7 Conclusions and outlook

The aim of this study was to illuminate the rainforestation system in comparison to other land uses from different angles, mainly its original rehabilitation approach, biomass production and carbon sequestration aspects. Parameter selection followed the rainforestation leitmotiv of land rehabilitation through accelerated succession, leading to a forest-like system of high diversity and enhanced resilience against environmental extremes. Consequently, the focus was set on parameters determining and concerning organic matter turnover and such expected to change within a relatively short time under rainforestation, i.e. 10-15 years. Methods had to be applicable under basic and low-budget conditions and comparable to those applied in other studies, an approach inspired by TSBF.

At the selected sites, differences were substantial. Soil analyses at the selected plots gave valuable insights into typical time-, rock- and relief-related processes. Major groups of soils – obviously calcareous and volcanic, but also slope, footslope and plateau positions as well as autochthonous and allochthonous types were distinguished and implications of these groups on nutrient and water balance identified. Assets and constraints of soils for agriculture were evaluated. Data from these sites also provided orders of magnitude as orientation to judge land use-specific changes. An important finding in this context was the elevated level of P in two subsoils, since P is usually the most limiting element in volcanic soils in Leyte. The ability of trees to bring nutrients from the subsoil to litter and humic horizons under the given conditions was later tested in a modelling scenario.

Environmental changes as supposedly caused by the rainforestation systems were assessed through a paired-plot approach across 7 existing rainforestation sites, which fulfilled the criteria for a paired plot approach, mainly minimal area and an adjacent reference plot. As in many tropical forest ecosystems, succession goes along with acidification and net-export of nutrients *from the soil*. Part of this is owed to leaching caused by torrential rains once the oftenly excellent soil water holding capacity is over its limits (leaching of N and P has been indicated by the modelling approach). Loss of bases is intensified by the decreasing pH. In addition, nutrient uptake into plants can play an important role in soil depletion of certain elements (Nykvist 1997), so that concentrations especially of macronutrients in soils can decrease over time under reforestation. This may not meet expectations from such systems, if restoration of soil fertility is evaluated merely from a productivity perspective. Gross productivity rates of ecosystems usually decrease as succession proceeds (Odum 1969). However, nutrients are not completely exported *from the ecosystem*, but rather stored in the plant biomass as in a bank account. They can be set free, when the rotation is finished or, in natural forests, when a gap opens. This corresponds to the function of fallows under numerous nomadic indigenous systems (examples in Posey & Balée 1989).

Looking at ecological functions of soils, tree canopy mitigates microclimatic extremes and, through addition of litter, increases organic matter contents and improves soil structure. As an example, the relatively open banana-dominated subplot 8 showed clear signs of erosion such as a thinner Ah horizon and higher topsoil bulk density than the surrounding subplots under tree canopy. Reduced erodibility is crucial for the steep slopes on the Cordillera Central in Leyte[94]. From this point of view, the role of trees as providers of environmental services lies in their provision of shade, formation of biomass, contribution to SOM and reduction of erosion.

Under the mentioned aspects of productivity and environmental services, systems

94 While landslides occur frequently even in old growth forests and the load of trees superimposed on the soil may in some cases increase the risk of landslides.

targeting the latter may be less profitable in the short run, but more sustainable. Late-successional ecosystems tend to stability, while pioneer stages aim at rapid biomass build-up (Odum 1969); the latter also applies for agricultural systems, which are arrested in a pioneer stage (Ewel 1999). Where financial liquidity is critical, sustainability can be a side effect but will not be a priority[95]. The aim of any successful agroforestry system must be to integrate both ends. Short-term rentability can be achieved through the integration of early-yielding species, which motivate farmers to maintain the plot during the first years. Continuous revenues from carbon sequestration can be another option to create income at an early stage of the system. As commodities, CER should not be considered as subsidies, but income from environmental services. In contrast, provision of all necessary inputs plus 'livelihood' subsidies by a project may hamper motivation of project 'beneficiaries'.

Regarding the first option, integrating early-yielding species has not been emphasised on the early rainforestation plots, but is now more accepted. Diversification in early-yielding species does not necessarily restrict short-term profitability, especially under low-capital smallholder conditions. In this context, an imbalanced focus on one particular cash crop fostered by project activities or even real demand could be fatal in case of pest or disease outbreaks[96] or a collapsing market.

Regarding income generation through CER, the modelling approach showed, that fast-growing pioneers quickly add large amounts of C to the system, but at a later stage stagnate in biomass production, unless late-successional species have been interplanted to take the lead in biomass production. Recalcitrant litter such as provided by many dipterocarp species would be more useful for SOM accumulation than easily decomposable *Gmelina* leaves. Considering preference of native species, pioneer trees such as *S. palosapis* or fast-growing species like *A. odoratissimus* could be an equivalent substitute fulfilling similar ecological functions as *Gmelina*. Constructing ecosystem functions with a minimum number of plant species (Langi in Gerold et al. 2001), surely falls short of imitating an intact natural ecosystem. Too many factors and interrelationships are not known, so that apart from obvious measurable functions such as biomass or nutrient contents, ecosystems can hardly be engineered. Instead of trying to determine and reduce 'functional redundancy', pursuing maximum diversity appears more appropriate.

On the other hand, the argument of native species should not be taken too far since many of the most popular fruits cultivated in the Philippines are not native. Unless pure stands are installed, a few exotic species should be accepted within the system.

The integration of annuals or early yielding species can play a role for carbon balances during the first years, but then loses importance. Under the aspect of soil conservation, any crop or soil cover is of advantage in order to reduce erosion and to supply biomass for humification. Improved microclimatic conditions under cover crops may cause more intensive litter decomposition, humification and formation of stable aggregates, but not necessarily mineralisation.

When CDM projects are planned, the influential role of soils has to be considered. Small changes in soil C balances can have large impact on the total C stocks (Powlson 2005). Apart from the soil-conserving factors mentioned before, design and management such as planting on contour lines and mulching can be other promising ways of soil conservation facilitated by trees (Mercado 2007, PhD thesis, unpublished). The effect of mulching on

95 Philosophies based on sustainability may thus be considered a luxury phenomenon as they require investments that do not yield immediate returns. Not coincidentally, the fundaments of sustainability in forestry were laid by a government official (Oberberghauptmann v. Carlowitz 1713) and extended to a broader concept by the Brundtlandt commission in 1987, and not by smallholders.

96 Such as Sigatoka on abaca plantations in Southern Leyte.

SOM was well reproduced with WaNuLCAS, but an effect on erosion could not be deducted from the simulations.
In this context, the relative accuracy of the simulations must be addressed again. WaNuLCAS worked well as a *scientific* model (Passioura 1996) in order to explore hypotheses and tendencies, which were then cross-checked with field observations: For example, elevated P contents in the topsoil over a subsoil with relatively high P; the topsoil P was supposedly accumulated at the surface through tree leaf litter. For its use as an *engineering* model, i.e. to quantitatively predict growth or carbon pools, interpretation needs to be exercised with caution. Relative biomass magnitudes of the various agroforestry components were realistic when compared to measurements on site, but absolute dimensions would require more inventory data. Values fit well into literature data, but overestimated the measured dipterocarp growth.
In practice, the growth experiment at Cienda site showed that, apart from planting time, good planting material is critical for the successful installation of any system. The most sensitive abaca was used as a bioindicator for site conditions. In this context, reserves are important for the plants to recover after stress phases. The issue of tissue culture vs. corms can probably be reduced to reserves, which are greater in corms. Key factors for abaca survival identified through logistic regression were mostly water-related while nutrient deficiency did not play a major role. If plantlets are of sufficient size, transplanted after dry season and management is carried out properly, even plantations of *M. textilis* can prosper under full sun as was observed at LSU in 2005. Leaf pruning after transplanting may be helpful to avoid water stress as long as roots are not yet fully developed. For growth, different factors were critical. Unlike for survival, the most influential factor according to a multiple regression across subplots was N supply. In the modelling approach, N supply was the second ranking constraint after light (in a scenario under canopy). A combination of abaca with leguminous creepers like *Pueraria phaseoloides* (kudzú), *Desmodium ovalifolium*, *Canavalia ensiformis* or *Arachis pintoi* can reduce evaporation and at the same time improve N supply. The first species, however, is competitive and can only be sown, if proper maintenance is ensured. Losses of plants in the upper centre part of Cienda plot were mainly attributable to kudzú, which suffocated even small trees.

After a long series of failures, reforestation activities in the Philippines became more successful in the 1990s, but often *donor projects had a high and probably unsustainable economic cost* (Chokkalingam et al. 2006). This might have been a reason, why the rainforestation approach in Leyte has not left the stage of demonstration plots. Once the solvent donors retreated, ownership among farmers was missing. Under these conditions of lacking incentives and revenues from the plot, which were also observed at Cienda, labour *may be a major constraint to the adoption of complex agroforestry systems* (Craswell 1997). Franzel et al. (2004) assessed key factors for successfully implementing agroforestry on a wider scale. They found that for all case studies, one of them conducted in the Philippines, marketing, among others, was not sufficiently addressed by projects. Polinar (2004) comes to the same conclusion, poor marketing outlets, adding delayed return of investments to the shortcomings of present initiatives. Thus, additional sources of income for rainforestation farms are urgently needed, if implementation shall be successful and last longer than a project cycle. CDM projects are expected to provide such additional income from the beginning and at a justifiable effort. However, this still needs to be proved since no CDM A/R project has been implemented in the Philippines by now.
Principally, agroforestry projects in the Philippines are eligible under the umbrella of

afforestation or reforestation. Special procedures have been introduced for small-scale projects <2180MgC addressing low-income individuals or communities.
In the light of the upcoming dramatic IPCC assessment report 2007, KANNINEN'S (2004) argument that the international community cannot afford not to make use of agroforestry becomes ever more valid. LUC measures can globally sequester an annual 1 to 2 GtC, if all available options are made use of. This would include agroforestry, although such systems grow comparably slower than e.g. tree plantations. LEHMANN & GAUNT (2004) state that agroforestry due to its share of annuals is not an appropriate measure to increase long-term carbon pools in the soil unless special attention is paid to carbon conservation. This could be achieved by incorporation of charred lignified biomass, which is not extracted for use. The comparative advantage of agroforestry in turn is the potential of earlier income generation and thus accessibility and acceptance by small farmers (PENA 2004).
LASCO ET AL. (2004) have estimated potential agroforestry land areas on the basis of existing degraded uplands (grassland and brushland areas) to cover more than 3.5 million ha in the Philippines. Adding other farmland in need of stabilisation or soil conservation, 5.7 million ha could potentially be planted to agroforestry systems. For CDM projects, these figures might need to be corrected downward depending on the national forest definition: If a low threshold level is defined as minimum canopy coverage for a forest, then many degraded grasslands under coconut would be considered forests and could not be reforested anymore. These extensive areas would consequently not be eligible for CDM A/R projects. Once eligibility is given, bureaucratic procedures such as the formulation of a Project Design Document (PDD)[97] will probably require expert assistance, e.g. by an NGO. Apart from CDM eligibility and bureaucracy, land tenure can be a limiting factor for implementation of agroforestry plots (POLINAR 2004). Uncertain property titulation can keep people from investing in trees. A large portion of forest land is not private and among alienable and disposable (A&D) lands, claims are not always indisputable. Further, harvesting timber requires the approval of the Dept. for Environment and Natural Resources (DENR). The administrative act can discourage farmers, who do not dispose of resources for travelling and feel uncomfortable when dealing with authorities. Another factor discouraging any initiative is harvesting on other peoples' land, which is common and often informally accepted in Leyte. Finally, small plot size (POLINAR 2004) and low income lead to allocation of areas to the most profitable land use under a short-term perspective. Agroforestry is only implemented, if on a farmer's own initiative at all, in home gardens or as abaca underplanted in state-owned natural forests.
An economic evaluation of the scenarios was not undertaken since more detailed and precise data would have been necessary. Still, some general considerations can be discussed here. In comparison to an agroforestry system not participating in CDM, additional costs consist in formulation of the PDD including follow-up, and in certification. Both items are difficult to estimate since experiences do not yet exist in the Philippines; facilitation of the process could be an input provided by local NGOs or development agencies. Investment into planting material and labour force cannot be expected from low-income groups as long as they are not well-organised or advised by professionals. Mostly, willingness to work depends on so-called livelihood support, meaning that farmers are paid, directly or in form of food, for work on their own land. Apart from monetary constraints, production or purchase and transport of planting material are obstacles for the successful implementation of agroforestry systems.
Table 29 resumes the main advantages and disadvantages of the rainforestation

97 As published in Annex 1 of the Report of the First Meeting of the Afforestation and Reforestation Working Group, July 2004, Bonn.

approach as detailed above, subdivided into internal and external factors. Arguments specifically relevant in context with CDM projects are printed in italics.

Table 29: SWOT analysis of rainforestation with respect to C sequestration in CDM projects

Strengths	**Weaknesses**
Based on native plants, adapted to local conditions Simple technology, easy to replicate Soil conservation *No additional inputs required for CDM* *Additional products, risk minimisation*	Investment required Knowledge required Difficulties to supply seedlings Maintenance costs Late yields, if additional elements are not introduced *Uncertainty regarding procedures*
Opportunities	**Threats**
Land rehabilitation, sustainable land use Conservation of species and genetic diversity (within species) *Additional income generation* *Better acceptance and dissemination through added value*	Availability of areas (tenure, distance) Demotivation through projects, lacking ownership Abaca boom and encroachment into natural forests *Bureaucratic efforts for accreditation* *Instability of CO_2 prices*

The idea to minimise transaction costs and accurately meet demands by means of market-based mechanisms has been tested before the ratification of the Kyoto protocol. The World Bank's Prototype Carbon Fund, the Singapur ASEAN Carbon Fund and other voluntary initiatives of oil or travel companies are examples, which showed that emission trade technically works and attracts interest among stakeholders (s. DE CONNINCK & V.D. LINDEN 2003). A more principal question regarding CDM projects in developing countries is, if they lead to more sustainability. Industrialised countries have been responsible for 85% of anthropogenic atmospheric CO_2 and accused to act ruthlessly and aggressively in not doing their ecological homework (K. Töpfer, former director of UNEP[98]). According to the definition by BASS ET AL. (2000), leakage occurs, *when a project's activities and outputs create incentives to increase GHG emissions from processes taking place elsewhere*. From a holistic standpoint, this is exactly what happens, when reforestation projects deflect attention from the roots of the problem and protract patterns of mass consumerism and myths of unlimited growth in industrialised countries. In public debate, however, the reasoning that CDM would be counter-productive in the long run as it does not tackle problems in Annex I countries, was outweighed by the cost-effectiveness argument.

Agroforestry can only be one part of a global mitigation strategy (ALBRECHT & KANDJI 2003, CHAMBERS ET AL. 2001), which needs to concentrate on reduction of fossil fuel burning. In turn, following the principle of risk minimisation in agroforestry, the reliance on carbon projects should not be overemphasised. As all commodities, prices of emission rights can drop drastically, as happened in April 2006 in Germany[99]. Lobbyism of polluters and exaggerated estimates of certificate demand has led to issuance of too many certificates and collapse of the market (German Advisory Council on the Environment 2006[100]). In summary, CDM appears a promising option to generate income from agroforestry, if paperwork for project application can be limited to a reasonable extent. On the other hand,

98 in www.tagesschau.de, download 25/09/06
99 tageszeitung, 29/04/06
100 National Implementation of the EU Emissions Trading Scheme: Market-based climate change mitigation or the continuation of energy subsidies by other means? www.umweltrat.de

CO_2 certificates should be seen as only one component of a farmer's portfolio diversified as much as possible.

Future research

Although inventory data from the 'mother of rainforestation' at LSU were available, these did not cover biomass data of more than 10 years (from 1991 until Kolb's inventory 2001). Extrapolations beyond 10 years of age remained speculation. Meanwhile, a range of 16 years could be covered, if an inventory would be carried out again. This would make simulations more reliable, especially with respect to the growth of native timber trees like *S. contorta* and *D. validus*. Other interesting species like the pioneer *Melia dubia* or high value timber like molave (*Vitex parviflora*), *Hopea spp*. and others could be subject of future scenarios.

Erosion as an important constraint for upland soils in Leyte could be assessed to more extent using WaNuLCAS. Erosion has been modelled with good results by Samaniego (2006) for soils in Thailand. The added value of modelling would mainly consist in the partial replacement of labour-intensive measurements such as aggregate stability and erosion. Several management options could be assessed within short time and the most promising ones tested in the field.

Another important field for more detailed research is related to socio-economic factors, as profitability, availability of labour and acceptance are still critical factors for dissemination of the approach and continuance of the plots. An economic evaluation was not included in this study as it would have required more detailed field data. Basic data on rentability of rainforestation systems exist (Ahrens et al. 2004, Dirksmeyer 1998) but need to be updated and complemented. On the present basis an evaluation of demand and market saturation, transport costs and other parameters could not be estimated accurately. Increased opportunity costs due to necessary owner's presence on site at harvesting time are also difficult to estimate. This presence would be required to protect harvestible products against theft rather than for the harvest itself. Furthermore, costs of certification for CDM projects are still difficult to determine as only few practical experiences exist for reforestation CDM projects (none in the Philippines). As mentioned before, prices for carbon certificates have been strongly fluctuating. In the EU, distribution of certificates has by far exceeded the actual demand, so that prices decayed drastically. Integration of further socio-economic parameters into WaNuLCAS is intended (v. Noordwijk 2004) and cooperation with the model developers could be part of future research.

C in durable wood/fibre products: GPG-LULUCF provides accounting for harvested wood products from A/R areas, but the evaluation methodologies are still under development. In this case study, abaca fibres could play an important role for the carbon balance of a CDM project. The fibres are not woody, but their durability easily exceeds that of paper pulp given with 1.8 to 2 years (GPG-LULUCF Annex 3A.1), especially, when used as component of mould board in a matrix of synthetic resin. On the other hand, excessive export of biomass from the plot could lead to nutrient imbalances, which would have to be addressed.

