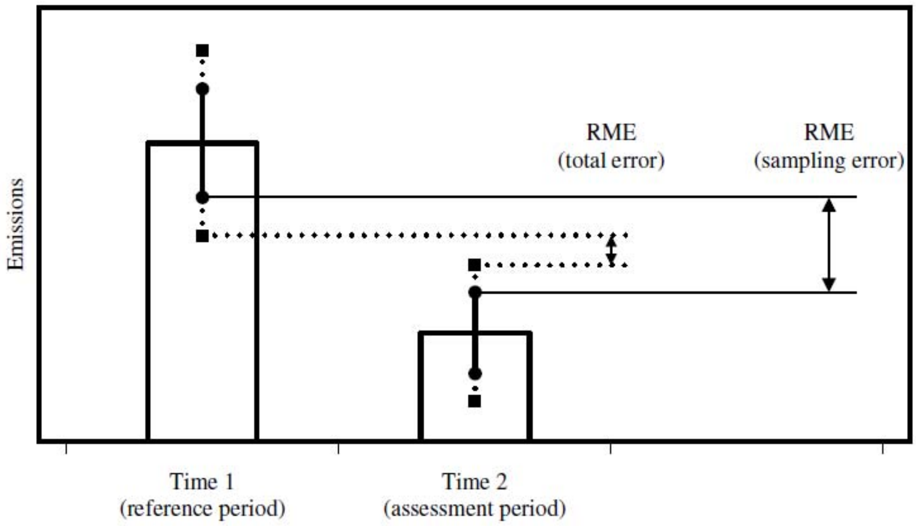

Figure 3.1. *Reliable Minimum Estimate (RME) in terms of confidence interval (sampling error, bold lines) and total survey error (dashed lines) (from Köhl et al. 2009).*

Therefore it will be important to reduce the sampling and non-sampling errors as much as possible. More detailed and accurate measurements, however, generally also imply a substantial increase in costs involved in monitoring (Köhl et al. 2011). Yet to make a REDD-plus scheme effective and efficient, costs of monitoring and the anticipated benefits from reducing emissions need to be in balance. There are a few ways to reduce uncertainty at relatively little additional costs. Those are mostly related to a balanced and efficient sampling design with using a stratification of the forest area and a focus on those carbon pools that contribute most to the uncertainty. To develop such scheme may need a step-wise approach that is regularly evaluated.

In the following we will give a brief overview of the various methods that are available for setting up an integral assessment of regional, nation-wide greenhouse gas budgets.

3.1.1 Remote sensing: the scope for RADAR remote sensing

Remote sensing will be essential to assess changes in forest area (deforestation), level of forest degradation and forest conservation (i.e. activity data). For detection of changes methodologies are being developed based different sensors/satellite systems (e.g. Chambers et al. 2007). Both radar and optical systems have advantages and disadvantages. Advantages of radar include the possibility to look through clouds, haze and smoke, allowing frequent and repetitive observation of forest. This feature appears to be especially important for reliable monitoring in the humid tropics, although recently also optical systems or mixed approaches have been used successfully for these ecosystems (e.g. Landsat in combination with airborne LiDAR, Asner 2009). An additional advantage is that the radar signals penetrate through closed canopies revealing information on trunks and flooding. Consequently, radar can distinguish biomass and wetland classes invisible for optical remote sensing.

Here we give an example of an up to date vegetation and land cover map for 2010 for Suriname based on PALSAR radar data. Wageningen University participates in the Science Team of the Kyoto & Carbon (K&C)

Initiative lead by the Japanese Space Exploration Agency (JAXA)[1]. The role of Wageningen University is the development of operational radar monitoring systems for the humid tropics based on PALSAR data. To this aim large quantities of PALSAR data over Insular SE Asia, Colombia, Guyana, Suriname en Gabon have been acquired from the year 2007 onwards. The production of maps is largely carried out by SarVision, a partner and spin-off organisation of Wageningen University.

Within the framework of the above mentioned JAXA Kyoto & Carbon Initiative, SarVision produced a vegetation and land use map for Suriname for 2010 (Hoekman and Quinones 2011, Figure 3.2a). Future time series of maps using the same approach will allow the monitoring of changes in forest area and land-use change.