IPCC (2003) stresses the knowledge gap of downscaling from landscape-data to plot-level, permanence, saturation in fractions/compartments, stability (under changed climate) and increasing net biomass productivity. This study is a step towards generation of such plot-related data during the initial growth phase, but more data covering later development stages are still required.

8 Abstract

This study aimed at investigating rainforestation systems in Leyte, Philippines, under different aspects:

- Characterisation of relevant soils in Leyte with respect to physical, chemical and biological parameters relevant for tree growth,
- possible contributions of rainforestation to restoring soil fertility,
- performance of a recently planted rainforestation system under different microclimatic and soil conditions,
- potential of the rainforestation approach for projects under the umbrella of the Clean Development Mechanism (CDM).

In relation to growth conditions and as a basis for the assessment of rainforestation impact on soil characteristics, a thorough soil survey was carried out on 10 profiles across 8 rainforestation plots. Soils can be grouped by parent material into a volcanic and a calcareous category. The latter were formed on coralline limestone and are thus high in pH and available Ca^{2+} and Mg^{2+}. Contents of organic matter are high while concentrations of plant available P_{Bray} are low. Soils of the volcanic group are characterised by low pH and concentrations of basic cations as well as extremely low P_{Bray} contents. Organic matter levels are below those of the calcareous soils but still moderate. Volcanic soils could further be subdivided into a colluvial class of yellowish colour and moderately low bases and soils formed in situ. The latter are strongly weathered, reddish in colour and lower in pH and bases than the yellow group. Mixtures occur, where colluvial horizons have been superimposed on older soils.
In any of the analysed soils, N would not pose a limiting factor for tree growth. Pore volume and water infiltration were propitious for all sites, which is relevant in the context of erosion. However, lateral water flow on the clay horizons of Acrisols, Luvisols or Cambisols can lead to temporarily anaerobic conditions. For calcareous soils, drought and reduced rootability due to clayey subsoil posed the most relevant constraints.

The frequently claimed role of rainforestation in the rehabilitation of degraded soils was assessed in a paired plot approach. Chemical and biological soil parameters under 10 year old rainforestation were contrasted with such under adjacent fallow or *Gmelina sp.* plots. The most clear tendencies across all seven sampled sites were lower available Mg^{2+} and pH under rainforestation use. Other differences were less distinct; even when there were trends in the majority of sites, differences were often not statistically significant at the chosen level. Generally, a depletion of soil reserves e.g. in basic cations can be explained by uptake into the plants. A feed-back of these elements to the topsoil via leaf litter, however, could be observed only for available P at Marcos site: On the P-rich subsoil, concentrations in the topsoil (3.10mg/kg) were also elevated as compared to the underlying AB/Bt horizon (0.47mg/kg) and topsoils at other sites (0.7 to 1.98mg/kg)[101]. In conclusion, plant uptake of single elements can reach orders of magnitude, which can even lead to a clear reduction of soil stocks (e.g. significantly for Mg^{2+} in 6 of 10 cases). At the same time, generally lower pH under rainforestation (7 of 10 cases, four of them significant) may have contributed to elevated losses, especially of basic cations. A general improvement of the sampled soils in terms of chemical or biological characteristics through rainforestation could not be observed. In this sense rainforestation serves as a

101 In comparison of land uses per site, burning played a role for elevated topsoil P (under Marcos and Patag grassland).

bank for nutrients rather than immediate soil improver. Capital in form of nutrients can be withdrawn totally (clear cut) or in rates (by pruning and mulching).

To evaluate the performance of different promising tree species, a mixed-species tree system was installed on a 1ha plot. Six timber and four fruit species were planted, most of them native to the region. The concept of rainforestation, commonly understood as high-density closed canopy system was modified in so far as the usually dense tree spacing was changed into a 5x5m grid, interplanted with *Musa textilis* (abaca). The plot varied strongly on a small scale due to heterogeneous canopy closure and relief. Methodologically, the entire area was divided into 10 subplots in representative positions to be sampled. Soil physical and chemical properties, microbial activity, PAR and root density were determined and correlated to plant survival and growth at consecutive inventories. Due to the multitude of measured parameters a principal component analysis was employed first to identify groups of similar parameters. For *Musa textilis*, the most sensitive species, which was used as an indicator, logistic regressions were calculated to determine the influence of all relevant parameters on survival rates. Subplot characteristics had a strong effect on abaca performance, the most important predictors for survival being organic matter contents, parameters related to biological activity and leaf litter production, which resembled canopy closure and thus indirectly light intensity, but also reflect soil moisture. To assess growth, multiple regressions were formulated. This was done for biomass at five inventories and growth between these dates. C_{org} and N_{LOM} were the most relevant variables determining the regressions used for biomass and growth of abaca. Survival rates of tree species varied between 48 and 98%. Apparently, size and condition of the seedling at the time of transplanting played the most important role for performance.

Assessing the potential of rainforestation for CDM measures, the following observations were made: Smallholder agroforestry projects are generally eligible under the Clean Development Mechanism in the rubric of Afforestation/Reforestation[102]. In the context of this study, amounts of sequestered CO_2 during 10 and 20 years, respectively, were estimated under different management options using the WaNuLCAS model. Despite all given uncertainty associated with modelling, one very obvious finding was the dominant role of soil carbon for the plot balance: Appropriate soil management, especially during land preparation (e.g. clearing vs. enrichment planting) is of paramount importance. The carbon balance would turn out even more unfavourable in case of burning, which was not part of the modelling exercise. Erosion, on the other hand, did not affect carbon stocks significantly in an additional scenario. This is in accordance with the low erodibility found in the soil surveys, but may differ on a small scale, depending on vegetation cover, soil management or compaction, among others. Looking at the modelled contribution of various tree species to the carbon balance, *Musa textilis* had a significant influence only during the very first years; later on, the principal share of carbon was bound in the tree component. Here, *Gmelina arborea* built up biomass more quickly than a rainforestation plot composed of *Shorea contorta* and *Durio zibethinus*, but was then overtaken. In absolute quantities of CO_2 sequestration, magnitudes matched inventory and modelled data given in various literature sources for Leyte and the Philippines. Relative to inventory data by Kolb (2003) from two of the existing rainforestation sites, modelled values overestimated growth. This may have been caused by unfavourable weather conditions

102 under certain country-specific conditions and if the plot was not forested before 1990. See chapter 1 for more details.

(instead of complete real time data a three-year loop was used) or neglect of maintenance as well as inaccuracy and error propagation in context with the inventories.

9 Kurzfassung

Auf Leyte, Philippinen, wurde in den 1990er Jahren der Rainforestation-Ansatz zur Inwertsetzung degradierter Flächen durch Aufforstung mit einheimischen Baumarten entwickelt. Im Rahmen der vorliegenden Arbeit wurden auf bestehenden Rainforestation-Flächen folgende Aspekte untersucht:

- Standortskundliche Charakterisierung typischer Böden in Hanglagen im Hinblick auf physikalische, chemische und biologische Parameter;
- Beitrag der Rainforestation-Systeme zur Bodenrehabilitation im Vergleich mit traditionellen Landnutzungen;
- Identifizierung geeigneter Wuchsbedingungen einer Neupflanzung unter kleinräumig unterschiedlichen Boden- und Klimabedingungen;
- mittel- bis langfristige Potenziale zur CO_2-Sequestrierung einer Rainforestation-Pflanzung im Rahmen von Projekten des Clean Development Mechanism (CDM) mit Hilfe eines Wachstumsmodells.

Zunächst wurden Bodenprofile an 8 Rainforestation-Standorten gegraben und zur Charakterisierung der Bodeneigenschaften horizontweise beprobt. Die Böden in den Hanglagen Leytes können zunächst nach ihrer Entstehung aus Korallenkalk oder Vulkangestein unterschieden werden. Die Kalkböden (Cambisol und Leptosol) sind neben typischerweise alkalischen pH-Werten und hohen Gehalten an verfügbaren Ca^{2+}- und Mg^{2+}-Ionen durch niedrige Gehalte an pflanzenverfügbarem Phosphor gekennzeichnet. Die Vulkanböden (Luvisols, Cambisols, Nitisol) weisen dagegen in aller Regel pH-Werte zwischen 4 und 5, relativ geringe effektive KAK und extrem geringe P-Gehalte auf. Eine weitere Unterteilung der vulkanischen Standorte in Kolluvien und *in situ* entstandene Böden ist möglich.
Von den untersuchten Standorten waren die wenigsten hinsichtlich ihrer Humus- und Stickstoffgehalte unterversorgt. Auch Porenvolumen und Wasserinfiltration, beide relevant für Bodenerosion, wurden durchgehend als günstig eingestuft. Allerdings kann Hangzugwasser über B_T-Tonhorizonten wechselfeuchte Bedingungen hervorrufen. Besonders auf den Kalkböden kann das Pflanzenwachstum zudem durch temporäre Trockenheit und Verhärtung der tonreichen Unterböden eingeschränkt werden.

Im Zusammenhang mit der Durchführung von Rainforestation-Projekten wurde in der Vergangenheit oft die Vorzüglichkeit dieser Systeme bei der Rehabilitation übernutzter bzw. erodierter Hanglagen herausgestellt. Diese Aussage wurde mittels eines Vergleichs mindestens 10-jähriger Rainforestationflächen an 7 verschiedenen Standorten zu jeweils direkt benachbarten Brachen bzw. Aufforstungen mit *Gmelina arborea* untersucht. Dazu wurden Bodenproben der Flächen auf chemische und biologische Parameter hin analysiert und per t-Test verglichen. Statistisch signifikante Unterschiede zwischen den Landnutzungen bestanden bei den pH-Werten und Gehalten an austauschbarem Mg^{2+}, welche in Rainforestation-Böden unter denjenigen der jeweiligen Referenzflächen lagen. Für Ca^{2+} und P waren die Unterschiede weniger deutlich. Eine generelle Verarmung von Böden an basischen Kationen durch Festlegung in Pflanzen erscheint plausibel. So fand NYKVIST (1997) in malaysischen Waldökosystemen eine Einlagerung von 50% des im Ökosystem enthaltenen Ca^{2+} in der Pflanzenbiomasse. Zugleich würde eine mit der Sukzession einhergehende Versauerung des Bodens (wie von KELLMAN (1970) für Sekundärsukzessionen in Mindanao beschrieben) eine Entbasung, also den Verlust verfügbarer Kationen, des Bodens begünstigen. Dass Bäume als Nährstoffpumpen fungieren können, konnte u.a. am Standort Marcos gezeigt werden. Der P-Gehalt im Oberboden lag dort mit über 3mg kg^{-1} deutlich über den gemessenen P-Gehalten im darunter liegenden Horizont mit 0.47mg kg^{-1}. Verbesserte Bodenfruchtbarkeit bzgl. chemischer oder biologischer Parameter durch Rainforestation konnte mit dem verwendeten Ansatz nicht festgestellt werden. Das System kann in diesem Sinne eher als Kapitalanlage von Nährstoffen angesehen werden, welche in unterschiedlichem Maße durch Rückschnitt oder Rodung wieder freigesetzt werden können.

Nahe einer der bestehenden Flächen wurde 2004 eine neue Rainforestation-Pflanzung, bestehend aus einheimischen Wertholzarten, Obstbäumen und *Musa textilis* (Abaca) angelegt. Hier wurde die Entwicklung der Pflanzen während der kritischen ersten Jahre hinsichtlich Überlebensraten und Biomassezuwachs während wiederholter Inventuren erfasst.
Da die Parzelle von einem Hektar Größe hinsichtlich Geländeform, Bodeneigenschaften und Kronenschluss kleinräumig stark variierte, wurden 10 deutlich voneinander verschiedene Teilflächen zur intensiven Beprobung gewählt. Durch die Auswahl wurde ein möglichst weiter Bereich an Umweltbedingungen abgedeckt. Bodenphysikalische und -chemische Parameter sowie mikrobielle Biomasse und Aktivität im Boden und photosynthetisch aktive Einstrahlung wurden ebenso erfasst wie die Streuproduktion und Wurzellängendichte der vorhandenen Vegetation. Diese Parameter wurden zu Überlebens- und Zuwachsraten von *Musa textilis* in der Neupflanzung in Beziehung gesetzt: Überlebenswahrscheinlichkeiten wurden für jede Position unter den gegebenen Umweltfaktoren mit Hilfe von Logit-Funktionen errechnet. Dabei waren die wichtigsten Standortfaktoren bzgl. der Überlebensraten Humusgehalt, biologische Aktivität im Boden und Streuproduktion. Alle drei Größen hängen wesentlich mit der Bodenfeuchte zusammen. Dies war von Bedeutung, da die höchste Mortalität von Abacapflanzen stets während Trockenperioden auftrat.
Zur Bewertung von Einflussgrößen auf Pflanzenbiomasse und -wachstum wurden multiple Regressionen erstellt. Organischer Kohlenstoff und N in der leicht abbaubaren organischen Bodensubstanz waren die bedeutendsten Steuergrößen für Biomasse und Zuwachs von *M. textilis* in einer anschließenden Sensitivitätsanalyse.

Zur Bewertung des Potenzials kleinbäuerlicher Agroforstpflanzungen für CDM-Projekte wurde ein Modellansatz gewählt. Mit Hilfe des Modells WaNuLCAS (Water, Nutrients, Light and Carbon in Agroforestry Systems) wurden Wachstumsverläufe von Pflanzen auf Grundlage eigener Messungen von Standorteigenschaften (s.o.) und Pflanzenparametern simuliert. Dabei wurden über Zeiträume von 10 bzw. 20 Jahren CO_2-Bilanzen für verschiedene Management-Varianten verglichen.
In allen Modellläufen war der C-Haushalt des Bodens von herausragender Bedeutung für die CO_2-Bilanz der gesamten Parzelle. Damit erhalten Bodenschutzmaßnahmen wie Erosionsvermeidung und Humusmehrung besonderes Gewicht bei der Anlage und Pflege der Systeme.
Bei Betrachtung der in der Pflanzenmasse gespeicherten Mengen an CO_2 zeigte sich eine gute Übereinstimmung mit Literaturdaten von Lasco und Mitarbeitern für Leyte (diverse Publikationen, s. Kap. 6). Von Kolb (2003) erhobene Inventurdaten für zwei der beprobten Standorte wurden dagegen im Modell überschätzt. Ein nennenswerter Beitrag der schnellwachsenden *M. textilis* zur CO_2-Sequestrierung ergab sich in den Modellsimulationen nur während der Anfangsphase. Spätestens zwei Jahre nach der Pflanzung wurde *M. textilis* jedoch ausschattiert und Bäume dominierten die CO_2-Bilanz der Biomasse. Im Vergleich verschiedener Pflanzsysteme zeichnete sich *Gmelina arborea*

als Pionierart durch schnellen Aufbau von Biomasse, verbunden mit hoher CO_2-Fixierung, aus. Dieses System wird gewöhnlich im Aufforstungsansatz staatlicher Programme favorisiert. Eine dem Rainforestation-Ansatz entsprechende Kombination einheimischer Nutzholz- und Obstbaumarten benötigte dagegen längere Zeit zur Entwicklung, nahm aber insgesamt über knapp 20 Jahre größere Mengen an CO_2 auf.