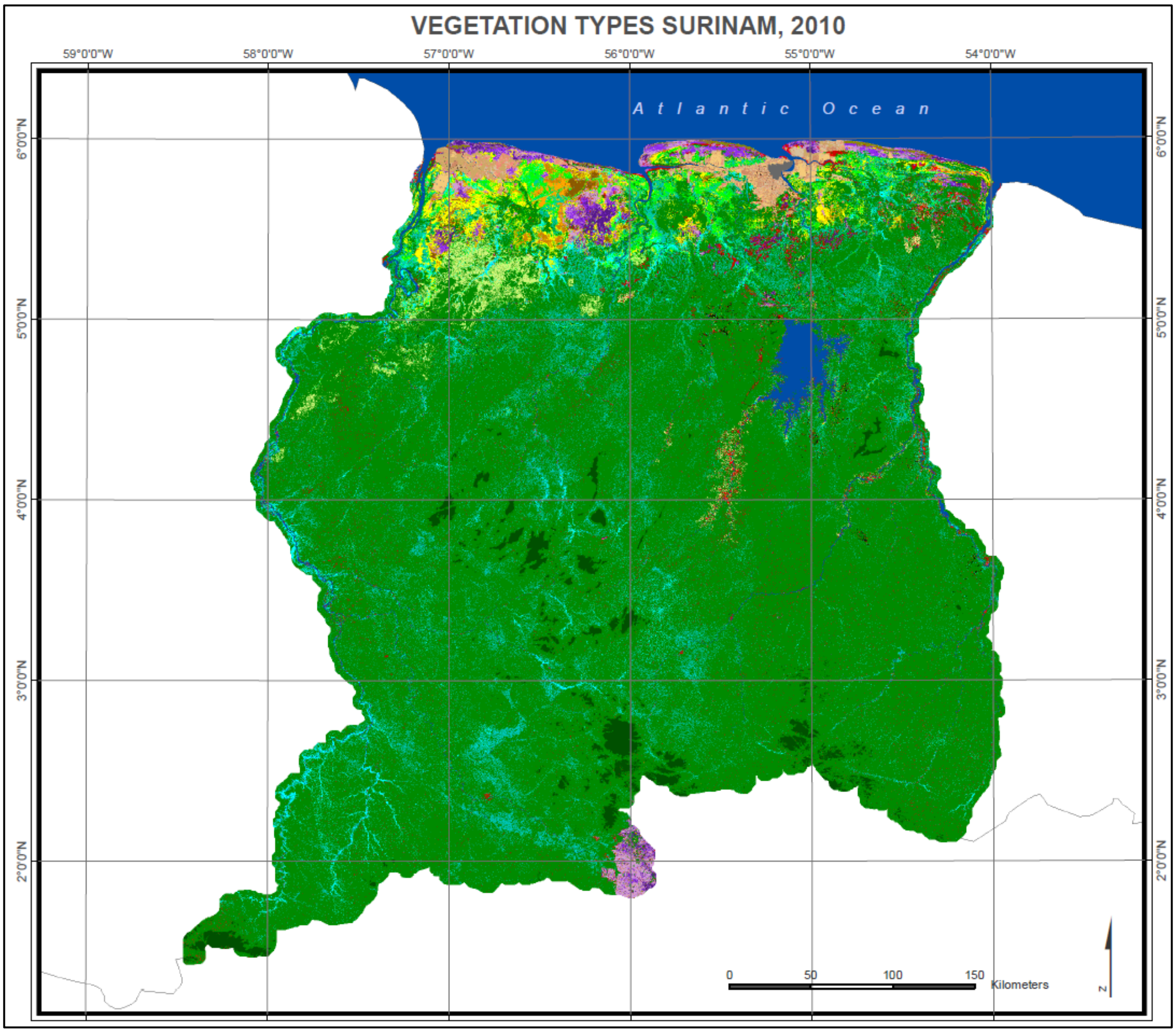

Figure 3.2.a. *Land cover map of Suriname for 2010 based on PALSAR data (Hoekman and Quinones 2011). For legend see Figure 3.1.b, below.*

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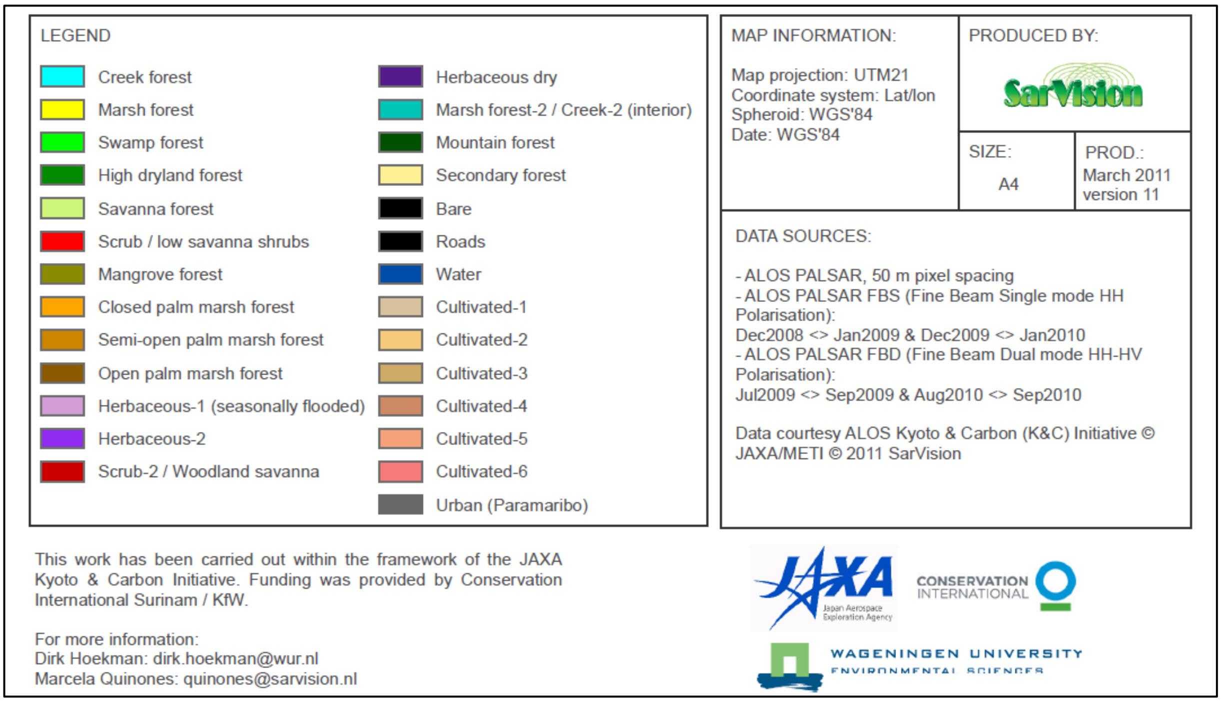
[1] See: http://www.eorc.jaxa.jp/ALOS/en/kyoto/kyoto_index.htm