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11 References

- AG Bodenkunde (1982): Bodenkundliche Kartieranleitung, 3rd ed. Schweizerbart, Stuttgart, Germany.
- Agricultural Experiment Stations of Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont and West Virginia (ed.)(1995): Bulletin # 493, 2nd edition. Agricultural Experiment Station, University of Delaware, Newark, USA.
- Ahrens, O., S. Henders, M. Langkau, S. Lindemann, T. Müller & M. Petri (2004): Cost-benefit analysis – comparison of different land uses in Leyte, Philippines. Faculty of Forest Science and Wood Ecology, Georg-August University, Göttingen, Germany. Unpublished.
- Albrecht, A. & S.T. Kandji (2003): Carbon sequestration in tropical agroforestry systems. Agriculture, Ecosystems and Environment 99:15–27.
- Alvarez, C.R., R. Alvarez, M.S. Grigera & R.S. Lavado (1998): Associations between organic matter fractions and the active soil microbial biomass. Soil Biology & Biochemistry 30(6):767-733.
- Akinnifesi, F.K., B.T. Kang & D.O. Lapido (1999): Structural root form and fine root distribution of some woody species evaluated for agroforestry systems. Agroforestry Systems 42:121-138.
- Albrecht, A. & S.T. Kandji (2003): Carbon sequestration in tropical agroforestry systems. Agriculture, Ecosystems and Environment 99:15-27.
- Anderson, A.B., A. Gely, J. Strudwick, G.L. Sobel & M.G.C. Pinto (1985): Um sistema agroflorestal na várzea do estuário amazônico. Acta Amazonica 15 (1-2): 195-224.
- Anderson, J.M.E. & J.S.I. Ingram (eds.)(1993): Tropical soil biology and fertility. A handbook of methods, 2nd edition. CAB International, Wallingford, UK.
- Anderson, J.P.E. & K.H. Domsch (1978): A physiological method for the quantitative measurement of microbial biomass in soils. Soil Biology & Biochemistry 10:215-221.
- Anderson, T.-H. (1994): Physiological analysis of microbial communities in soil: Applications and limitations. In: Ritz, K., Dighton, J. & K.E. Giller (1994): Beyond the biomass. British Society of Soil Science, Wiley-Sayce, UK.
- Anderson, T.-H. & K.H. Domsch (1985): Maintenance carbon requirements of actively-metabolizing microbial populations under in-situ conditions. Soil Biology & Biochemistry 17 (2):197-203.
- Anderson, T.-H. & K.H. Domsch (1986): Carbon assimilation and microbial activity in soil. Journal of Plant Nutrition and Soil Science 149:457-468.
- Anderson, T.-H. & K.H. Domsch (1989): Ratios of microbial biomass carbon to total organic carbon in arable soils. Soil Biology & Biochemistry 21 (4):471-479.
- Anderson, T.-H. & K.H. Domsch (1990): Application of eco-physiological quotients (qCO_2 and qD) on microbial biomasses from soils under different cropping histories. Soil Biology & Biochemistry 22(2):251-255.
- Anderson, T.H. & R.G. Joergensen (1997): Relationship between SIR and FE estimates of microbial biomass C in deciduous forest soils at different pH. Soil Biology & Biochemistry 29(7):1033-1042.
- Andersson, M., A. Michelsen, M. Jensen, A. Kjøller (2004): Tropical savannah woodland: Effects of experimental fire on soil microorganisms and soil emissions of carbon dioxide. Soil Biology & Biochemistry 36:849–858.
- Anonymous (1993): Greater Tongonan Geothermal Field integrated resource assessment. LGP Geoscientific, Manila, Philippines.
- Aquino, R. et al. (1983): Semi-detailed geology of the Bato-Lunas and vicinity Burauen

geothermal prospect. PNOC Leyte, Philippines.
- Aragon, J.S. (2004): Leaf litter decomposition of *Dipterocarpus validus* Brandis (Dipterocarpaceae) and *Gmelina arborea* Roxb. (Verbenaceae) in two forest sites in Mt. Pangasugan. B.Sc. thesis, Leyte State University, Philippines.
- Arakawa, H. (ed.)(1969): World survey of climatology Vol.8. Climates of Northern and Eastern Asia. Elsevier, Amsterdam, The Netherlands.
- Ashton, M.S. & F. Montagnini (eds.)(2000): The silvicultural basis for agriforestry systems. CRC Press, Boca Raton, USA.
- Ashton, M.S. & M.J. Ducey (2000): Agroforestry systems as successional analogs to native forests. In Ashton, M.S. & F. Montagnini (eds.)(2000): The silvicultural basis for agriforestry systems. CRC Press, Boca Raton, USA.
- Asio, V.B., C.C. Cabunos & Z.S. Chen (2006): Morphology, physiochemical characteristics, and fertility of soils from quaternary limestone in Leyte, Philippines. Soil Science 171(8): 648-661.
- Asio V., R. Jahn & K. Stahr (1999): Changes in the properties of a volcanic soil (Andisol) in Leyte due to conversion of forest to other land uses. Philippine Journal of Science 128/1, 1-13.
- Asio, V.B. (1994): Upland agriculture, population pressure and environmental degradation in the Philippines: A review and analysis. Annals of Tropical Research Vol.X, ViSCA, Baybay, Leyte, Philippines.
- Asio, V.B. (1996): Characteristics, weathering, formation and degradation of soils from volcanic rocks in Leyte, Philippines. PhD Dissertation University of Hohenheim. Hohenheimer Bodenkundliche Hefte 33.
- Asio, V.B., R. Jahn, K. Stahr & J. Margraf (1998): Soils of the tropical forests of Leyte, Philippines. II: Impact of different land uses on status of organic matter and nutrient availability. In Schulte, A. & D. Ruhiyat (eds.): Soils of tropical forest ecosystems. Springer Berlin, Germany. pp. 38-44.
- Associación de Agricultura Ecológica (1998): Pasos hacía una agricultura más rentable y ecologicamente apropiada. Pto. Maldonado, Perú.
- Bacolcol, T., E. Barrier & T. Duquesnoy (2004): Study of the Philippine Fault in the Visayas through spatial geodesy. Western Pacific Geophysics Meeting, Honolulu, Hawaii, Aug 16-20, 2004.
- Balée, W. (1989): The culture of Amazonian forests. In Posey, D.A. & W. Balée (eds.): Resource management in Amazonia: Indigenous and folk strategies. The New York Botanical Garden, USA. Advances in Economic Botany, Vol.7.
- Balesdent, J. (1996): The significance of organic separates to carbon dynamics and its modeling in some cultivated soils. European Journal of Soil Science 47:485-493.
- Balzer, P. (1994): The climate in ViSCA, Baybay, Leyte, Philippines. Annals of Tropical Research Vol.X, ViSCA, Baybay, Leyte, Philippines.
- Bareth, G. (2000): Emissionen klimarelevanter Gase aus der Landwirtschaft – Regionale Darstellung und Abschätzung unter Nutzung von GIS am Beispiel des württembergischen Allgäus. PhD Dissertation University of Hohenheim, Germany. Hohenheimer Bodenkundliche Hefte 56.
- Barrera, A., I. Aristorenas & J. Tingzon (1954): Soil survey of Leyte province, Philippines. Bureau of Print, Manila, Philippines.
- Barrios, E., F Kwesiga, R.J. Buresh & J.I. Sprent (1997): Light fraction soil organic matter and available nitrogen following trees and maize. Soil Sciences of America Journal 61:826-831.
- Bass, S., O. Dubois, P. Moura Costa, M. Pinard, R. Tipper & C. Wilson (2000): Rural livelihood and carbon management. IIED Natural Resources Issues Paper No.1. IIED,

London, UK.
- BATISTEL, C.C. (2004): Effects of leaf decomposition of selected exotic and indigenous tree species on forest soil quality. B.Sc. Thesis, Leyte State University, Philippines.
- BATTAGLIA, M. (2004): What is CABALA? http://www.ffp.csiro.au/downloads/CABALA.pdf, download 04/03/07.
- BAUHUS, J. & C. MESSIER (1999): Image analysis – evaluation of fine root length and diameter measurements obtained using RHIZO image analysis. Agronomy Journal 91:142-147.
- BAYALA, J., J.S.J. OUEDRAOGO, M.V. NOORDWIJK, B. LUSIANA & Z. TEKLEHAIMANOT (2004): Separating tree-soil-crop interactions in agroforestry parkland systems in Saponé (Burkina Faso) using WaNuLCAS. Presentation 1st Agroforestry World Congress, Florida, USA.
- BAYRANTE, L.F. (1982): The geology of the Burauen Geothermal Prospect Leyte, Central Philippines. Technical Bulletin Vol. I, No.1:35-47. PNOC Geothermal Division, Manila, Philippines.
- BECK, L. & L. GASPAROTTO (2000): Fauna de solo e decomposição da serapilheira em florestas primárias e secundárias e em sistema de cultivo misto na Amazônia. Relatório Final 1996-1999. Internet Source http://www.cpaa.embrapa.br/env52 download Feb 11th, 2007.
- BECK, T., R.G. JOERGENSEN, E. KANDELER, F. MAKESCHIN, E. NUSS, H.R. OBERHOLZER & S. SCHEU (1997): An inter-laboratory comparison of ten different ways of measuring soil microbial biomass C. Soil Biology & Biochemistry 29 (7):1023-1032.
- BEERBAUM, S. (2001): Kosteneffiziente CO_2- Minderungsmaßnahmen im Rahmen des Clean Development Mechanism – dargestellt am Beispiel Deutschland und Indien. PhD Dissertation University of Hohenheim. Logos, Berlin, Germany.
- BIRKELAND, P.W. (1999): Soils and geomorphology. 3rd ed. Oxford University Press, New York, USA.
- BOOGAARD, H.L., C.A. VAN DIEPEN, R.P. ROTTER, J.M.C.A. CABRERA & H.H. VAN LAAR (1998): WOFOST 7.1; user's guide for the WOFOST 7.1 crop growth simulation model and WOFOST control center 1.5. SC-DLO.Techn. Doc. 52, Wageningen, The Netherlands.
- BORINES, L.M. & V.G. PALERMO (2006): Major diseases of abaca and the role of plant disease diagnostic laboratory (PDDL). Flyer, Leyte State University, Philippines.
- Brack Egg, A. (1999): Diccionario enciclopédico de plantas útiles del Perú. CBC, Cusco, Perú.
- BRAKE, M., H. HÖPER & R.G. JÖRGENSEN (1999): Land-use induced changes in activity and biomass of microorganisms in raised bog peats at different depths. Soil Biology & Biochemistry 31:1489-1497.
- BRECKLING, B. & P. BIRKENMEIER (2000): Landnutzungsalternativen im Regenwald. P. Lang, Frankfurt/Main, Germany.
- BROWN S. (1997): Estimating biomass and biomass change of tropical forests, a primer. FAO Forestry paper 134, FAO, Rome, Italy.
- BROWN, S., L.R. IVERSON, A. PRASAD & D. LIU (1993): Geographical distribution of carbon in biomass and soils of tropical Asian forests. Geocarto International 4.
- BROWN, W.H. (1919): Philippine fiber plants. Dept. Of Agriculture and Natural Resources, Bureau of Forestry. Bulletin No.19. Bureau of Printing, Manila, Philippines.
- BROWN, S. & A.E. LUGO (1990): Effects of forest clearing and succession on the carbon and nitrogen contentof soils in Puerto Rico and US Virgin Islands. Plant and Soil 124:53-64.
- BUGAYONG, L.A. (2004): Government policy as determinant of local agroforestry practices in the Philippines. In: First World Congress of Agroforestry, Book of Abstracts. Orlando,

FL, USA.

- BULLECER, R.C. & M. STARK (2004): Coconut-based agroforestry farming systems in Central Philippines. Presentation 1st World Congress of Agroforestry, Book of Abstracts. Orlando, FL, USA.
- BURESH, R.J. (1999): The contribution of trees to nutrient cycling and availability. In: Report of the first research co-ordination meeting of the FAO/IAEA co-ordinated research project on the use of nuclear techniques for developing integrated nutrient and water management practices for agroforestry systems. FAO/IAEA.
- BUREAU OF COAST AND GEODETIC SERVICE (1982): Map of Baybay, Scale 1:50000. Sheet 3952 II. DENR, Cebu, Philippines.
- CAB INTERNATIONAL (2002): Tree compendium. Online - data base. www.cabicompendium.org download Feb 11th, 2007.
- CADISCH, G. & K.E. GILLER (1997): Driven by nature. Plant litter quality and decomposition. CAB International, Wallingford, UK.
- CADISCH, G., H. IMHOF, S. URQUIAGA, R.M. BODDEY & K.E. GILLER (1996): Carbon turnover (^{13}C) and nitrogen mineralization potential of particulate light soil organic matter after rainforest clearing. Soil Biology & Biochemistry 28(12):1555-1567.
- CANNELL, M.G.R., M. V.NOORDWIJK & C.K. ONG (1996): The central agroforestry hypothesis: The trees must acquire resources that the crop would not otherwise acquire. Agroforestry Systems 34: 27-31.
- CAREY, E.V., A. SALA, R. KEANE & C.R. MU (2001) in Global Change Biology: Are old forests underestimated as global carbon sinks? pp. 339-344. Blackwell.
- CENIZA, M.J.C., P.P. MILAN, V.B. ASIO, S.B. BULAYOG, M.D. NAPIZA, M.J.M. BANDE, H.L. MONDAL, D.B. POSAS & J. POGOSA (2004): Status, ecological changes and market study of rainforestation farms. Unpublished report.
- CHAMBERS, J.Q., N. HIGUCHI, E.S. TRIBUZY & S.E. TRUMBORE (2001): Carbon sink for a century. Nature 410:429.
- CHERTOV, O.G. & A.S. KOMAROV (1996): SOMM – a model of soil organic matter and nitrogen dynamics in terrestrial ecosystems. In: POWLSON, D.S., P. SMITH & J.U. SMITH (EDS.): Evaluation of soil organic matter models. Springer, Berlin, Germany, in cooperation with NATO Scientific Affairs Division.
- CHOKKALINGAM, U., A.P. CARANDANG, J.M. PULHIN, R.D. LASCO, R.J.J. PERAS & T. TOMA (EDS.) (2006): One century of forest rehabilitation in the Philippines. Approaches, outcomes and lessons. SMK Grafika Desa Putera Jakarta, Indonesia.
- CLARK, D.A., S. BROWN, D.W. KICKLIGHTER, J.Q. CHAMBERS, J.R. THOMLINSON & J. NI (2001): Measuring net primary productivity in forests: Concepts and field methods. Ecological Applications 11(2):356-370.
- CLARK, D.A., S. BROWN, D.W. KICKLIGHTER, J.Q. CHAMBERS, J.R. THOMLINSON, J. NI & E.A. HOLLAND (2000): Net primary production in tropical forests: An evaluation and synthesis of existing field data. Ecological Applications 11(2):371–384.
- CODY, R.P. & J.K. SMITH (1997): Applied statistics and the SAS programming language, 4th ed. Prentice-Hall, NJ, USA.
- COICAP (COORDINADORA INDÍGENA CAMPESINA DEL PERÚ (1999): Manual práctico de forestería análoga. Pto. Maldonado, Perú.
- COLEMAN, K. & D.S. JENKINSON (1996): RothC-26.3 – A model for the turnover of carbon in soil. In: POWLSON, D.S., P. SMITH & J.U. SMITH (EDS.): Evaluation of soil organic matter models. Springer, Berlin, Germany, in Cooperation with NATO Scientific Affairs Division.
- COLEMAN, K., D.S. JENKINSON, G.J. CROCKER, P.R. GRACE, J. KLÍR, M. KÖRSCHENS, P.R. POULTON & D.D. RICHTER (1997): Simulating trends in soil organic carbon in long-term

experiments using RothC-26.3. Geoderma 81:29-44.
- CONKLIN, H.C. (1957): Hanunóo agriculture. A report on an integral system of shifting cultivation in the Philippines. FAO Forestry Development Paper No. 12. Food and Agriculture Organization, Rome, Italy.
- CONNELL, J.H. (1978): Diversity in tropical forests and coral reefs. Science 199:1302-1310.
- CRASWELL, E.T., A. SAJJAPONGSE, D.J.B. HOWLETT & A.J. DOWLING (1997): Agroforestry in the management of sloping lands in Asia and the Pacific. Agroforestry Systems 38(1-3): 121-137.
- CUENCA, G., J. ARANGUREN & R. HERRERA (1983): Root growth and litter decomposition in a coffee plantation under shade trees. Plant and Soil 71:477-486.
- CUEVAS, V. & P.E. SAJISE (1978): Litterfall and leaf litter decomposition in a Philippine secondary forest. Kalikasan, Philippine Journal of Biology 7(II):99-109.
- DAGOY, F.J., F.D. POLIQUIT, L.G. HINAY & L.S.E. RACHO (1994): Sociodemographic profile of the upland farmers in the MPSAP pilot barangays. Annals of Tropical Research. Special Issue on Tropical Ecology No.1. ViSCA, Baybay, Leyte, Philippines.
- DARGANTES, B.D. & W. KOCH (1994): Case studies on the occupation and cultivation of the forest lands of Leyte, Philippines. Annals of Tropical Research, Special Issue on Tropical Ecology No.1, ViSCA, Baybay, Leyte, Philippines.
- DAUB, M. (2002): Litter arthropod community and its impact on decomposition – a contribution to restoration biodiversity in rainforestation systems, Leyte; Philippines. Master thesis University of Hohenheim.
- DAVIS, S.D., V.H. HEYWOOD & A.C. HAMILTON (EDS.)(1995): Centres of plant diversity: A guide and strategy for their conservation. Vol. II: Asia, Australasia and the Pacific. IUCN, Cambridge, UK.
- DE CONNINCK, H.C. & N.H. VAN DER LINDEN (2003): An overview of carbon transactions. Report to ECN Project 7.7513.03.01. Energy Research Centre of the Netherlands. http://www.ecn.nl/library/reports/2003/c03022.html download Feb 11th, 2007.
- DEL RIO, J. & A. GUTIERREZ (2006): Chemical composition of abaca (*Musa textilis*) leaf fibers used for manufacturing of high quality paper pulps. J. Agric. Food Chem. (54): 4600-4610.
- DENICH, M. &M. KANASHIRO (EDS.)(1998): Potential land-use and management of altered and abandoned areas in the Brazilian Amazon region. MCT/CNPq, Brasília, Brasil.
- DIEHL, D. (2005): Growth of tree seedlings on Leyte/Philippines correlated with litter production and decomposition. BSc Thesis, Hohenheim University, unpublished.
- DILLY, O. (2001): Microbial respiratory quotient during basal metabolism and after glucose amendment in soils and litter. Soil Biology & Biochemistry 33:117-127.
- DILLY, O. & J.-C. MUNCH (1998): Ratios between estimates of microbial biomass content and microbial activity in soils. Biology & Fertility of Soils 27:374-379.
- DINESH, R., S.G. CHAUDHURI & T.E. SHEEJA (2004): Soil biochemical and microbial indices in wet tropical forests: Effects of deforestation and cultivation. Journal of Plant Nutrition and Soil Sciences 167:24-32.
- DIRKSMEYER, W. (1998): Rainforestation farming: A farmer's guide to biodiversity management in the Philippines.
- DIXON, R.K. (1995): Agroforestry Systems: Sources or sinks of greenhouse gases? Agroforestry Systems 31:99-116.
- DODOR, D.E. & M.A. TABATABAI (2003): Effect of cropping systems on phosphatases in soils. Journal of Plant Nutrition and Soil Sciences 1/2003:7-13.
- DONALD, R.G., D.W. ANDERSON & J.W.B. STEWART (1993): Potential role of dissolved organic carbon in phosphorus transport in forested soils. Soil Science Society of

America Journal 57:1611-1618.
- DUNGER, W. & H.J. FIEDLER (EDS.)(1997): Methoden der Bodenbiologie. 2nd ed. Fischer, Jena, Germany.
- DURST, P.B., T.R. WAGGENER, T. ENTERS & T.L. CHENG (2001): Forests out of bounds: Impacts and effectiveness of logging bans in natural forests in Asia-Pacific. FAO Regional Office for Asia and the Pacific. Bangkok, Thailand.
- ECKSTEIN, K. & J.C. ROBINSON (1996): Physiological responses of banana (Musa AAA, Cavendish subgroup) in the Subtropics. VI. Seasonal responses of leaf-gas exchange to short-term water stress. Journal of Horticultural Science 71(5):679-692.
- ECKSTEIN, K., J.C. ROBINSON & C. FRASER (1997): Physiological responses of banana (Musa AAA, Cavendish subgroup) in the Subtropics. VII. Effects of windbreak-shading on phenology, physiology and yield. Journal of Horticultural Science 72(3):389-396.
- EISENBEIS, G. (2004): Soil Ecology Methods. Internet source: http://www.uni-mainz.de/FB/Biologie/Zoologie/abt1/eisenbeis/Homepage_Minicontainer.htm download Feb 11th, 2007.
- EWEL, J.J. (1999): Natural systems as models for the design of sustainable systems of land-use. In: LEFROY, T., R. HOBBS, M. O´CONNOR & J. PATE (EDS): Agriculture as mimic of natural ecosystems. Kluwer, Dordrecht, The Netherlands.
- FALLOON, P.D., P. SMITH, J.U. SMITH, J. SZABÓ, K. COLEMAN, S. MARSHALL (1998): Regional estimates of carbon sequestration potential: Linking the Rothamsted carbon model to GIS databases. In Biology and Fertility of Soils 27:236-241.
- FANG, C., P. SMITH, J.B. MONCRIEFF & J.U. SMITH (2005): Similar response of labile and resistant soil organic matter pools to changes in temperature. Nature 433:57-59.
- FAO Gateway for Land and Water Information. www.fao.org download Feb 11th, 2007.
- FAO, ISSS, ISRIC (1999): World reference base for Soil Resources. FAO, Rome, Italy.
- FAO (1995): Mangosteen cultivation. FAO plant production and protection paper 129. FAO, Rome, Italy.
- FAO (1982): Fruit-bearing forest trees. Forestry Paper 34. FAO, Rome, Italy.
- FEIGL, B.J., G.P. SPARLING, D.J. ROSS & C.C. CERRI (1995): Soil microbial biomass in Amazonian soils: Evaluation of methods and estimates of pool sizes. Soil Biology & Biochemistry 27(11):1467-1472.
- FELLER, C. & M.H. BEARE (1997): Physical control of soil organic matter dynamics in the Tropics. Geoderma 79:69-116.
- FIBER INDUSTRY DEVELOPMENT AUTHORITY (FIDA): Technoguide on abaca. Extension Flyer.
- FIELD, C.B. (2001): Plant physiology of the „missing“ carbon sink. In Plant Physiology 125:25-28.
- FILIP, Z. (2002): International approach to assessing soil quality by ecologically-related biological parameters. Agriculture, Ecosystems and Environment 88:169-174.
- FOXWORTHY, F.W. (1932): Dipterocarpaceae of the Malay Peninsula. Malayan Forest Records 10. Cited after NG (1966).
- FRANKO, U. (1996): Modeling approaches of soil organic matter turnover within the CANDY system. In: POWLSON, D.S., P. SMITH & J.U. SMITH (EDS.): Evaluation of soil organic matter models. Springer, Berlin, Germany, in cooperation with NATO Scientific Affairs Division.
- FRANZEL, S., G.L. DENNIN, J.P.B. LILLESØ & A.R. MERCADO JR. (2004): Scaling up the impact of agroforestry: Lessons from three sites in Africa and Asia. Agroforestry Systems 61-62(1-3): 329-344.
- GAISER, T. (1993): Bedeutung der organischen Bodensubstanz für Eigenschaften und Ertragfähigkeit von Vertisolen und Acrisolen in Süd-Benin. PhD Dissertation University of Hohenheim. Hohenheimer Bodenkundliche Hefte Vol. 12, Hohenheim, Germany.

- GAUNT, J.L., S.P. SOHI, J.R.M. ARAH, N. MAHIEU, H. YANG & D.S. POWLSON in KIRK, G.J.D. & D.C. OLK (EDS.)(2000): Carbon and nitrogen dynamics in flooded soils, pp. 89-99: A physical soil fractionation scheme to obtain organic matter fractions suitable for modelling. IRRI, Manila, Philippines.
- GEORGE, T.S., P.J. GREGORYA, M. WOODA, D. READA & R.J. BURESH (2002): Phosphatase activity and organic acids in the rhizosphere of potential agroforestry species and maize. Soil Biology & Biochemistry 34(10):1487-1494.
- GEROLD, G., M. FREMEREY & E. GUHARDJA (EDS.) (2004): Land use, nature conservation and the stability of rainforest margins in Southeast Asia. Springer, Berlin, Heidelberg, Germany.
- GIFFORD, R.M. (2000): The CO_2 fertilizing effect: Relevance to the global carbon Cycle (Ch. 5). In WIGLEY, T.M.L. & D.S. SCHIMEL (EDS.): The carbon cycle. Cambridge University Press, UK.
- GINOGA, K., Y.C. WULAN, & M. LUGINA (2005): Potential of agroforestry and plantation systems in Indonesia for carbon stocks: An economic perspective. ACIAR Working paper CC14, ACIAR Project ASEM 2002/066.
  http://www.une.edu.au/febl/Economics/carbon download Feb 12th, 2007.
- GÖLTENBOTH, A. (1998): Influence of chemical soil characteristics on the growth of selected tree species in rainforestation systems on Leyte, Philippines. Diploma Thesis, unpublished.
- GOLLER, R., W. WILCKE, K. FLEISCHBEIN, C. VALAREZO & W. ZECH (2006): Dissolved nitrogen, phosphorus, and sulfur forms in the ecosystem fluxes of a montane forest in Ecuador. Biogeochemistry 77(1):57-89.
- GREGORICH, E.G., M.R. CARTER, D.A. ANGERS, C.M. MONREAL & B.H. ELLERT (1994): Towards a minimum data set to assess soil organic matter quality in agricultural soils. Canadian Journal of Soil Science 74:367-385.
- GROETSCHEL, A., R.R. AQUINO, I. BUCHHOLZ, A. IBKENDANZ, T.G. MAZO, N.A. SALES, J. SEVEN & K.C. VICENTUAN (2001): Natural resource management strategies on Leyte Island, Philippines. SLE, Berlin, Germany.
- GUARTE, R.C. & F.G. SINON (2005): Processing of high quality abaca (*Musa textilis*) fibers for industrial application. Presentation 2nd S-S-N Natural Fibre Dialogue, Leyte State University, Leyte, 4th-6th March 2005.
- GUO, L.G. & R.M. GIFFORD (2002) in Global Change Biology 8/4: 345-360. Soil carbon stocks and land use change: A meta analysis. Blackwell Science, UK.
- HAIRIAH, K., S.M. SITOMPUL, M. V. NOORDWIJK & C. PALM (2001): Methods for sampling carbon stocks above and below ground. ASB Lecture Notes. International Centre for Research in Agroforestry.
- HARCOMBE, P.A. (1980): Soil nutrient loss as a factor in early tropical secondary succession. In: Biotropica 12(2):8-14; Special Issue on Tropical Succession.
- HART, R.D. (1980): A natural ecosystem analog approach to the design of a successional crop system for tropical forest ecosystems. Biotropica 12(2):73-82; Special Issue on Tropical Succession.
- HARTGE, K.H. & R. HORN (1999): Einführung in die Bodenphysik. 3rd ed. Enke, Stuttgart.
- HARTGE, K.H. & R. HORN (1989): Die physikalische Untersuchung von Böden. Enke, Stuttgart, Germany.
- HASHIMOTO, S., N. TANAKA, M. SUZUKI, A. INOUE, H. TAKIZAWA, I. KOSAKA, K. TANAKA, C. TANTASIRIN & N. TANGTHAM (2004): Soil respiration and soil CO_2 concentration in a tropical forest, Thailand. Journal of Forest Research 9(1):75-79.
- HE, J.-S., K.S. WOLFE-BELLIN, B. SCHMID & F.A. BAZZAZ (2005): Density may alter diversity-productivity relationships in experimental plant communities. Basic and Applied Ecology

6:505-517.

- HECHT, S.B. & D.A. POSEY (1989): Preliminary results on soil management techniques of the Kayapó indians. In POSEY, D.A. & W. BALÉE (EDS.): Resource management in Amazonia: Indigenous and folk strategies. The New York Botanical Garden, Advances in Economic Botany, Vol.7.
- HOUGHTON, J.T., Y. DING, D.J. GRIGGS, M. NOGUER, P.J. VAN DER LINDEN, X. DAI, K. MASKELL & C.A. JOHNSON (2001): Climate change 2001: The scientific basis. Contribution of working group I to the third assessment report of the Intergovernmental Panel on Climate Change. Published for the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK.
- INSAM, H. & K.H. DOMSCH (1988): Relationship between soil organic carbon and microbial biomass on chronosequences of reclamation sites. Microb. Ecol. 15:177-188.
- INSAM & HASELWANDTER (1989): Metabolic quotient of the soil microflora in relation to plant succession. Oecologia 79:174-178.
- IPCC (2003): Meeting on current scientific understanding of the processes affecting terrestrial carbon stocks and human influences upon them. Geneva, Switzerland, 21–23 July 2003. www.ipcc.ch/pub/carbon.pdf download Feb 11th, 2007.
- IPCC (2001): Third Assessment Report. WGII: Climate Change 2001 – Impacts, adaptation and vulnerability. IPCC, Geneva, Switzerland.
- IPCC (2000): Summary for policy makers: Land use, land use change and forestry. Online source: http://www.ipcc.ch/pub/srlulucf-e.pdf download Feb 11th, 2007.
- IPCC (1996): Greenhouse gas inventories. Vol. II: Workbook. Vol. III: Reference manual: Guidelines for national greenhouse gas inventories. Bracknell, UK.
- ISAAC, S.R. & M.A. NAIR (2005): Biodegradation of leaf litter in the warm humid Tropics of Kerala, India. Biology & Fertility of Soils 37:1656-1664.
- IZQUIERDO, I., F. CARAVACA, M.M. ALGUACIL & A. ROLDÁN (2003): Changes in physical and biological soil quality indicators in a tropical crop system (La Havana, Cuba) in response to different agroecological management practices. Environmental Management 32(5) 639-645.
- JAHN, R. (1998): The soil resources of the Tropics — the necessity of intensified nutrient cycling within ecological land use systems. Proceedings of the International Conference on Applied Tropical Ecology in Visayas State College of Agriculture, Baybay, Leyte, Philippines.
- JAHN, R. & V. ASIO (1998): Soils of the tropical forests of Leyte, Philippines: I. Weathering, soil characteristics, classification and site qualities. In SCHULTE, A. & D. RUHIYAT (EDS.): Soils of tropical forest ecosystems: Characteristics, ecology and management. Springer, Berlin, Germany. pp.29-38.
- JAHN, R., H.-P. BLUME & V. ASIO (EDS.)(2003): Students guide for soil description, soil classification and site evaluation. Institute of Soil Science and Plant Nutrition, Martin Luther University, Halle/Saale, Germany.
- JAMALUDHEEN, V. & B. MOHAN KUMAR (1999): Litter of multipurpose trees in Kerala, India: Variations in the amount, quality, decay rates and release of nutrients. Forest Ecology and Management 115(1):1-11.
- JOERGENSEN, R.G. & X. CASTILLO (2001): Interrelationships between microbial and soil properties in young volcanic ash soils of Nicaragua. Soil Biology & Biochemistry 33:1581-1589.
- JOERGENSEN RG & S. SCHEU (1999): Depth gradients of microbial and chemical properties in moder soils under beech and spruce. Pedobiologia 43:134–199
- KAISER, E.A., T. MUELLER, R.G. JOERGENSEN, H. INSAM & O. HEINEMEYER (1992): Evaluation of methods to estimate the soil microbial biomass and the relationship with soil texture

and organic matter. Soil Biology and Biochemistry 24(7):675-683.

- Kanninen, M. (2004): Agroforestry Systems and Carbon Sequestration: Potential and Perspectives. Presentation 1st Agroforestry World Congress 2004, Florida, USA.
- Kellman, M.C. (1970): Secondary plant succession in tropical montane Mindanao. Publication BG/2. Australian National University, Canberra, Australia.
- Ketterings, Q.M., R. Coe, M. v.Noordwijk, Y. Ambagau & C.A. Palm (2001): Reducing uncertainty in the use of allometric biomass equations for predicting above-ground tree biomass in mixed secondary forests. Forest Ecology and Management 146:199-209.
- Khanna, P.K. (1998): Nutrient cycling under mixed-species tree systems in Southeast Asia. Agroforestry Systems 38:99-120.
- Köppen, W. (1931): Grundriss der Klimakunde. 2. Aufl. W. de Gruyter & Co., Berlin, Germany.
- Kolb, M. (2003): Silvicultural analysis of rainforestation farming areas on Leyte Island, Philippines. Magister Thesis, University of Göttingen, Germany.
- Kummer, D.M. & B.L. Turner II (1994): The human causes of deforestation in Southeast Asia. BioScience 44(5):323-328.
- Kummer, D.M. (1992): Deforestation in the Postwar Philippines. Ateneo de Manila University Press, Manila, Philippines.
- Langenberger, G. (2005): Age of first fruiting in two planted Philippine Dipterocarp species. Flora Malesiana Buletin 13(4):369-370.
- Langenberger, G. (2003): Diversität, Struktur und Reliefabhängigkeit der Vegetation in einem Tieflandregenwald der Insel Leyte, Philippinen. Apia Verlag, Laubach, Germany.
- Lasco, R.D., F.B. Pulhin, R.V.O. Cruz, J.M. Pulhin & S.S.N. Roy (2005a): Carbon budgets of terrestrial ecosystems in the Pantabangan-Carranglan Watershed. AIACC Working Paper No.10.
- Lasco, R.D., F.B. Pulhin & M.R.N. Banaticla (2005b): Potential carbon sequestration projects in the Philippines. In: J.E. Padilla, E.E. Tongson & R.D. Lasco (eds.): PES: Sustainable financing for conservation and development. WWF, ICRAF, Manila, Philippines.
- Lasco, R.D. & F.B. Pulhin (2004): Carbon Sequestration of Agroforestry Systems in Southeast Asia: Potentials for the Clean Development Mechanism (CDM). Presentation 1st Agroforestry World Congress, Florida, USA.
- Lasco R.D., F.B. Pulhin, J.M. Roshetko & R. Banaticla (2004): LULUCF climate change mitigation projects in the Philippines: A Primer. Laguna, Philippines.
- Lasco R.D., J.S. Lales, M.T. Arnuevo, I.Q. Guillermo, A.C. de Jesus, R. Medrano, O.F. Bajar & C.V. Mendoza (2002): Carbon dioxide (CO_2) storage and sequestration of land cover in the Leyte Geothermal Reservation. Renewable Energy 25(2):307-315.
- Lasco, R.D., R.G. Visco & J.M. Pulhin (2001): Secondary forests in the Philippines: Formation and transformation in the 20th century. Journal of Tropical Forest Science 13 (4): 652-670.
- Lasco, R.D. & P.D. Suson (1999): A *Leucaena leucocephala* -based indigenous fallow system in central Philippines: The Naalad. Int. Tree Crops J. 10:161-174.
- Lavelle, P. & A.V. Spain (2005): Soil ecology. Springer, Dordrecht, The Netherlands.
- Lavelle, P., E. Blanchart, A. Martin, S. Martin & A. Spain (1993): A hierarchical model for decomposition in terrestrial ecosystems. Application to soils in the Humid Tropics. Biotropica 25(2):130-150.
- Lehmann, J. & J. Gaunt (2004): Carbon Sequestration in Soils under Agroforestry. Presentation 1st Agroforestry World Congress, Florida, USA.
- Lehmann, J., D. Günther, M. Socorro da Mota, M. Pereirade Almeida, W. Zech & K. Kaiser (2001): Inorganic and organic soil phosphorus and sulfur pools in an Amazonian

multistrata agroforestry system. Agroforestry Systems 53:113-124.
- Leite, L.F.C., E.S. Mendonça & P.L.O.A. Machado (2004): Simulação pelo modelo CENTURY da dinâmica da matéria orgânica de um Argissolo sob adubação mineral e orgânica. R. Bras. Ci. Solo 28:347-358.
- Lin, Q. & P.C. Brookes (1999): An evaluation of the substrate-induced respiration method. Soil Biology & Biochemistry 31:1969-1983.
- Lloyd, J. (1999): The CO_2 dependence of photosynthesis, plant growth responses to elevated CO_2 concentrations and their interactions with soil nutrient status. Temperate and boreal forest productivity and the combined effects of increasing CO_2 concentrations and increased nitrogen deposition at a global scale. Functional Ecology 13/4:439-459.
- Loague, K. & R.E. Green (1991): Statistical and graphical methods for evaluating solute transport models: Overview and application. Journal of Contaminant Hydrology, 7:51-73.
- Luizão, R.C.C., T.A. Bonde & T. Rosswall (1992): Seasonal variation of soil microbial biomass – the effects of clearfelling a tropical rainforest and establishment of pasture in the Central Amazon. Soil Biology & Biochemistry 24(8):805-813.
- Mackensen, J., R. Klinge, D. Ruhiyat, & H. Folster (2003): Assessment of management-dependent nutrient losses in tropical industrial tree plantations. Ambio 32(2):106-112.
- Magid, J., G. Cadisch & K.E. Giller (2002): Short and medium term plant litter decomposition in a tropical Ultisol elucidated by physical fractionation in a dual ^{13}C and ^{14}C isotope study. Soil Biology & Biochemistry 34(9):1273-1281.
- Mamilov, A.S. & O.M. Dilly (2002): Soil microbial eco-physiology as affected by short-term variations in environmental conditions. Soil Biology & Biochemistry 34:1283-1290.
- Mao, D.M., Y.W. Min, L.L. Yu, R. Martens & H. Insam (1992): Effect of afforestation on microbial biomass and activity in soils of tropical China. Soil Biology & Biochemistry 24(9):865-872.
- Margraf, J. & P.P. Milan (1996): Rainforestation farming. A farmer's guide to biodiversity management for the Philippines. GtZ Applied Tropical Ecology Program, Manila, Philippines.
- Marschner, H. (1993): Mineral Nutrition of Higher Plants. Academic Press, London.
- Martius, C., H. Höfer, M.V.B. Garcia, J. Römbke, B. Förster & W. Hanagarth (2004): Microclimate in agroforestry systems in central Amazonia: Does canopy closure matter to soil organisms? Agroforestry Systems 60:291-304.
- Masri, M. (1991): Root distribution of durian (*Durio zibethinus* Murr.) cv. D 24. MARDI Res. J 19(2):183-189. Malaysian Agricultural Research and Development Institute, KL, Malaysia.
- Menyailo, O.V., J. Lehmann, M. da Silva Cravo & W. Zech (2003): Soil microbial activities in tree-based cropping systems and natural forests of the central Amazon, Brazil. Biology & Fertility of Soils 38:1-9.
- Mercado Jr., A., M.v. Noordwijk, T. Hilger & G. Cadisch (2006): *Acacia mangium* as an intercrop in mixed tree-based contour hedgerow systems on sloping acid upland soils. Submitted journal article (Agroforestry systems).
- Mercado Jr., A., G. Cadisch, M. v.Noordwijk & T. Hilger (2005): Nitrogen facilitation and competition in timber tree – maize agroforestry systems. Presentation. Smallholder agroforestry options for degraded tropical soils. International Consultation Workshop 18-21 August 2005, Malang, Indonesia.
- Milz, J. (2001): Guía para el establecimiento de sistemas agroforestales en Alto Beni, Yucumo y Rurrenabaque. Edited by DED & Care - Mirna. Grupo Design, La Paz, Bolivia.