LEGEND

- 🟦 Creek forest
- 🟨 Marsh forest
- 🟩 Swamp forest
- 🟩 High dryland forest
- 🟩 Savanna forest
- 🟥 Scrub / low savanna shrubs
- 🟫 Mangrove forest
- 🟧 Closed palm marsh forest
- 🟧 Semi-open palm marsh forest
- 🟫 Open palm marsh forest
- 🟪 Herbaceous-1 (seasonally flooded)
- 🟪 Herbaceous-2
- 🟥 Scrub-2 / Woodland savanna
- 🟪 Herbaceous dry
- 🟦 Marsh forest-2 / Creek-2 (interior)
- 🟩 Mountain forest
- 🟨 Secondary forest
- ⬛ Bare
- ⬛ Roads
- 🟦 Water
- 🟫 Cultivated-1
- 🟧 Cultivated-2
- 🟫 Cultivated-3
- 🟫 Cultivated-4
- 🟧 Cultivated-5
- 🟥 Cultivated-6
- ⬛ Urban (Paramaribo)

MAP INFORMATION:

Map projection: UTM21
Coordinate system: Lat/lon
Spheroid: WGS'84
Date: WGS'84

PRODUCED BY:

SarVision

SIZE:

A4

PROD.:

March 2011
version 11

DATA SOURCES:

- ALOS PALSAR, 50 m pixel spacing
- ALOS PALSAR FBS (Fine Beam Single mode HH Polarisation):
Dec2008 <> Jan2009 & Dec2009 <> Jan2010
- ALOS PALSAR FBD (Fine Beam Dual mode HH-HV Polarisation):
Jul2009 <> Sep2009 & Aug2010 <> Sep2010

Data courtesy ALOS Kyoto & Carbon (K&C) Initiative © JAXA/METI © 2011 SarVision

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Figure 3.2.b. *Legend of the Land cover map of Suriname (Hoekman and Quinones 2011). For map see Figure 3.1.a above.*

Although the resolution of the current map is relatively low (50m), it can be used to assess areas with activities that need further scrutiny at higher resolution. The current map, for instance, very clearly shows areas with small scale gold mining (Figure 3.2, mix of black (bare) and red (scrub/savanna) areas to the east and the west of the Brokopondo reservoir and along the border with French Guiana), probably the activity with currently the largest impact on forest area and forest degradation in Suriname and Guyana. The mined areas show up as a mix of bare areas and scrub /savanna indicating the degraded status of the forest around the pits (see e.g. Arets et al. 2006). To detect further expansion of existing mining areas may need remote sensing at a higher resolution, but a recent time series based on PALSAR data for Guyana shows reliable results (pers. com. Quinones 2011).

3.1.2 Biomass plots and increment measurements

The basic need to monitor national biomass carbon stocks and changes over time is the establishment of a well-planned, representative network of biomass plots. This is needed both to make direct estimates of Suriname's biomass, as well as to calibrate remote sensing methods to scale up the biomass plot information. To reduce the uncertainty of carbon stock estimates it is recommended to first stratify the forest area into areas which can be anticipated to have similar forest characteristics. For the plot design and operation, several methods are available, all with advantages and disadvantages. A detailed proposal for the design of a plots network and for the design of plots and their operation is given in Chapter 3.2.

However, a clear disadvantage of using biomass plots to estimate carbon budgets is that they only give information on above-ground biomass and dead organic material. Root biomass and soil carbon stocks are usually not measured easily, and thus the overall carbon stocks and stock changes are to be based on assumptions on the above-below ground ratios of biomass and carbon. As an alternative, there are also other methods to measure the carbon exchange of whole ecosystems, including roots and soils, or even whole regions, at once. These methods are described below (eddy correlation, aircraft fluxes, inversion modelling).

3.1.3 Direct measurement of whole-ecosystem carbon exchange: Eddy correlation

Eddy correlation represents the most direct measurement of surface-atmosphere exchange, for reasonably large surfaces. In an assessment study, measurements would be typically set up in one or a few of the dominant vegetation (forest) types in the area of interest.