- MOLINA, J.A.E. (1996): Description of the model NCSOIL. In: POWLSON, D.S., P. SMITH & J.U. SMITH (EDS.): Evaluation of soil organic matter models. Springer, Berlin, Germany in cooperation with NATO Scientific Affairs Division.
- MOLLISON, B. (1988): Permaculture. A designer's manual. Tagari Publications, Tasmania, Australia.
- MONGELI PENEIREIRO, F. (1999): Sistemas agroflorestais dirigidos pela suçessão natural: Um estudo de caso. MSc Thesis Universidade de Sao Paulo. Unpublished.
- MONTAGNINI, F. (2002) IN REDDY, V. (ED.)(2002): Management of tropical plantation forests and their soil-litter system. Science Publishers, Enfield, UK.
- MONTAGNINI, F. & P.K.R. NAIR (2004): Carbon sequestration: An underexploited environmental benefit of agroforestry systems. Agroforestry Systems 61:281-295.
- MORENO, L.O., A.A. PARAC & F.L. OCON (2005): Fiber characteristics of promising abaca accessions in NARC germplasm suited for specific iIndustry end uses. Presentation 2nd S-S-N Natural Fibre Dialogue, Leyte State University, Leyte, Philippines, 4th-6th March 2005.
- MOREIRA, A. & E. MALAVOLTA (2004): Dinâmica da matéria orgânica e da biomassa microbiana em solo submetido a diferentes sistemas de manejo na Amazônia Ocidental. Pesqisa agropecuaria brasileira 39(11):1103-1110.
- MULIA, R., P. PURNOMOSIDDHI & B. LUSIANA (2001): Tree parameterization in WaNuLCAS model. International Centre for Research in Agroforestry, Bogor, Indonesia.
- MULIA, R. (2001): Brief explanation for WanFBA. A program for estimating shoot and root biomass. International Centre for Research in Agroforestry.
- MURTHY, S.V.K. & B.R.V IYENGAR (1997): Root distribution and morphology in some banana (*Musa paradisiaca*) varieties. Indian Journal of Agricultural Sciences (IND) 67, (11):495-499.
- MURTY, D., M.F. KIRSCHBAUM, R.E. MCMURTRIE & H. MCGILVRAY (2002): Does conversion of forest to agricultural land change soil carbon and nitrogen? A review of the literature. In Global Change Biology 8(2):105-123. Blackwell.
- NAMRIA (National Mapping and Resource Information Authority): Land cover statistics 2003. Internet Source www.namria.gov.ph, download Feb 11th, 2007.
- NATIONAL STATISTICAL COORDINATION BOARD: Gross regional domestic product 2004. Internet source, download 20/05/07 from www.nscb.gov.ph
- NATIONAL STATISTICS OFFICE (2000): 2000 census of population and housing – reports by region. Internet source, download 20/05/07 from www.census.gov.ph
- NG, F.S.G. (1966): Age of first flowering in Dipterocarps. Malay. Forester 29(4):290-295.
- NIEUWOLT, S. (1977): Tropical climatology. J. Wiley & Sons, Chichester, UK.
- NYKVIST, N. (1997): Total distribution of plant nutrients in a tropical rainforest ecosystem, Sabah, Malaysia. Ambio 26(3):152-157.
- NYKVIST, N., H. GRIP, B.L. SIM, A. MALMER & F.K. WONG (1994): Nutrient losses in forest plantations in Sabah, Malaysia. Ambio 23(3):210-215.
- ODUM, E.P. (1969): The strategy of ecosystem development. Science 164:262-270.
- ONG, C.K., M. V.NOORDWIJK, & G. CADISCH (EDS.)(2003): Below-ground interactions in tropical agro-ecosystems. Concepts and models with multiple plant components. CAB International, Wallingford, UK.
- PADOCH, C., J.C. INUMA, W. DE JONG & J. UNRUH (1985): Amazonian agroforestry: A market-oriented system in Peru. In: Agroforestry Systems 3:47-58.
- PAGEL, H., J. ENZMANN & H. MUTSCHER (1982): Pflanzennährstoffe in tropischen Böden - ihre Bestimmung und Bewertung. VEB Deutscher Landwirtschaftsverlag, Berlin, German Democratic Republic.
- PALM, C.A., C.N. GACHENGO, R.J. DELVE, G. CADISCH & K.E. GILLER (2000): Organic inputs

for soil fertility management in tropical agroecosystems: Application of an organic resource database. Agriculture, Ecosystems and Environment 1692:1–16.

- PANEM, C.C. (1992): Structures of the Greater Tongonan Area, Central Leyte, Philippines. PNOC Geothermal Division, Manila, Philippines.
- PASSIOURA, J.B. (1996): Simulation models: Science, snake oil, education, or engineering? Agronomy Journal 88:690-694.
- PAUSTIAN, K., E. LEVINE, W.M. POST & I.M. RYZHOVA (1997A): The use of models to integrate information and understanding of soil C at the regional scale. Geoderma 79:227-260.
- PAUSTIAN, K., G.I. ÅGREN & E. BOSATTA (1997B): Modelling litter quality effects on decomposition and soil organic matter dynamics. In CADISCH, G. & K. GILLER (EDS.): Driven by nature. CAB International, Wallingford, UK.
- PENA, N. (2004): LULUCF: Strategies for the future. 1Presentation 1st Agroforestry World Congress 2004, Florida, USA.
- POLINAR, A.N. (2004):Constraints to on-farm tree domestication among upland farmers in Southern Leyte, Philippines. Presentation 1st Agroforestry World Congress 2004, Florida, USA.
- POSEY, D.A. & W. BALÉE (EDS.)(1989): Resource management in Amazonia: Indigenous and folk Strategies. Advances in Economic Botany, Vol.7. The New York Botanical Garden, NY, USA.
- POWLSON, D. (2005): Will soil amplify climate change? Nature 433:204f.
- POWLSON, D.S., P. SMITH & J.U. SMITH (eds.)(1996): Evaluation of soil organic matter models. Springer, Berlin, Germany, in cooperation with NATO Scientific Affairs Division.
- QUIMIO, J.M., E.A. HERMONES & L. TAN (1998): Vegetation structure of five-year rainforestation farm in ViSCA. Poster, International Conference on Applied Tropical Ecology, 8-10 September 1998, ViSCA, Baybay, Leyte, Philippines.
- RAHAYU, N., M. V.NOORDWIJK & B. LUSIANA: Site-specific potential crop growth input parameters for WaNuLCAS, using WOFOST_Excel. Available online at www.worldagroforestrycentre.org/sea download Feb 11th, 2007.
- RAICH, J.W., C.S. POTTER, & D. BHAGAWATI (2003): Interannual variability in global soil respiration on a 0.5 degree grid cell basis (1980-1994). NDP-081. Carbon Dioxide Information Analysis Center, U.S. Department of Energy, Oak Ridge National Laboratory, Oak Ridge, Tennessee, USA.
- RAICH, J.W., A.E. RUSSELL & P.M. VITOUSEK (1997): Primary productivity and ecosystem development along an elevational gradient on Mauna Loa, Hawai´i. Ecology 78 (3): 707-721.
- RANGIN, C., C. MÜLLER & H.PORTH (1989): Neogene geodynamic evolution of the Visayan Region. Geologisches Jahrbuch Vol. 70:7-27. Bundesanstalt für Bodenforschung, Hannover, Germany.
- RAO, M.R., P.K.R. NAIR & C.K. ONG (1998): Biophysical interactions in tropical agroforestry systems. Agroforestry Systems 38:3-50.
- REDDY, M.V. (ED.)(2002): Management of tropical plantation forests and their soil-litter system. Science Publishers, Enfield, UK.
- REES, R.M., B.C. BALL, C.D. CAMPBELL & C.A. WATSON (2001): Sustainable management of soil organic matter. CAB International Wallingford, UK.
- REHM, S. & G. ESPIG (1996): Die Kulturpflanzen der Tropen und Subtropen. Ulmer, Stuttgart, Germany.
- RODRIGO, V.H.L., C.M. STIRLING, Z. TEKLEHAIMANOT & A. NUGAWELA (1997): The effect of planting density on growth and development of component crops in rubber / banana intercropping systems. Field Crops Research 52:95-108.
- RUHIGWA, B.A., M.P. GICHURU, B. MAMBANF & N.M. TARIAH (1992): Root distribution of *Acioa*

barteri, *Alchornea cordifolia*, *Cassia siamea* and *Gmelina arborea* in an acid Ultisol. Agroforestry Systems 19: 67-78.

- RUSSELL, A.E. (2002): Relationships between crop-species diversity and soil characteristics in Southwest Indian agroecosystems. Agriculture, Ecosystems and Environment 92:235-249.
- SALES, R.F., R.D. LASCO & M.R.N. BANATICLA (2005): Carbon storage and sequestration potential of smallholder tree farms on Leyte Island, The Philippines. In: ACIAR smallholder forestry project ASEM 200/008 Redevelopment of a timber industry following extensive land clearing: Proceedings from the end-of project workshop, Ormoc City, Philippines 19-21 August 2004. ACIAR, Ormoc, Philippines.
- SALICK, J. (1989): Ecological base of Amuesha agriculture, Peruvian Upper Amazon. In POSEY, D.A. & W.BALÉE (EDS.)(1989): Resource management in Amazonia: Indigenous and folk Strategies. Advances in Economic Botany, Vol.7. The New York Botanical Garden, NY, USA.
- SANTOS, F. & S.G. RAMOS (1995): The geology of the Bato-Lunas Geothermal Prospect, Province of Leyte. Geoscientific Dept., Geothermal Division, PNOC, Makati, Philippines.
- SCHACHTSCHABEL, P., H.-P. BLUME, G. BRÜMMER, K.-H. HARTGE & U. SCHWERTMANN (1992): Lehrbuch der Bodenkunde, 13. Auflage. Enke, Stuttgart, Germany.
- SCHIMEL, D.S., J.I. HOUSE, K.A. HIBBARD, P. BOUSQUET, P. CIAIS, P. PEYLIN, B.H. BRASWELL, M.J. APPS, D. BAKER, A. BONDEAU, J. CANADELL, G. CHURKINA, W. CRAMER, A.S. DENNING, C.B. FIELD, P. FRIEDLINGSTEIN, C. GOODALE, M. HEIMANN, R.A. HOUGHTON, J.M. MELILLO, B. MOORE 3RD, D. MURDIYARSO, I. NOBLE, S.W. PACALA, I.C. PRENTICE, M.R. RAUPACH, P.J. RAYNER , R.J. SCHOLES, W.L. STEFFEN & C. WIRTH (2001): Recent patterns and mechanisms of carbon exchange by terrestrial ecosystems. Nature 414:169-172.
- SCHINNER, F., E. KANDELER, R. ÖHLINGER & R. MARGESIN (1993): Bodenbiologische Arbeitsmethoden. 2nd edition. Springer, Berlin, Heidelberg, Germany.
- SCHLICHTING, E., H.-P. BLUME & K. STAHR (1995): Bodenkundliches Praktikum. 2nd ed. Blackwell, Berlin, Germany.
- SCHNEIDER V. DEIMLING, T., H. HELD, A. GANOPOLSKI & S. RAHMSTORF (2006): Climate sensitivity estimated from ensemble simulations of glacial climate. Climate Dynamics 27(2-3):149-163.
- SCHOENAU, J.J. & J.R. BETTANY (1987): Organic matter leaching as a component of carbon, nitrogen, phosphorus and sulphur cycles in a forest, grassland, and gleyed soil. Soil Science Society of America Journal 51:646-651.
- SCHROEDER, P. (1994): Carbon storage benefits of agroforestry systems. Agroforestry Systems 27:89-97.
- SCHROTH, G. & F.L. SINCLAIR (EDS.)(2003): Trees, crops and soil fertility - Concepts and research methods. CABI Publishing, Wallingford, UK.
- SCHROTH, G., J. LEHMANN, M.R.L. RODRIGUES, E. BARROS & J.L.V. MACÊDO (2001): Plant-soil interactions in multi-strata agroforestry in the Humid Tropics. Agroforestry Systems 53:85-102.
- SCHROTH, G., U. KRAUSS, L. GASPAROTTO, J.A. DUARTE A., & K. VOHLAND (2000): Pests and diseases in agroforestry systems of the Humid Tropics. Agroforestry Systems 50:199-241.
- SCHULTE, E.E. (1995): Recommended soil testing procedures for the Northeastern United States. In: AGRICULTURAL EXPERIMENT STATIONS OF CONNECTICUT, DELAWARE, MAINE, MARYLAND, MASSACHUSETTS, NEW HAMPSHIRE, NEW JERSEY, NEW YORK, PENNSYLVANIA, RHODE ISLAND, VERMONT AND WEST VIRGINIA (ED.), 2nd edition. Bulletin # 493. Agricultural Experiment Station, University of Delaware, Newark, USA.
- SCHÜTT, P. (ED.)(2004): Bäume der Tropen. Nikol, Hamburg, Germany.

- Schwendenmann, L.C. (2002): Below-ground carbon dynamics as a function of climate variability in undisturbed soils of a neotropical rain forest. PhD Dissertation University of Göttingen, Germany.
- Shively, G.E., C.A. Zelek, D.J. Midmore & T.M. Nissen (2004): Carbon sequestration in a tropical landscape: An economic model to measure its incremental cost. Agroforestry Systems 60:189-197.
- Smiley, G.L. (2006): Biophysical resource use and productivity in cocoa-gliricidia agroforests of central Sulawesi. PhD Dissertation University of Hohenheim. Margraf, Weikersheim, Germany.
- Smith, P., J.U. Smith, D.S. Powlson, W.B. McGill, J.R.M. Arah, O.G. Chertov, K. Coleman, U. Franko, S. Frolking, D.S. Jenkinson, L.S. Jensen, R.H. Kelly, H. Klein-Gunnewiek, A.S. Komarov, C. Li, J.A.E. Molina, T. Mueller, W.J. Parton, J.H.M. Thornley & A.P. Whitmore (1997): A comparison of the performance of nine soil organic matter models using datasets from seven long-term experiments. Geoderma 81:153-225.
- Smith, W.B. & G.J. Brand (1983): Allometric biomass equations for 98 species of herbs, shrubs and small trees. USDA Forest Service, North Central Forest Experiment Station, Research Note NC-299.
- Soerianegara, I. & R.H.M.J. Lemmens (eds.)(1993): Plant resources of South East Asia, Vol.5,1: Major commercial timbers. PROSEA. Backhuys Publ., The Netherlands.
- Soils Research, Testing and Plant Analysis Laboratory, DASS, LSU (not dated): Standard methods of analysis for soil and plant tissue samples. Unpublished.
- Spek, L.Y. & M. v.Noordwijk (1994): Proximal root diameters as predictors of total root system size for fractal branching models. II. Numerical Model. Plant and Soil 164:119-128.
- Stover, R.H. (1982): Valery and Grand Nain: Plant and foliage characteristics and a proposed banana ideotype. Tropical Agriculture 59:303-305.
- Svensson, K. & M. Pell (2000): Soil microbial tests for discriminating between different cropping systems and fertiliser regimes. Biology & Fertility of Soils 33:91-99.
- Trexler, M.C. & C. Haugen (1991): Using tropical forestry to mitigate global warming: A preliminary carbon assessment. Draft final report to the US Environmental Protection Agency, Washington DC, USA.
- Tsegaye, A. & P.C. Struik (2003): Growth, radiation use efficiency and yield potential of enset (*Ensete ventricosum*) at different sites in southern Ethiopia. Annuals of Applied Biology 142:71-81.
- Turner, D.W. (1990): Modelling demand for nitrogen in the banana. Acta Horticulturae 275:497-503.
- Turner, D.W. (1972a): Banana plant growth 1. Gross morphology. Australian Journal of Experimental Agriculture and Animal Husbandry 12:209-215.
- Turner, D.W. (1972b): Banana plant growth: Dry matter production, leaf area growth and analysis. Australian Journal of Experimental Agriculture and Animal Husbandry 2:217-224.
- Uhl, C. & C.F. Jordan (1984): Succession and nutrient dynamics following forest cutting and burning in Amazonia. Ecology 65(5):1476–1490.
- Uhl, C.(1987): Factors controlling succession following slash and burn agriculture in Amazonia. Journal of Ecology 75:377-407.
- v. Noordwijk, M., G. Cadisch & C.K. Ong (2004): Below-ground interactions in tropical agroecosystems: Concepts and models with multiple plant components. CAB International, Wallingford, UK.
- v. Noordwijk, M., B. Lusiana & N. Khasanah (2004): WaNuLCAS 3.0. Background on a model of water, nutrient and light capture in agroforestry systems. ICRAF, Bogor,

Indonesia.
- v. Noordwijk, M. & R. Mulia (2002): Functional branch analysis as tool for fractal scaling above- and belowground trees for their additive and non-additive properties. Ecological Modelling 149(1-2):41-51.
- v. Noordwijk, M., S. Rahayu, K. Hairiah, Y.C. Wulan, A. Farida & B.Verbist (2002): Carbon stock assessment for a forest-to-coffee conversion landscape in Sumber-Jaya (Lampung, Indonesia): From allometric equations to land use change analysis. Science in China, Series C, 45, Suppl.
- v. Noordwijk, M. (2002): Scaling trade-offs between crop productivity, carbon stocks and biodiversity in shifting cultivation landscape mosaics: The FALLOW model. Ecological Modelling 149:113-126.
- v. Noordwijk, M. (1999): Scale effects in crop-fallow rotations. Agroforestry Systems 47:239-251.
- v. Noordwijk, M., C. Cerri, P.L. Woomer, K. Nugroho & M. Bernoux (1997): Soil carbon dynamics in the humid tropical forest zone. Geoderma 79:187-225.
- v. Noordwijk, M., L.Y. Spek & P. de Willigen (1994): Proximal root diameters as predictors of total root system size for fractal branching models. I. Theory. Plant and Soil 164:107-118.
- v.Carlowitz, H.C. (1713): Sylvicultura oeconomica, oder haußwirthliche Nachricht und naturmäßige Anweisung zur Wilden Baum Zucht. J.Fr. Braun, Leipzig, Germany.
- Veldkamp, E. (1994): Organic carbon turnover in three tropical soils under pasture after deforestation. Soil Science Society of America Journal 58:175-180.
- Velicogna, I. & J. Wahr (2006): Acceleration of greenland ice mass loss in spring 2004. Nature 443:329-331.
- Verchot, L.V., M. v.Noordwijk, T. Tomich & S. Kandji (2004): Climate Change: Linking adaptation and mitigation through agroforestry. Presentation, 1st Agroforestry World Congress, Florida, USA.
- Verheij, E.W.M. & R.E. Coronel (ed.)(1991): Plant resources of South East Asia, Vol.2. Pudoc, Wageningen, The Netherlands.
- Waldrop, M.P., T.C. Balser & M.K. Firestone (2000): Linking microbial community composition to function in a tropical soil. Soil Biology & Biochemistry 32(13):1837-1846.
- Wardle, D.A., G.W. Yeates, K.S. Nicholson, K.I. Bonner & R.N. Watson (1999): Response of soil microbial biomass dynamics, activity and plant litter decomposition to agricultural intensification over a seven-year period. Soil Biology & Biochemistry 31:1707-1720.
- Wardle, D.A. & D. Parkinson (1990): Interactions between microclimatic variables and the soil microbial biomass. Biology and Fertility of Soils 9:273-280.
- Weidelt, H.J. & V.S. Banaag (1982): Aspects of management and silviculture of Philippine Dipterocarp forests. GtZ Eschborn, Germany.
- Whitford, H.N. (1911): The forests of the Philippines. Part I: Forest types and products. Department of the Interior, Bureau of Forestry, Bulletin No. 10. Manila, Philippines.
- Wischmeier, W.H. & D.D. Smith (1978): Predicting rainfall erosion losses – a guide to conservatrion planning. Agriculture handbook 537. USDA, Washington, USA.
- World Agroforestry Centre: Online Agroforestry Tree database. Online resource. Download from www.worldagroforestrycentre.org on 20/05/2007.
- World Agroforestry Centre: Online Wood Density database. Online resource. Download from www.worldagroforestrycentre.org on 20/05/2007.
- Yadav, R.S. & J.C. Tarafdar (2001): Influence of organic and inorganic phosphorus supply on the maximum secretion of acid phosphatase by plants. Biology & Fertility of Soils 34:140-143.

- YAN, T., L. YANG & C.D. CAMPBELL (2003): Microbial biomass and metabolic quotient of soils under different land use in the Three Gorges Reservoir. Geoderma 115:129-138.
- YANG, J., D.J. GREENWOOD, D.L. ROWELL, G.A. WADSWORTH & I.G. BURNS (2000): Statistical methods for evaluating a crop nitrogen simulation model, N_ABLE. Agricultural Systems 64(1):37-53.
- YOUNG, A. (1997): Agroforestry for soil management. CAB International, Wallingford, UK.
- YUMUL, G.P., C.B. DIMALANTA, R.A. TAMAYO & R.C. MAURY (2003): Collision, subduction and accretion events in the Philippines: A synthesis. Island Arc 12(2):77-91.
- ZANG, S.X. & J.Y. NING (2002): Interaction between Philippine Sea Plate (PH) and Eurasia (EU) Plate and its influence on the movement of Eastern Asia. Chinese Journal of Geophysics 45(2):188-197.
- ZECH, W., N. SENESI, G. GUGGENBERGER, K. KAISER, J. LEHMANN, T.M. MILANO, A. MILTNER & G. SCHROTH (1997): Factors controlling humification and mineralization of soil organic matter in the Tropics. Geoderma 79:117-161.
- ZIKELI, S. (1998): Nutrient status and nutrient cycle of the tropical rain forest. Master Thesis University of Halle, Germany.
- ZÖFEL, K. (2004): Regeneration of soil fertility through reforestation? Studies on P-availability on deforested and forested sites on Leyte, Philippines. M.Sc. Thesis (Diplomarbeit) University of Hohenheim. Unpublished.

12 Appendices

Table 30: Overview soil chemical data paired plots chapter 4

	PH		C_{org}		N_T		Phosphatase		P_{Bray}		Ca^{2+}		Mg^{2+}		K^+		Na^+		BR 24h		BR 72h		C_{mic}	
			[%]				μgPhenol $g^{-1}3h^{-1}$		mg/kg										$\mu gCO_2\ g^{-1}\ h^{-1}$				$\mu g\ g^{-1}$	
	Ø	SD	Ø	SD	Ø	SD	Ø	SD	Ø	SD	Ø	SD	Ø	SD	Ø	SD	Ø	SD	Ø	SD	Ø	SD	Ø	SD
Ci-Rainfo	4.67	0.22	3.50	0.33	0.29	0.04	37.05	17.10	0.52	0.33	415.8	58.1	412.0	103.6	101.82	8.06	62.15	31.41	6.46	1.31	4.39	1.15	977.2	246.6
Ci-Grass	4.97	0.27	3.51	0.67	0.30	0.04	113.41	20.78	0.43	0.12	529.2	144.0	532.7	218.9	115.96	33.77	172.12	158.10	7.79	1.66	3.84	1.24	988.3	309.0
LSU-Rainfo	4.96	0.15	1.98	0.25	0.22	0.03	23.60	6.13	0.46	0.03	3009.0	50.5	701.9	36.0	177.84	46.85	50.54	11.99	2.40	0.56	2.95	0.40	295.2	109.0
LSU-Annuals	5.05	0.27	2.23	0.25	0.25	0.03	24.59	7.58	0.51	0.10	3307.4	203.4	929.0	97.8	223.61	145.05	69.91	13.89	2.69	0.52	3.14	0.42	491.6	197.1
LSU-Grass	nd	nd	2.24	0.19	0.23	0.02	35.34	6.32	0.52	0.03	2156.2	45.7	1446.4	83.5	107.74	21.67	73.65	12.69	3.44	0.43	3.62	0.38	365.4	95.3
Mar-Rainfo	4.98	0.11	2.67	0.44	0.26	0.04	58.41	15.31	0.47	0.05	3046.0	491.4	782.1	36.3	110.65	48.95	153.62	76.82	3.23	1.14	3.25	0.36	393.8	154.9
Mar-Grass	5.36	0.29	2.76	0.46	0.30	0.05	32.15	nd	0.63	0.08	4314.7	195.9	1113.4	78.1	247.02	79.73	101.88	25.04	2.98	0.83	3.17	0.49	347.6	103.2
Mar-Gme	5.04	0.19	3.32	0.52	0.32	0.04	47.76	15.27	0.54	0.07	4352.2	9.2	1020.3	2.7	188.05	76.07	118.98	1.38	4.12	1.25	4.01	0.87	464.9	148.8
Pang-Rainfo	4.96	0.08	2.77	0.20	0.26	0.02	28.40	nd	0.38	0.06	920.6	141.2	469.3	34.9	95.95	20.66	40.03	7.54	2.74	1.34	2.45	1.08	372.0	156.4
Pang-Grass	4.75	0.35	2.28	0.25	0.21	0.02	31.88	nd	0.39	0.07	998.0	106.6	311.5	31.9	79.22	20.17	70.22	29.35	1.76	0.89	1.35	0.41	287.7	114.5
Pat-Rainfo	4.79	0.22	1.76	0.10	0.17	0.01	37.69	9.19	0.41	0.07	2001.0	9.1	1116.6	21.2	130.27	79.02	107.94	32.72	1.37	0.13	1.33	0.12	294.2	78.2
Pat-Grass	4.98	0.20	2.08	0.24	0.18	0.02	36.27	22.14	0.53	0.17	976.8	8.2	544.5	5.1	303.20	9.89	90.42	0.07	1.62	0.33	1.71	0.13	371.0	85.5
Pat-Gme	5.36	0.12	2.29	0.46	0.19	0.04	24.12	23.70	0.39	0.02	1533.4	13.8	877.3	3.8	304.72	50.19	90.58	4.72	4.13	1.08	3.78	1.01	381.0	200.7
Mai-Rainfo	6.61	0.13	2.68	0.26	0.23	0.02	22.00	14.99	34.72	4.93	5640.7	876.8	1021.4	89.2	136.14	21.99	70.30	9.40	4.32	0.60	2.82	0.42	564.4	162.3
Mai-Grass	6.66	0.12	2.21	0.34	0.20	0.04	27.39	26.86	17.94	0.11	6029.4	200.4	1262.2	119.6	108.78	24.83	75.76	7.49	5.05	1.54	3.03	0.68	601.1	83.8
Pun-Rainfo	8.02	0.18	4.17	0.30	0.36	0.03	1.69	0.53	2.73	0.23	11717.3	179.3	246.4	0.6	189.37	81.92	80.74	29.45	22.37	0.97	8.68	0.36	526.8	90.8
Pun-Grass	7.83	0.33	4.14	0.08	0.33	0.02	0.95	0.50	2.87	0.55	12492.4	801.3	197.4	8.6	88.37	34.21	60.06	20.15	22.65	0.91	8.53	0.27	441.2	55.6

Laboratory data chapter 5:

Table 31: Soil organic carbon at Cienda subplots, 0-5cm and 7-12cm depth

	Carbon contents Loss on Ignition method, 0-5cm depth [%]										**Carbon contents Loss on Ignition method, 7-12cm depth [%]**									
Subplot	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	5.37	6.07	6.55	5.86	5.41	4.51	4.99	5.02	5.65	4.29	4.03	4.91	4.18	4.14	4.19	3.66	3.68	4.19	4.67	3.65
	5.35	5.53	6.31	5.64	5.91	4.46	5.47	4.84	6.63	5.34	4.00	4.77	4.19	4.09	3.59	4.00	4.01	4.24	5.48	4.46
	4.87	5.96	5.40	5.40	5.43	4.66	4.88	5.25	5.46	7.47	3.98	4.27	3.65	4.70	4.03	4.24	3.90	4.27	4.16	4.70
	5.53	5.57	5.58	5.65	5.89	5.40	4.01	4.90	5.76	6.36	4.94	4.19	3.81	4.20	4.37	3.86	3.56	4.15	4.33	5.10
	4.21	6.06	5.20	5.23	5.44	4.55	4.48	4.58	6.52	4.63	4.04	4.56	3.91	3.88	4.23	3.70	3.86	4.21	5.25	4.83
	5.30	4.80	5.36	4.75	4.20	4.61	5.30	4.02	5.02	5.52	5.13	3.85	5.37	3.96	4.35	4.23	3.78	3.97	4.23	3.68
	5.47	4.76	6.53	5.47	4.95	5.52	5.28	3.95	5.60	6.32	4.29	4.03	4.13	2.26	3.45	3.76	4.05	3.82	5.53	4.02
	6.82	5.57	5.63	4.90	5.49	5.22	5.64	5.19	4.63	5.50	4.09	3.83	3.42	4.48	3.76	4.37	4.43	3.83	4.14	4.09
	5.98	6.86	5.02	5.57	7.34	4.63	5.39	4.40	5.01	5.21	4.45	3.94	4.80	4.03	4.62	3.93	4.10	3.77	3.49	5.14
	5.46	5.31	4.19	4.72	6.90	5.10	4.83	4.96	4.79	4.98	3.89	3.69	5.57	3.66	4.32	3.65	4.07	4.27	4.57	4.28
	5.73	5.05	5.76	5.52	4.85	4.83	5.44	5.35	5.68	4.94	3.79	4.05	4.58	4.35	4.75	3.57	4.11	4.18	4.11	3.70
	5.08	4.91	5.72	5.46	4.63	4.40	5.84	5.01	5.75	7.78	3.94	4.34	4.04	4.22	4.78	3.52	4.21	4.14	4.39	3.70
	4.86	5.16	5.65	5.53	5.22	5.15	6.39	4.13	5.70	5.94	4.03	3.89	4.23	4.54	3.64	4.49	4.76	4.08	4.81	4.54
	5.33	5.78	6.04	4.81	5.54	5.85	5.56	4.22	5.18	6.12	4.07	4.20	4.75	5.06	4.09	3.85	4.04	3.94	4.17	4.64
	5.29	5.80	6.02	4.61	5.00	6.14	4.79	4.93	5.19	5.45	5.19	4.16	3.93	4.04	3.57	3.90	3.76	3.87	4.85	4.35
	4.34	6.21	4.81	5.38	5.33	6.25	4.89	4.21	5.12	5.79	4.30	4.15	4.21	4.06	4.02	4.75	3.92	3.72	3.83	4.12
	5.79	5.46	5.54	4.35	5.35	6.00	5.18	4.12	5.06	5.45	2.31	4.09	4.63	4.29	4.06	4.59	3.70	3.62	3.68	3.85
	6.02	5.53	6.05	5.09	4.31	5.76	4.64	4.51	4.59	5.48	4.00	4.06	4.39	3.98	3.60	3.88	3.81	4.16	3.70	4.01
	5.83	7.68	6.36	5.37	5.23	5.66	4.80	4.90	4.47	5.72	3.33	3.82	3.94	3.71	3.64	3.68	3.95	3.73	3.87	4.13
	5.14	5.90	6.44	5.42	6.13	5.85	5.61	4.57	5.26	4.95	4.20	5.37	4.34	4.16	4.12	3.67	3.94		3.99	3.83
	4.76		6.38	5.30	3.96	5.04	5.48	4.73	4.81	5.37	4.00	4.16	4.88	4.34	4.05	3.77	3.98		3.94	3.73
					4.05	5.01	4.79	5.07	5.08	5.34		4.32		4.02	3.59	3.54	3.86			3.79
									5.00											
Average	5.36	5.70	5.74	5.24	5.30	5.21	5.17	4.68	5.30	5.63	4.09	4.21	4.33	4.10	4.04	3.94	3.98	4.01	4.34	4.20
StDev	0.59	0.70	0.61	0.40	0.84	0.59	0.52	0.43	0.56	0.82	0.60	0.40	0.53	0.52	0.40	0.36	0.26	0.21	0.58	0.47

	Subplot 11	
	0-5cm	**7-12cm**
	6.71	6.14
	6.14	5.93
	5.75	4.97
	5.71	5.87
	5.63	5.27
	6.10	4.88
	5.70	5.18
	5.27	2.66
	5.43	4.47
	4.97	4.75
	5.21	4.82
	5.44	5.40
	5.46	4.86
	6.42	4.69
	6.42	4.80
	5.89	4.65
	6.58	5.26
	6.09	5.01
	6.37	5.07
	5.74	6.00
	5.97	5.17
	5.80	5.21
	5.31	4.83
	5.73	4.65
	6.82	4.94
	5.62	5.36
	4.93	4.53
	4.80	5.17
	5.63	4.57
	5.38	4.61
	5.76	4.38
	5.78	4.99
	6.31	4.95
		4.78
		5.53
		4.66
		4.26
		4.79
		4.46
Average	5.78	4.94
StDev	0.51	0.58

Table 32: Organic matter fractions at Cienda subplots

Organic Matter Fractions obtained by sieving and flotation in water, Cienda subplots