Eddy correlation measurements are typically done from a tower, extending above the vegetation. The technique in its basic form only considers vertical transport, and assumes horizontal transport to be negligible. This effectively implies an assumption of *horizontal homogeneity* in average vegetation and terrain characteristics, as well as a *horizontal* surface. The scale of these assumptions is at the same order as the flux 'footprint', i.e. several hectares to square kilometres. This is, of course, in practice never achieved and hence the method carries a degree of uncertainty that increases with terrain complexity, usually of order 10-30% of flux values.

Flux tower locations therefore need to be carefully planned, in order to ensure representativeness for the region while minimizing uncertainties associated with terrain. Flux tower structures, if acquired locally, do not need to be extremely expensive any more, and the necessary equipment is of order several ten thousands of euro's nowadays. If set up well, with remote data access, a tower flux site does not need much more maintenance than about two-weekly.

We recommend seek possibilities to set up a forest tower site in the Kabo or Mapane forest areas, because these have been well-researched in the past, contain biomass plots and are reasonably well accessible. A walk-up tower would be needed (scaffolding design, aluminium) of about 50 m tall. On top of that tower, the eddy correlation equipment as well as an automatic weather station need to be installed. Along the tower height, automatic air sampling for CO_2 concentration analysis is recommended. Power for the systems will have to be provided by solar energy panels, installed along the same tower.

For lower vegetation, a shorter mobile tower can be used, moving measurements from time to time between different vegetation types, such as crops, pastures, and short re-growth. We suggest employing a system like that to study the CO_2 exchange over swamps, rice paddies and grassland.

For a good assessment of the carbon budget, at least a year's worth of data is needed. Gaps in data sets can be accounted for if there are sufficient measurements across seasons and sufficient supporting data of environmental conditions to allow interpolation models to be calibrated.

3.1.4 Larger scale: flux measurements from aircraft

Eddy correlation equipment can also be deployed from a dedicated aircraft. Several of such low- and slow-flying 'flux aircraft' now exist and have been tested in various large-scale campaigns. A flux aircraft generates spatial data, not temporal. Thus, we can construct maps of surface fluxes at specific times. If flights are repeated often enough, of course also time series can be constructed. Results from aircraft flux measurements look very promising, capable of detecting different landscape elements and features in the landscape in terms of their carbon exchange.

Flux aircraft incur a significant initial investment, but their running costs are reasonable and partly dependent on hourly rates for pilots and fuel prices. If an existing aircraft could be employed for a set period alongside continuous measurements at on eddy tower site, this could provide valuable information for scaling up the tower point measurements to a region.

Alterra owns and manages a small aircraft to measure these fluxes. A possibility would be to transport the plane to Suriname for a set period and fly a number of transects in a campaign mode, for example during the transition from wet to dry season.

3.1.5 Larger scale: boundary-layer budgets

An alternative to the direct flux measurements using turbulent transport is the *budget* method. In this case, we consider the lowermost part of the atmosphere, which is in daily contact with the surface, as a giant 'cuvette' - a box that can be considered closed at top and sides. The only factor influencing the concentrations of CO_2 in this virtual box is then considered to be the vegetated surface, which emits greenhouse gases to or extracts them from that box. If the top of this box is either very high or the top of the 'planetary boundary-layer', and if there is no large-scale horizontal heterogeneity in the landscape and atmosphere, we can indeed compute the regional surface flux from the mass balance of this virtual box (Lloyd et al. 2007).

Concentration measurements need to be done well up in the boundary-layer, preferably through a profile using a balloon or an aircraft. This limits the frequency with which such measurements can be done. Furthermore, the problem of horizontal heterogeneity is even larger than with eddy correlation, and the top of the boundary-layer is often hard to define. Nevertheless, with updated methods this method deserves further exploration, especially in combination with the methods to be discussed hereafter.

For now, we do not recommend using this method in Suriname.

3.1.6 Large scale: Atmospheric inversion modelling

A more comprehensive budget method is one where horizontal variation in atmospheric concentrations is measured across a large region (such as a continent, or the whole globe). These concentrations are then brought together with the reconstructed atmospheric transport from model and meteorological observations, such that from the modelled transport and observed concentration changes, it can be calculated how much greenhouse gas was exchanged when and where.

This method is mainly an option to be applied within the framework of international collaboration. If Suriname would set up one or more high-precision observation sites (oceanic border, tall towers, or regular aircraft profiling) the global inversion models would be able to quantify the overall greenhouse gas budget of the Suriname region. This mainly implies investing in a tower and a high-precision measurement system, or in arranging regular (weekly) aircraft profiling flights.

Affordable, very high precision instrumentation for the measurement of CO_2 concentrations along with methane, is now available from Picarro (Synnyvale, CA, USA; http://www.picarro.com/). A concrete possibility would be to implement continuous measurements at at least one point in central or Southern Suriname, such as at the Tafelberg or Sipaliwinie stations of the Suriname Meteorological service. Especially if this would be combined with one other continuous measurement station at the northern coast (Albina, or other site with good access), then the inversion models would be able to generate good estimates of the CO_2 and methane uptake/emission of the country as a whole.

3.1.7 Small scale: soil chambers and floating chambers

As noted in the first section, the bulk flux methods described (such as Eddy correlation) measure GHG exchange of the whole ecosystem. In order to understand and predict the environmental response and variability of these ecosystems, the first issue is to distinguish the heterotrophic respiration, i.e. the CO2 emissions from decomposing plant material and organic matter and animals, from the net primary productivity (controlled by living plants). The most important component of this respiration is soil respiration, which can be measured using cuvettes on the soil connected to a gas-analyser. Usually these are manual sample-type measurements, in which transects and representative sample points within a vegetation need to be covered. This type of measurements can also be automated, for limited spatial coverage but to cover temporal viability.

A disadvantage of this method is that, in fact, not only heterotrophic respiration is measured but also root respiration. Thus, the ecosystem carbon budget is then subdivided into above-ground processes and soil processes.

For emissions from water surfaces (such as CH_4 from lakes) similar techniques can be used, but then using floating cuvettes.

At sites where continuous CO_2 fluxes are going to be measured, as suggested above, ideally there should also be measurements of soil CO_2 fluxes using chamber techniques, ate regular intervals (every few weeks or so), over a sufficiently large spatial sample.

Additionally, we would like to point out that it is important to start investigating the methane emissions from swamps and lakes, such as the Brokopondo reservoir. This should be done at first in a research mode, using floating chamber techniques.

3.2 Designing a network of inventory plots

For assessments of forest carbon stock and emission factors it will be essential to get accurate , precise and unbiased estimates of carbon stocks in different forest areas. In the scope of REDD different alternative sampling designs can be used. Usually forest surveys are carried out using random sampling or systematic sampling. When applying strict random sampling, the sample locations are chosen randomly, while in systematic sampling the sample locations are arranged systematically, usually in a square grid or other regular geometric network. Because large parts of Suriname, especially in the interior and South are rather inaccessible a systematic approach will probably not be a very cost effective sampling design.

3.2.1 Stratification of the forest area

A proven method to reduce the uncertainty of carbon stock estimates is the stratification of the total forest area in areas with similar characteristics and to estimate separate average carbon stocks and accompanying uncertainty for each stratum. If the number of strata is too high, however, the effect of stratification will diminish again. We propose to stratify the country into nine geographical regions that represent areas with roughly similar forest types. Within each of the regions we further recommend to focus on the most important (most dominant) vegetation and soil types. Depending on the exact definition of REDD policies, it can be considered to focus on those vegetation types with highest biomass per hectare, or on those vegetation types and areas that are most under threat of deforestation.

It is known that forest types and species composition in Suriname changes from west to east with the main rivers running from South to North as important dividers in forest composition. Also from North (coastal zone and Savanah belt) to South different forest types can be distinguished. Therefore we propose to stratify the forest in roughly the following monitoring sectors (see also map in Figure 3.3:

1. Northeast (NE): eastern border: Corantijn river; north: ocean; west: Coppename; South: transition savanna-High dry land forest
2. North Central (NC): eastern border: Coppename river; north: Ocean; West: Suriname river; south Savanna-High dry land forest
3. Northwest (NW): Eastern border: Suriname river; North: ocean; West: Marowijne river; South: transition savanna-High dry land forest
4. Central east (CE): Eastern border: Corantijn river; north: transition savanna-high dry land forest; west: watershed mountains; south ** not defined yet (about 3.5 degrees N)
5. Central (C): Eastern border: watershed mountains; North savanna-high dry land transition; West: Brokopondo lake, then watershed Suriname and Marowijne rivers; South: watershed Suriname and Tapanahony
6. Central West (CW): see 5 and: Western border Marowijne river, south: * not defined yet (about 3.5 degrees N)
7. South East (SE): Eastern border: national border; North see south 4; West: South from Juliana Top, to West of Sipaliwini savanna; South: National border
8. South Central (SC): see7 and 5; West: Line south from border 5 and 6; south: national border
9. SouthWest (SW): see 6 and 8; West and South national borders.

When more detailed data from initial monitoring come available , it may be needed to further revise this stratification