Element / Subplot	Aboveground biomass >2mm	Roots >2mm	Entire <2mm	LOM <2mm	HOM <2mm	Lost	Labile
	Fraction						
C	g kg^{-1} soil					[%]	
1	0.73	2.08	22.07	0.8	16.37	22	18.1
2	1.73	2.13	21.78	0.9	17.32	16	21.5
3	0.95	2.28	19.84	0.75	17.06	10	18.9
4	0.89	2.22	20.99	1.3	16.3	16	21.3
5	0.93	2.47	27.46	1.25	21.54	17	17.8
6	0.7	1.34	21.01	0.58	14.84	27	15.0
7	0.53	2.11	20.7	0.67	16.06	19	17.1
8	0.59	0.47	18.63	0.72	15.83	11	10.1
9	0.47	2.45	19.95	0.84	16.17	15	18.9
10	1.12	2.25	22.05	0.96	18.13	13	19.3
11	0.72	2.67	22.92	0.96	18.04	17	19.5
12	0.56	2.4	19.84	0.68	18.44	4	16.5
13	0.67	2.76	26.12	0.9	22.02	12	16.4
N	g kg^{-1} soil					[%]	
1	0.01	0.02	2.21	0.03	1.64	25	3.7
2	0.04	0.03	2.28	0.03	1.73	23	5.0
3	0.02	0.03	1.98	0.02	1.71	13	3.9
4	0.01	0.02	1.89	0.04	1.63	12	4.4
5	0.02	0.03	2.43	0.04	1.91	20	4.8
6	0.01	0.02	1.99	0.02	1.39	29	3.4
7	0.01	0.03	1.97	0.02	1.52	22	3.6
8	0.02	0.01	1.97	0.03	1.58	18	3.2
9	0.01	0.03	1.79	0.03	1.54	12	4.5
10	0.02	0.03	2.21	0.03	1.73	20	4.6
11	0.02	0.03	1.88	0.03	1.56	15	4.9
12	0.01	0.03	1.88	0.02	1.68	9	3.5
13	0.01	0.03	*4.91*	0.03	1.71	*64*	4.0
P	mg kg^{-1} soil					[%]	
1	0.88	1.53	409	1.97	327.31	19	1.3
2	1.81	1.55	422	1.82	330.78	21	1.5
3	1.03	2.26	412	1.76	364.69	11	1.4
4	0.87	1.41	391	2.98	322.69	17	1.6
5	1.14	1.98	406	2.52	376.91	7	1.5
6	0.95	1.37	399	0.95	350.51	12	0.9
7	0.48	1.7	392	1.32	338.05	13	1.0
8	0.94	0.51	380	1.77	303.33	20	1.0
9	0.4	1.76	371	1.41	301.56	18	1.2
10	0.92	1.73	416	2.28	484.56	-17	1.0
11	0.79	2.6	559	1.71	270.55	51	1.9
12	0.61	2.17	490	1.36	417.68	14	1.0
13	1.43	2	507	2.17	446.93	11	1.2

LOM = light organic matter (<2mm, floating in water)
HOM = heavy organic matter (<2mm, not floating in water)
Labile = share of C / N / P in LOM to such in the entire fraction
Lost = difference of entire fraction minus LOM and HOM as share of the entire fraction: (Entire<2 – LOM<2 - HOM<2) / Entire<2 x 100

Table 33: Substrate-induced respiration and C_{mic} at Cienda subplots

Substrate-Induced Respiration at 32° C and microbial carbon											
Subplot	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Soil dry matter [%]	55.19	53.69	56.63	57.57	58.65	78.12	61.95	64.62	51.88	58.38	64.09
	4.65	5.46	4.86	5.10	5.63	3.52	3.26	2.55	6.36	3.77	3.72
	4.98	5.81	5.18	5.10	5.78	3.52	3.55	2.55	6.54	3.77	3.86
CO_2 [mg 100g^{-1} h^{-1}]	4.98	5.46	5.18	5.10	5.31	3.29	3.55	2.55	6.36	3.77	3.72
	4.98	5.46	5.02	6.05	5.31	3.52	3.85	2.55	6.36	3.61	4.00
	4.82	5.81	5.18	5.41	5.78	3.52	3.55	2.55	6.71	3.45	4.15
Average	**4.88**	**5.60**	**5.08**	**5.35**	**5.56**	**3.47**	**3.55**	**2.55**	**6.47**	**3.67**	**3.89**
StDev	0.15	0.19	0.14	0.42	0.24	0.10	0.21	0.00	0.16	0.14	0.19
Coeff. Var. [%]	3.0	3.3	2.8	7.8	4.3	3.0	5.9	0.0	2.4	3.8	4.8
CO_2 [µg g^{-1} h^{-1}]	48.84	56.01	50.82	53.50	55.64	34.73	35.51	25.53	64.67	36.74	38.90
C_{mic} [µg g^{-1}]	1.61	1.85	1.68	1.76	1.83	1.14	1.17	0.84	2.13	1.21	1.28

Table 34: Basal respiration at Cienda subplots in a 30 day incubation experiment (non-cumulative depiction)

Successive[1] basal respiration over 30 days [µg CO_2 g^{-1} oven-dry soil h^{-1}]														
	1d		**3d**		**6d**		**12d**		**18d**		**24d**		**30d**	
Subplot	Ø	SD	Ø	SD	Ø	SD	Ø	SD	Ø	SD	Ø	SD	Ø	SD
1	3.51	0.24	2.55	0.36	1.78	0.17	1.69	0.53	1.12	0.37	1.12	0.25	1.02	0.27
2	4.16	0.13	3.26	0.24	2.18	0.12	1.69	0.24	1.48	0.26	1.12	0.27	1.02	0.08
3	4.27	0.51	3.91	0.37	2.13	0.25	2.10	0.19	1.58	0.09	1.50	0.17	1.54	0.24
4	3.72	0.38	3.71	0.49	1.53	0.07	1.61	0.14	1.39	0.21	1.16	0.19	1.19	0.17
5	3.01	0.29	3.86	0.19	2.14	0.24	1.79	0.15	1.69	0.38	1.35	0.11	1.30	0.08
6	1.25	0.81	2.20	0.23	1.32	0.14	0.96	0.12	0.94	0.09	0.86	0.15	0.79	0.09
7	1.13	0.27	2.12	0.52	0.77	0.06	0.96	0.11	0.92	0.21	0.83	0.29	0.79	0.11
8	1.61	0.30	2.43	0.17	1.20	0.08	1.14	0.13	1.33	0.37	0.91	0.14	0.88	0.07
9	2.63	0.34	2.82	0.17	1.50	0.14	1.33	0.06	1.45	0.31	1.31	0.26	1.28	0.13
10	2.26	0.41	2.83	0.20	1.18	0.13	1.22	0.13	1.50	0.46	1.09	0.10	1.27	0.31
11	4.48	0.51	3.04	0.19	1.45	0.13	1.53	0.04	2.01	0.60	1.57	0.38	1.39	0.19
12	3.89	0.72	2.63	0.35	1.43	0.16	1.22	0.07	1.23	0.42	1.03	0.09	1.04	0.06
13	5.17	0.50	3.65	0.21	2.00	0.37	1.74	0.29	1.58	0.19	1.44	0.18	1.36	0.13

[1] = not cumulative Ø = average, SD = st.dev.

Table 35: Root weight and root length density at Cienda

Root weight density [mg cm^{-3}] and root length density [cm cm^{-3}] Cienda subplots

	Weight						**Total RLD**	
	0-15cm depth			15-30cm depth				
Subplot	Ø <1.5mm	Ø >1.5mm	Total	Ø <1.5mm	Ø >1.5mm	Total	0-15cm depth	15-30cm depth
1	1.99	2.79	4.77	0.90	1.81	2.71	1.31	1.57
2	2.25	0.80	3.05	0.99	0.20	1.19	0.94	0.59
3	1.42	2.42	3.84	1.16	2.65	3.81	2.82	0.74
4	7.16	9.02	16.18	3.58	11.94	15.52	3.42	0.48
5	5.44	6.76	12.20	1.63	1.99	3.62	1.68	0.54
6	2.92	1.06	3.98	0.99	0.99	1.99	1.78	0.66
7	nd	nd	nd	0.57	1.42	1.99	nd	0.27
8	1.99	0.27	2.25	0.72	0.00	0.72	0.65	0.47
9	2.92	2.92	5.84	0.83	3.32	4.14	1.47	0.51
10	4.74	7.65	12.40	0.80	0.27	1.06	1.33	0.35
11	6.90	5.31	12.20	2.75	1.07	3.83	2.26	0.63
12	2.82	4.48	7.29	0.61	0.15	0.77	2.38	0.46

Table 36: Photosynthetically Active Radiation (PAR) at Cienda

Photosynthetically Active Radiation Cienda subplots [% of open area]

Row / Line*	X	W	V	U	T	S	R	Q	P	O	N	M	L	K	J	I	H	G	F	E	D	C	B	A
0		100		85	100	100	8	100	100	15	100	100												
1	100	100	100	87	100	25	100	8	100	100	99	100	100	42	11	19	2	16	3	75	3	31	4	88
2	100	100	100	100	24	100	100	100	100	8	20	52	54	57	6	58	10	2	3	6	46	100	3	2
3	100	100	100	9	62	100	20	100	5	100	57	100	33	18	96	9	3	52	97	2	97	3	3	1
4	100	100	100	34	100	100	100	100	100	11	57	96	100	100	8	100	19	7	4	2	15	44	8	2
5	100	100	100	5	89	9	11	6	100	100	38	100	4		3	100	2	3	96	100	96	3	57	8
6	24	97	85	6	40	100	100	100	100	7	7	100	91		8	19	61	26	98	2	94	58	40	3
7	72	83	48	99	83	9	100	8	96	100	100	100	49	9	3	28	12	3	30	4	2	92	3	2
8	21	67	27	96	100	20	100	4	36	31	100	51	72	4	6	100	70	15	15	11	17	6	24	2
9	19	28	39	9	100	14	8	100	100	38	87	100	7	2	2	100	6	60	69	2	22	5	4	2
10	25	32	38	98	14	6	100	100	100	9	100	39	13	55	94	18	95	4	100	2	3	2	3	1
11	61	56	55	100	7	6	5	100	4	2	100	4	3	8	4	96	19	3	2	4	92	3	19	3
12	47	42	42	13	10	8	17	4	8	4	60	100	12	100	19	46	13	3	53	68	6	5	2	
13	32	44	57	95	99	100	100	6	4	20	4	3	2	92	98	8	8	43	5	25	3	3	2	
14		43	52	100	24	7	100	100	100	5	100	4	3	96	81	98	6	100	17	6	3	1	40	
15		40	69	100	66	10	3	100	22	59	100	19	75	100	5	99	7	99	4	2	2	2		
16		28	33	100	89	100	67	4	70	80	56	50	100	100	3	97	11	3	2	3	7	2		
17			50	16	6	100	100	100	100	3	6	15	37	19	7	20	1	5	2	58	2	2		
18			20	83	60	31	7	81	5	8	3	1	8	73	13	93	8	39	92	11	6			
19			77	18	12	40	99	7	5	24	5	2	2	99	13	1	34	10	3	93	2			
20			69	24	93	23	12	6	2	80	3	5	10	43	11	1	2	2	3	84	1			

* see planting scheme chapter 2.3.2

Table 37: Leaf litter production at Cienda

Leaf litter production Cienda subplots 2005 [gDM m^{-2}]

Subplot	Jan 29-Mar 08	Mar 08-Apr 14	Apr 14-Jun 01	Jun 01-Jun 28	Jun 28-Aug 01	Aug 01-Sep01	Sep 01-Oct 01	Oct 01-Nov 01	Nov 01-Dec 01	Dec 01-Jan 01
1	8.39	4.30	8.25	4.53	3.53	3.83	4.71	8.67	7.40	4.05
2	19.75	4.04	2.40	1.23	3.78	1.52	1.24	0.95	0.85	2.23
3	7.50	21.97	5.58	1.42	0.57	1.07	2.24	2.64	3.78	2.28
4	1.94	17.83	4.70	3.03	9.16	3.04	2.24	8.53	2.49	1.31
5	9.29	5.05	17.15	6.12	2.65	2.32	3.59	4.67	3.23	6.77
6	1.08	0.91	1.47	0.81	0.15	0.31	0.27	0.62	0.35	0.48
7	0.46	0.02	0.04	0.03	0.63	3.68	0.40	0.07	0.01	3.90
8	16.75	3.77	1.69	0.89	2.09	1.53	2.42	1.89	1.25	2.16
9	0.21	0.07	8.74	0.02	0.11	0.01	0.93	0.04	0.00	1.63
10	23.12	1.95	2.59	0.64	2.67	1.47	2.29	1.68	0.90	0.72

Table 38: Leaf litter decomposition at Cienda

Litter decomposition Cienda subplots [% mass loss]

Subplot	1		2		Slope		11	
Mesh [mm]	0.1	4	0.1	4	0.1	4	0.1	4
Replicates	48.0	55.1	49.3	73.1	42.5	36.9	60.7	46.7
	54.8	43.8	47.7	78.3	35.4	37.1	46.1	54.1
	61.0	50.7	44.1	70.0	39.3	34.0	56.3	44.4
	66.1	50.8	53.3	88.7	34.1	40.7	45.1	41.5
	60.1	58.1	49.2	77.2	44.8	43.1	49.9	61.4
	53.1	53.3	53.5	78.9	38.7	31.7	42.2	63.1
	62.6	54.5	61.3	56.2	40.7	54.5	49.7	11.3
	55.8	54.5	60.1	57.1	35.4	45.9	52.1	43.3
	52.7	53.5	57.5	57.2	38.2	39.9	52.6	27.1
	57.6	51.2	53.3	56.7	35.1	36.0	50.5	65.8
	63.1	48.9	58.4	71.5	40.3	41.5	52.1	44.9
	45.5	57.9	58.3	78.5	42.5	39.4	55.7	54.3
	63.8	47.3	62.9	53.5	41.3	36.1	50.9	35.5
	57.1	97.8	58.8	64.2	39.1	40.7	55.5	59.3
	58.7	95.7	52.5	57.3	34.8	42.5	54.4	72.3
	65.5	64.1	57.2	55.5	40.5	34.3	50.0	56.1
	59.7	68.3	52.7	47.1	38.1	40.4	52.3	37.3
	60.2	95.9	54.9	56.1	39.0	68.8	55.8	72.1
Average	**58.1**	**61.2**	**54.7**	**65.4**	**38.9**	**41.3**	**51.8**	**49.5**
St.Dev.	5.7	17.2	5.0	11.7	3.0	8.6	4.4	15.8
Coeff.Var.	9.8	28.1	9.2	18.0	7.7	20.8	8.6	32.0

Subplot	3		6		8	
Mesh [mm]	0.1	4	0.1	4	0.1	4
Replicates	53.1	38.4	58.2	100.0	61.0	47.8
	55.3	53.8	67.7	82.2	56.3	54.4
	56.1	55.1	64.1	100.0	55.9	54.2
	55.1	51.1	50.5	83.3	57.9	45.9
	53.7	55.3	61.5	85.8	61.1	44.5
	47.8	50.6	57.6	72.5	45.5	55.4
	54.3	45.6	65.7	62.6	51.3	50.7
	51.7	45.3	62.7	68.3	50.6	58.1
	48.7	46.9	58.0	65.1	53.5	53.6
	47.2	49.5	64.7	64.3	42.3	45.6
	58.5	55.1	63.4	62.7	55.6	56.8
	53.5	48.9	57.7	69.2	59.0	54.9
	49.4	39.0	67.3	65.6	40.0	52.5
	59.5	46.6	66.2	100.0	47.7	60.0
	54.5	19.7	67.1	89.3	63.5	62.8
	60.6	49.6	71.3	100.0	60.5	53.9
	58.2	57.1	71.3	100.0	62.3	47.6
	53.1	53.1	66.6	42.9	60.5	48.1
	55.4	64.0	61.3	81.3	47.5	46.4
	57.9	47.9	48.5	73.6	62.1	49.8
	58.3	56.5	63.1	65.8	58.4	60.3
	56.8	50.6	54.9	58.3	58.9	44.3
	59.5	45.9	63.4	72.7	43.5	42.1
	48.0	48.0	56.7	94.9	46.3	40.7
	58.5	56.1	64.1	62.8	53.7	43.8
	57.1	56.8	66.1	60.3	58.3	47.0
	45.6	56.5	58.8	46.2	50.8	48.0
	49.9	42.1	61.7	47.3	53.0	44.3
	47.7	54.5	60.7	49.7	50.4	53.3
	52.1	44.2	56.5	58.3	65.9	58.1
	58.3	53.3	65.1	85.7	53.2	51.5
	50.1	54.6	56.5	94.4	62.9	44.8
	52.6	63.1	60.9	100.0	50.5	49.7
	nd	43.2	57.2	87.2	50.3	53.3
	nd	42.7	65.5	69.8	45.5	52.8
	nd	nd	62.5	98.2	47.6	48.7
Average	**53.9**	**49.7**	**61.8**	**75.6**	**54.0**	**50.7**
St.Dev.	4.2	8.0	5.1	17.6	6.7	5.5
Coeff.Var.	7.8	16.2	8.3	23.2	12.5	10.9