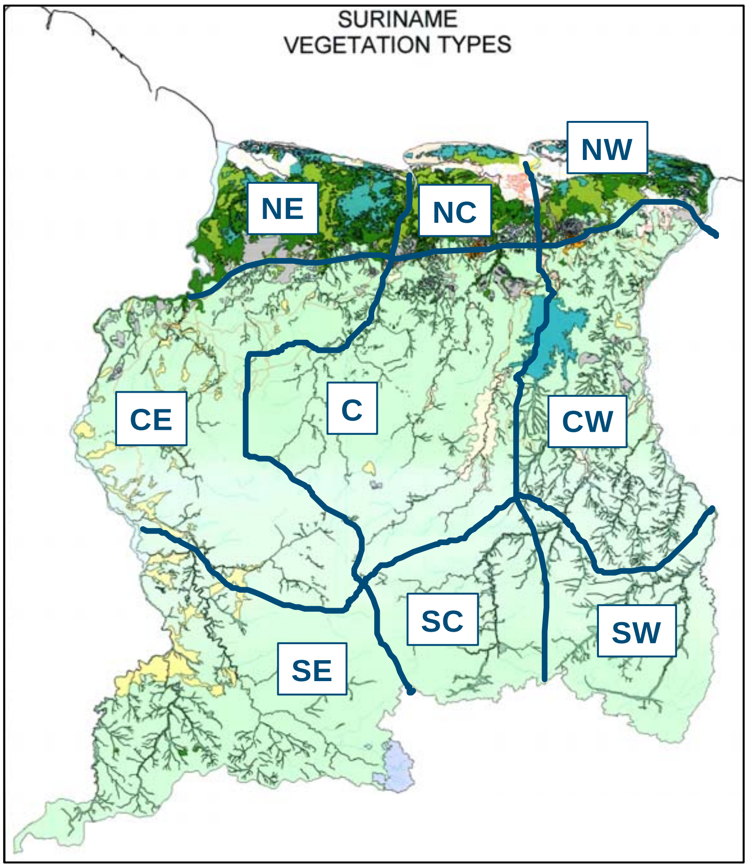

Figure 3.3. *Rough outline of the proposed geographical zoning. Vegetation map from CELOS-NARENA.*

3.2.2 RAINFOR methodology

The RAINFOR consortium has over almost a decade built up much experience in censuring biomass of tropical forests, and designed standardized methodologies. All information on design and methodologies can be found at their website: http://www.geog.leeds.ac.uk/projects/rainfor/

The methodology not only gives guidelines for measuring live wood biomass but also for recording dead biomass. Especially when the net sink strength over time of a forest is to be estimated, it is important to also include mortality and decomposition of dead material.

In this methodology as well as in other literature (e.g. Clark and Clark 2000), it is recommended to stratify the domain to be sampled, according to forest/vegetation type, climate, water regime and soil type. A representative number of plots, of representative size, should then be established in each of the most important strata. We propose that for Suriname, a stratification is set up according to nine geographical regions, and within those the main soil and vegetation types. A proposal for this is presented below.

Within each stratum, plot locations should be assigned strictly randomly (using a map prior to field visit). Probably, however, little abundant situations such a s steep slopes or water logged areas should be avoided in these strata.

The number of plots and plot size within a stratum to achieve a certain accuracy, has been studied for example by Clark and Clark (2000) for a forest in Costa Rica. Together with the RAINFOR manuals, we conclude from these studies that a plot size of between 0.5 and 1 ha, and a number of 10-15 plots per stratum are to be recommended. It is useful to choose a standard size and shape of the plots. The RAINFOR manuals provide further details.

If the objective would only be to monitor the changes in biomass over time (i.e., productivity), less plots are needed, as long as exactly the same plots are censused at each time interval.

A second RAINFOR methodology document describes protocols for estimation of the amount of course woody debris (CWD), or, necromass. Two approaches are proposed. The first method requires sampling all CWD with diameter >10 cm in the whole plot, while the second assumes linear transects, where fallen material is only recorded when crossing a line while dead trees are recorded within a band of 10 m wide. Within those two approaches, the descriptive methodologies are similar: measuring circumferences, length and void space of logs/branches, estimating density through sub-sampling, drying and weighing, recording dead trees and decomposition classes.

Clearly the linear method is more efficient, but then there will be a mismatch between the biomass and the CWD sampling plots/lines.

3.2.3 Alternative methodology

A different plot management manual has been given by Dennis Alder and Marijke van Kuijk (A&K) for Guyana, and which is largely followed in Suriname with major modifications as to area sampled. There are some noticeable differences between this methodology and the one described by the RAINFOR consortium:

- A&K use transects of 3 circular plots of 0.5 ha, 1 km apart for trees with DBH > 20 cm and a radius of 8 m within that for trees with DBH >5 cm.
- RAINFOR gives more details on measuring deformed, fluted, stilt-rooted and re-sprouting trees, and for trees on slopes.

- RAINFOR gives instructions for measuring trees with very high buttresses using a digital camera.
- RAINFOR gives much attention to detailed measurement of lianas and hemi-epiphytes.
- RAINFOR recommends measuring the height of all tagged trees, but A&K do so for only the eight tallest trees in the (0.5 ha) plots.

Both methods have their own advantages and drawbacks. The main difference between the two approaches is the size of the sampling plots. With A&K, it is easier, with many small plots, to quickly cover the variability in a large area. Also, this method allows more efficient recording of the largest tree size classes, because of the stratified approach. However, the larger RAINFOR plots are likely to give a more rigorous and repeatable sample for homogeneous forest areas. Because of the more compact, large plots edge effects will be much less. Edge effect errors are twofold: firstly, the relative uncertainty in the sampled surface area will be larger, due to uncertainly in determination of the perimeter of plots. Secondly, the small circular plots of A&K are hard to interpret when there are dead, oblique or fallen trees in the plot: the size of these plots is smaller than typical wind throw gap size.

A&K have, in the methodology described, only sampled relatively small areas for necromass. As necromass is as important for the net carbon budget of forests as the living biomass, rigorous sampling over larger areas is believed to be essential. The RAINFOR methodology provides a better opportunity for this, although of course the A&K method can be combined with more rigorous necromass sampling such as along the RAINFOR methods.

Chave et al. (2003) found that spatial variation in AGB is very high and that when applying small sample plots the average AGB is not normally distributed but strongly skewed to the left. Plots smaller than 0.25 ha seem to be not suitable for estimation of AGB over larger areas. Also their error analysis shows that regarding confidence in the estimate there is a trade-off between sample plot size and the number of subplots that need to be established to know the mean biomass with 20% error. The total area that needs to be sampled, however, decreases with more, but smaller plots (in this example 481*0.01 ha, or 4.81 ha when using 10 x 10 m plots or 9 * 1 ha in the case of using 1 ha plots.

Since travel logistics are relatively difficult and expensive, particularly in the interior of Suriname, additional time needed for measuring more trees in the bigger plots may weigh up against cost of travel and time needed to reach locations.

Also other studies show that using smaller plots (i.e. 0.25 ha) can be problematic to get reliable estimates of AGB and other potentially important carbon stocks like course woody debris (e.g. Baker et al. 2004; Chave et al. 2004; Rice et al. 2004). The RAINFOR methodology prescribes a minimum plot size of 0.5 ha

3.2.4 Time investment in setting up plots

Indicative time investments involved in setting up new plots according the RAINFOR methodology:

Locating and stringing a plot: 3-4 people, 2 days
Tree tagging, painting, mapping and measurement: 4 people, 3 days
Large trees and tree heights: 2 people, 1 ½ days
Topography: 2 people, ½ day
Botanical collection: 2-3 people, 10 days [assuming moderate prior knowledge and median Amazon alpha-diversity, 150 species per ha]
Total ~19 person-days for biomass only, ~48 person-day including botanical characterisation

Indicative time investments involved in re-measuring existing plots (RAINFOR):

Locating and stringing the plot: 3 people, 0.5 day
Tree tagging, painting and measurement: 4 people, 2 days
Large trees: 2 people, 1 day
Botanical collection of new recruits: 1-2 people, 1 day (less in low diversity forests)
Total ~13 person-day

The CWD sampling is not included in these time estimates. This is clearly a big additional job, requiring people to record, to measure and to spot, as well as to take samples. It is however, essential to also include CWD in the estimate of above ground carbon budgets.

Additional time may need to be allocated for significant rain delays, breaks for field-team rest and recreation, and unforeseen circumstances. Botanical collection-times are very variable, being sensitive to the difficulty (number of species), weather conditions, and the physical skills and technical knowledge of the team.

3.3 Current and future needs for a MRV system in Suriname

For a MRV system in Suriname an important first step would be to develop an institutional and governance system in which responsibilities and tasks are laid down.

On 3 August 2011 the government of Suriname installing a special agency within the Cabinet of President of the Republic of Suriname to consolidate its existing climate change efforts and to accelerate the setup of a structural approach of its climate change strategy. With this step the government emphasised again her commitment to contribute to combating climate change taking into account the national circumstances. This Climate Compatible Development Agency will be tasked, amongst others, with formulating Government's climate change policies, including the development and the execution of the Climate Compatible Development Strategy.

The Ministery of Physical Planning and Land Forest Management (MIN van RGB) and her technical work arm the Foundation for Forest Management and Production control (SBB) will be instrumental in the implementation of the technical activities such as setting up MRV, Forest Carbon Assessment and other REDD-plus related technical activities. To design a tailor-made MRV-system it is necessary to formulate a National REDD-plus policy. Furthermore to guarantee an efficient establishment of a MRV-system it is needed to develop a roadmap with all the activities that need to be carried out and to identify and involve the responsible institutions.

The effective involvement of relevant stakeholders and institutions such as CELOS, the private sector, the national and international NGO’s, indigenous and Maroon people will be continued and strengthened`. At this moment Celos is playing an important role in the development of the protocol for the field measurements, while in the future they might be a suitable institution to host the remote sensing unit which is needed to help measure the activity data.

The Governement of Suriname has carried out following activities:

- The development of a Forest Cover map commissioned by the Ministry of RGB with financial assistance of CI and KfW (see Figure 3.1.a, Hoekman and Quinones 2011).
- Implementation of the Project” Capacity Improvement for Efficient Forest Carbon Stock Assessment”. The project implementation is coordinated by the Ministry of RGB and the field activities are carried out by the

Foundation for Forest Management and Production Control (SBB) Within this project personnel from different institutions, CELOS, HERBARIUM, LBB have been involved and trained in Forest Carbon Assessment. The first phase (first year of the planned 3 years) of the project is funded by the WWF, Tropenbos Suriname and Capaciteit Fonds Bos en Nature (CBN). In this phase 12 transects will be established end of this year. Up till now 9 transects have been established. The results of these activities will also be used in setting up an MRV. Funding for the remaining phases is still not available yet

3.4 Recommendations

To develop a national MRV system in Suriname further capacity needs to be developed to carry out the field measurements, remote sensing, data analysis and reporting. As indicated in the introduction the reporting needs to be transparent and verifiable. This means that the data underlying the reports need to be accessible and accurate. In the current preparatory phase towards a formal UNFCCC REDD-plus mechanism we recommend to take some time to evaluate and where needed to modify the monitoring scheme. Currently SBB is measuring a number of sample plots/transects, which are measured in high detail. The data from these plots can be used together with the data provided in Chapter 1 of this report to assess the levels and the major sources of uncertainty in the carbon stock estimates. Insights from such evaluation may be used to adjust and improve the sampling scheme to further reduce uncertainty and, potentially reduce time investments by reducing unnecessary measurements of carbon pools that are not a major source of uncertainty.

Data quality and permanence
Given the difficulties in accessing historic data and the quality of some of the available data, the development of the MRV system of Suriname will need to explicitly pay attention to data handling and data storage issues. Since the monitoring will be done over a long time, it is important to store data in a safe place and if necessary update or convert electronic copies of data to new software versions if applicable. Data collected in the field should to be entered in a database system as soon as possible and data need to be checked on obvious errors and consistency to guarantee data quality. Large deviations between censuses need to be double checked in the field. As part of the quality system an indication of data reliability and extent of measurement and data entry errors should be assessed by

- Re-measuring 10% of the plots re-measured by a different field crew.
- Repeating 10% of the laboratory measurements by different lab personnel.
- Re-entering 10% of the data by another independent person.

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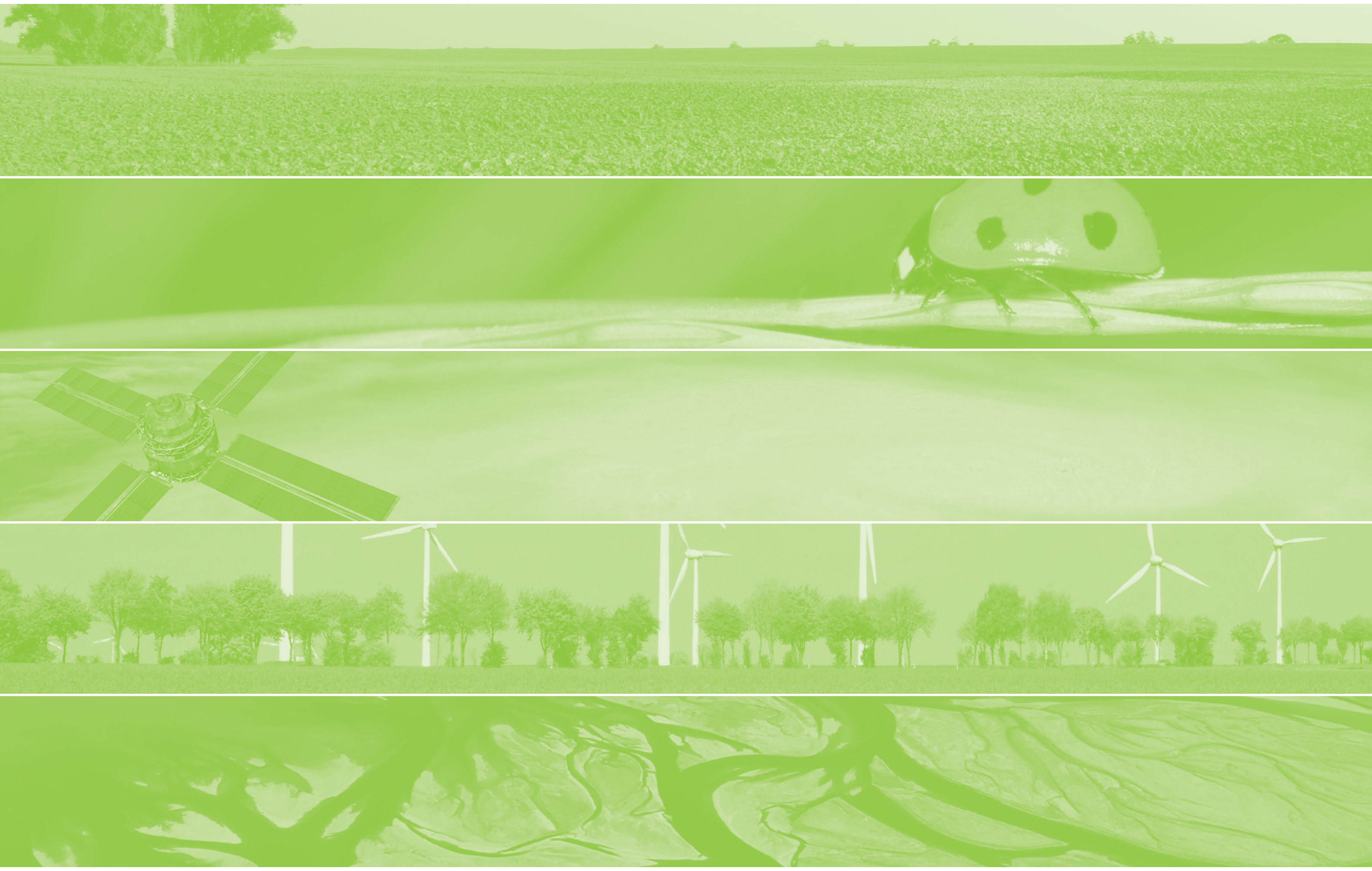

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