Table 39: Correlations between environmental parameters, Cienda subplots

Pearson correlations	PAR	C_{org} LoI 0-5cm	C_{org} LoI 7-12cm	$C_{org\ EA}$	C_{mic} 32° C	C_{mic}/ C_{org}	BR 1d	BR 3d	BR 6d	BR 12d	BR 18d	BR 24d	BR 30d	qCO_2 24d	Soil resp.	pH	C_{LOM}	N_{LOM}	P_{LOM}	Root dec. 0.1mm	Root dec. 4mm	Leaf litter prod.	RWD 0-15 fine	RWD 0-15 thick	RWD 15-30 fine
C_{org} LoI 0-5cm	-0.366																								
C_{org} LoI 7-12cm	-0.290	.705*																							
$C_{org\ EA}$	-0.364	.960**	.875**																						
C_{mic} 32° C	-0.361	0.520	.650*	0.609																					
C_{mic}/C_{org}	-0.316	0.317	0.454	0.393	.967**																				
BR 1d	-.788**	.643*	.708*	.716*	.718*	0.601																			
BR 3d	-.831**	0.491	0.466	0.517	.632*	0.578	.799**																		
BR 6d	-.674*	0.545	0.579	0.596	.675*	0.585	.850**	.766**																	
BR 12d	-.816**	0.568	0.551	0.603	.651*	0.563	.932**	.861**	.896**																
BR 18d	-.702*	0.400	0.588	0.505	0.526	0.449	0.625	.833**	.654*	.681*															
BR 24d	-0.607	0.562	0.611	0.624	.760*	.686*	.767**	.844**	.760*	.861**	.805**														
BR 30d	-0.613	0.590	0.572	0.630	0.607	0.517	.668*	.817**	0.580	.748*	.831**	.944**													
qCO_2 24d	-0.068	-0.345	-0.271	-0.339	-.709*	-.726*	-0.302	-0.105	-0.243	-0.135	0.126	-0.124	0.037												
Soil respiration	-0.191	0.542	0.252	0.465	0.242	0.141	0.321	0.487	0.488	0.339	0.201	0.252	0.199	-0.246											
pH	0.292	-.777*	-0.139	-0.567	-0.446	-0.418	-0.472	-0.358	-0.349	-0.421	0.205	-0.166	-0.115	.817*	-0.557										
C_{LOM}	-0.424	.802**	0.613	.788**	.744*	.636*	.683*	0.551	0.439	0.514	0.350	0.502	0.502	-.701*	0.398	-.805*									
N_{LOM}	-0.480	0.616	.634*	.669*	.721*	.639*	0.564	0.628	0.528	0.452	.704*	0.544	0.545	-0.499	0.336	-0.442	.775**								
P_{LOM}	-.799**	0.376	0.455	0.433	.714*	.689*	.877**	.820**	.772**	.823**	0.568	0.613	0.476	-0.435	0.346	-0.508	.635*	0.607							
Root dec. 0.1mm	0.299	-.829**	-0.390	-.722*	-0.121	0.058	-0.409	-0.275	-0.148	-0.352	-0.138	-0.325	-0.481	0.039	-0.304	.977**	-0.609	-0.241	-0.096						
Root dec. 4mm	0.160	-0.494	-0.270	-0.442	-.648*	-.640*	-0.233	-0.479	-0.410	-0.349	-0.512	-0.619	-0.583	0.422	-0.319	0.420	-0.500	-.683*	-0.256	0.178					
Leaf litter prod.	-.960**	0.252	0.149	0.230	0.306	0.297	.717*	.713*	.645*	.793**	0.597	0.558	0.529	0.091	0.023	-0.240	0.299	0.347	.733*	-0.214	-0.142				
RWD 0-15, fine	-0.630	0.242	0.005	0.170	0.327	0.371	0.328	0.582	0.161	0.310	0.518	0.413	0.562	-0.109	0.016	-0.412	0.490	0.554	0.414	-0.299	-0.417	0.565			
RWD 0-15, th.	-0.556	0.050	-0.055	0.014	0.302	0.380	0.257	0.534	0.197	0.202	0.472	0.278	0.372	-0.149	0.106	-0.279	0.355	0.526	0.436	-0.005	-0.299	0.467	.911**		
RWD 15-30, fine	-0.389	-0.032	-0.031	-0.033	0.401	0.492	0.362	0.464	0.056	0.263	0.117	0.257	0.278	-0.355	0.058	-0.398	0.444	0.188	0.546	-0.061	0.003	0.302	0.609	.632*	
RWD 15-30, th.	-0.588	0.003	-0.065	-0.023	0.350	0.433	0.428	0.604	0.226	0.355	0.262	0.264	0.282	-0.275	0.232	-0.421	0.426	0.302	.662*	-0.030	-0.032	0.486	.705*	.788**	.928**

* = significant at α = 0.05

** = significant at α = 0.01

Table 40: Mann-Whitney tests abaca mean biomass per subplot. * Different at α = 0.05; ** different at α = 0.01

Inventory 240704

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
S1		0.006**	0.004**	0.267	0.287	0.000**	0.018*	0.108	0.068	0.000**
S2	0.006**		0.000**	0.002**	0.076	0.000**	0.000**	0.094	0.000**	0.853
S3	0.004**	0.000**		0.100	0.001**	0.156	0.965	0.000**	0.346	0.000**
S4	0.267	0.002**	0.100		0.055	0.008**	0.180	0.008**	0.539	0.000**
S5	0.287	0.076	0.001**	0.055		0.000**	0.002**	0.769	0.012*	0.033*
S6	0.000**	0.000**	0.156	0.008**	0.000**		0.237	0.000**	0.032*	0.000**
S7	0.018*	0.000**	0.965	0.180	0.002**	0.237		0.000**	0.410	0.000**
S8	0.108	0.094	0.000**	0.008**	0.769	0.000**	0.000**		0.001**	0.016*
S9	0.068	0.000**	0.346	0.539	0.012*	0.032*	0.410	0.001**		0.000**
S10	0.000**	0.853	0.000**	0.000**	0.033*	0.000**	0.000**	0.016*	0.000**	

Inventory 050505

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
S1		0.008**	0.569	0.813	0.135	0.090	0.842	0.000**	0.716	0.000**
S2	0.008**		0.019*	0.017*	0.151	0.000**	0.041*	0.488	0.008**	0.003**
S3	0.569	0.019*		0.779	0.311	0.021*	0.871	0.000**	0.406	0.000**
S4	0.813	0.017*	0.779		0.221	0.033*	0.921	0.000**	0.549	0.000**
S5	0.135	0.151	0.311	0.221		0.009**	0.342	0.010*	0.113	0.000**
S6	0.090	0.000**	0.021*	0.033*	0.009**		0.104	0.000**	0.291	0.000**
S7	0.842	0.041*	0.871	0.921	0.342	0.104		0.001**	0.568	0.000**
S8	0.000**	0.488	0.000**	0.000**	0.010*	0.000**	0.001**		0.000**	0.000**
S9	0.716	0.008**	0.406	0.549	0.113	0.291	0.568	0.000**		0.000**
S10	0.000**	0.003**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	

Inventory 040705

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
S1		0.334	0.121	0.023*	0.611	0.018*	0.465	0.000**	0.330	0.000**
S2	0.334		0.902	0.512	0.203	0.003**	0.738	0.054	0.090	0.000**
S3	0.121	0.902		0.431	0.061	0.001**	0.547	0.002**	0.018*	0.000**
S4	0.023*	0.512	0.431		0.012*	0.000**	0.218	0.025*	0.003**	0.000**
S5	0.611	0.203	0.061	0.012*		0.057	0.273	0.000**	0.644	0.000**
S6	0.018*	0.003**	0.001**	0.000**	0.057		0.005**	0.000**	0.126	0.000**
S7	0.465	0.738	0.547	0.218	0.273	0.005**		0.004**	0.125	0.000**
S8	0.000**	0.054	0.002**	0.025*	0.000**	0.000**	0.004**		0.000**	0.000**
S9	0.330	0.090	0.018*	0.003**	0.644	0.126	0.125	0.000**		0.000**
S10	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	

Inventory 300406

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
S1		0.374	0.103	0.167	0.438	0.010*	0.618	0.006**	0.029*	0.000**
S2	0.374		0.764	0.905	0.152	0.002**	0.237	0.260	0.006**	0.001**
S3	0.103	0.764		0.777	0.036*	0.001**	0.081	0.158	0.001**	0.000**
S4	0.167	0.905	0.777		0.057	0.001**	0.119	0.124	0.002**	0.000**
S5	0.438	0.152	0.036*	0.057		0.046*	0.814	0.003**	0.148	0.000**
S6	0.010*	0.002**	0.001**	0.001**	0.046*		0.033*	0.000**	0.340	0.000**
S7	0.618	0.237	0.081	0.119	0.814	0.033*		0.009**	0.107	0.000**
S8	0.006**	0.260	0.158	0.124	0.003**	0.000**	0.009**		0.000**	0.000**
S9	0.029*	0.006**	0.001**	0.002**	0.148	0.340	0.107	0.000**		0.000**
S10	0.000**	0.001**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	

Table 41: Leaf area equations for tree species

Species	Leaf area equation
Dipterocarpus validus	**$A = 0.7965\ l\ w - 0.0001\ (l\ w)^2$**
Shorea contorta	**$A = 0.6458\ l\ w + 0.0018\ (l\ w)^2$**
Shorea palosapis	**$A = 0.69\ l\ w + 0.0002\ (l\ w)^2$**
Toona calantas	**$A = 0.45\ l\ w$**
Durio zibethinus	**$A = -0.0357 + 0.735\ l\ w$**
Garcinia mangostana	**$A = 0.616\ l\ w + 0.0004\ (l\ w)^2$**
Lansium domesticum	**$A = 13.84\ l\ w + 0.18\ (l\ w)^2$**
Artocarpus heterophyllus	**$A = 0.6894\ l\ w - 0.0006\ (l\ w)^2$**
Artocarpus odoratissimus	**$A = 0.6424\ l\ w$**
Gmelina arborea	**$A = 0.6745\ l\ w$**

Table 42: Wood density (0% water contents) and carbon contents of different plant tissues for planted tree species,* Gmelina *and abaca.

Tree Species	Wood density [g cm^{-3}]				Carbon contents [%]				
	Twig	Branch	Stem	Root	Leaf	Twig	Branch	Stem	Root
Dipterocarpus validus	0.50	0.58	0.65[103]	0.51	45.1	51.3	50.3	51.8	49.3
Shorea contorta	0.54	0.54	0.58	0.52	43.7	47.3	53.7	58.8	50.3
Shorea palosapis	0.43	0.49	0.43	n.d.	51.2	nd	53.2	56.1	44.2
Toona calantas	0.45	0.51	n.d.	0.54	45.1	47.8	51.3	nd	45.3
Nephelium lappaceum	0.64	0.68	0.76	0.81	48.8	49.8	56.3	56.8	55.3
Durio zibethinus	0.43	0.52	n.d.	0.45	44.6	50.8	52.7	51.7	51.8
Garcinia mangostana	0.64	0.68	n.d.	n.d.	43.5	nd	nd	nd	nd
Lansium domesticum	0.68	0.70	0.70	0.70	41.8	50.3	51.7	52.3	47.8
Artocarpus heterophyllus	0.49	0.51	0.56	0.53	40.4	49.3	48.3	47.9	49.3
Artocarpus odoratissimus	0.44	0.52	0.53	0.43	36.2	47.8	49.8	53.8	53.8
Gmelina arborea			0.39	0.44	38.1	50.7	51.8	47.4	53.8
Musa textilis	-	-	-		41.5	-	-	46.0[104]	44.6
Cocos nucifera		-			45.1	48.3[105]	-	nd	55.8

Average C content of three composite undergrowth samples was 42.8%. Leaf C contents for *D. validus* are close to the 44.96%C analysed by GÖLTENBOTH (1998).

103Estimated on the basis of twig and branch density and PHILIPPINE COUNCIL FOR AGRICULTURE AND RESOURCES RESEARCH (1977): The Philippines recommends for Dipterocarps. I. Lumber. Los Banos.
104Pseudostem
105Stalk

Table 43: Total extractable polyphenolics (TEP) contents of fresh leaves and fine roots

	TEP [%]	
	Leaves	**Fine roots**
D. validus	6.65	8.46
S. contorta	9.75	13.1
S. palosapis	6.33	n.d.
T.calantas	9.24	n.d.
G. arborea	1.56	2.14
N. lappaceum	9.80	9.17
G. mangostana	5.07	n.d.
D. zibethinus	1.36	7.31
A. heterophyllus	3.70	n.d.
A. odoratissima	6.48	5.74
L. domesticum	3.20	4.14
M. textilis	1.09	2.51
C. nucifera	9.26	2.56

Table 44: Leaf weight ratio of planted species calculated as dry weight leaves per dry weight shoot

Leaf weight ratio	
D. validus	0.31
S. contorta	0.30
G. arborea	0.16
A. heterophyllus	0.28
A. odoratissima	0.43
N. lappaceum	0.30
L. domesticum	0.17
M. textilis 103cm	0.11
M. textilis 184cm	0.42
M. textilis 318cm	0.43

Table 45: Alternative version of the multiple regression expressing C, N und P_{LOM} as % of entire sample (see text for explanation).

Dependent variable	Equation	r^2	P
Biomass July 24th, 2004	$y = 2.4863$[106] $+ 5.6794N_{LOM} – 3.2352C_{mic}/C_{org}$	0.6696	0.0207
Biomass May 5th, 2005	$y = 385.1339 – 2.8542PAR + 37.9541N_{LOM} - 300.5528P_{LOM}$	0.8913	0.0027
Biomass July 4th, 2005	$y = 448.7870 – 3.4329PAR + 43.0689N_{LOM} - 362.5662P_{LOM}$	0.8860	0.0031
April 30th, 2006	$y = 1819.8258 – 13.6734PAR + 160.2172N_{LOM} - 1452.4589P_{LOM}$	0.8943	0.0025
Growth inventory 1 – 2	$y = 358.5835 – 2.6681PAR + 34.7497N_{LOM} - 286.5093P_{LOM}$	0.8997	0.0021
Growth inventory 2 – 3	$y = 66.8429 – 0.6700PAR + 2.6922C_{LOM} – 83.0886P_{LOM}$	0.8029	0.0155

106Intercept not significant at α = 0.05 (P = 0.62)

Table 46: Example of plant calibration in WaNuLCAS (for site PN3; see model runs on enclosed CD for model settings of more species and at other sites). Relevant values applied for tree calibration (Oil palm, rubber, N fixation and pest impact set zero; root type = 0)

Parameters	**Units**	***S. contorta***	***D. validus***	***G. arborea***	***D. zibethinus***	***A. heterophyllus***
Length of vegetative cycle	days	6205	4380	1460	2920	1460
Length of generative cycle	days	180	180	30	100	135
Earliest day to flower in a year	Julian day	90	90	60	150	30
Latest day to flower in a year	Julian day	150	150	120	180	360
Initial stage	[]	0.058824	0.04	0.05	0.125	0.25
Stage after pruning	[]	0.29411765	0.416667	0.25	0.625	0.25
Max. growth rate	kg m^{-2}	0.085	0.075	0.0356	0.0089	0.02
Fraction of growth reserve	[]	0.05	0.05	0.05	0.05	0.05
Leaf weight ratio	[]	0.6062	0.8573	0.4950	0.6641	0.7
Specific leaf area	m^2 kg^{-1}	18.9196	20.5217	17.3	10.6696	9.4423
Water requirement for dry matter production	l kg^{-1}	400	300	367.4235	300	212.1320
Fraction biomass allocatedn to fruit	[]	0	0	0.01	0.1	0.1
Max. canopy height above bare stem	m	15	12	15	18	25
Ratio between canopy width and height	[]	0.5	0.5	0.4	0.333	0.3
Max. canopy radius	m	7.5	6	6	6	7.5
Maximum leaf area index	[]	2.6667	4	2.6667	2.6667	4
Ratio leaf area index min. and max.	[]	1	1	0.5	1	0.9
Relative light intensity at which shading starts to affect tree growth	[]	0.35	0.3	0.1	0.2	0.15
Extinction light coefficient	[]	0.7826	0.7	0.4950	0.7342	0.8573
Rainfall water stored at leaf surface	mm	0.25	1	1	1	0.25
Coefficient related to tree root conductivity	cm day^{-1}	1.0E-05	1.0E-05	1.0E-05	1.0E-05	1.0E-05
Plant potential for max. transpiration	cm	-500	-1000	-500	-500	-1500
Plant potential for min. transpiration	cm	-20000	-30000	-3000	-1500	-4500
N concentration in carbohydrate reserves	g g^{-1}	0.22	0.22	0.11	0.22	0.33
N concentration in leaf component	g g^{-1}	0.03125	0.025	0.0125	0.0275	0.0375
N concentration in twig component	g g^{-1}	0.015	0.015	0.0075	0.015	0.0225
N concentration in wood component	g g^{-1}	0.01	0.01	0.005	0.01	0.015
N concentration in fruit component	g g^{-1}	0.0075	0.015	0.015	0.0225	0.0225
N concentration in root component	g g^{-1}	0.01	0.01	0.01	0.01	0.01
P concentration in carbohydrate reserves	g g^{-1}	0.022	0.022	0.011	0.022	0.0495
P concentration in leaf component	g g^{-1}	0.003125	0.0025	0.00125	0.00275	0.005625
P concentration in twig component	g g^{-1}	0.0015	0.0015	0.00075	0.0015	0.003375
P concentration in wood component	g g^{-1}	0.001	0.001	0.0005	0.001	0.00225
P concentration in fruit component	g g^{-1}	0.00075	0.0015	0.0015	0.00225	0.003375
P concentration in root component	g g^{-1}	0.001	0.001	0.001	0.001	0.0015

Parameters	Units	*S. contorta*	*D. validus*	*G. arborea*	*D. zibethinus*	*A. heterophyllus*
Litterfall caused by drought	day-1	0.1	0.1	0.1	0.1	0.03
Treeshold value for litterfall due to drought	[]	0.9	0.7	0.5	0.7	0.9
Reducing factor for N of litterfall	[]	0.85	0.85	0.85	0.85	0.85
Reducing factor for P of litterfall	[]	0.85	0.85	0.85	0.85	0.85
Lignin fraction of litterfall	[]	0.2	0.2	0.05	0.1	0.1
Lignin fraction of pruned biomass	[]	0.4	0.4	0.1	0.4	0.4
Lignin fraction of root	[]	0.2	0.2	0.05	0.15	0.15
Polyphenol fraction of litterfall	[]	0.0975	0.0665	0.0156	0.05	0.0370
Polyphenol fraction of pruned biomass	[]	0.1310	0.0846	0.0214	0.0731	0.06
Polyphenol fraction of root	[]	0.1310	0.0846	0.0214	0.0731	0.06
Intercept for total biomass equation	kg	0.35850266	0.42032406	0.82304565	0.55986736	0.2534828
Power for total biomass equation	cm^{-1}	2.42852598	2.52702458	2.55602073	1.23504819	1.74094669
Intercept for branch biomass equation	kg	0.00137966	0.00045142	0.00191702	0.00186401	0.00204394
Power for branch biomass equation	cm^{-1}	3.99136449	5.32374294	3.83690076	2.97686043	3.19836794
Intercept for Leaf&twig biomass equation	kg	0.33659699	0.41555195	0.80775386	0.49947191	0.18450442
Power for Leaf&twig biomass equation	cm^{-1}	2.10980295	2.32935183	2.48643129	1.03320421	1.17975306
Intercept for litterfall equation	kg	0.00274465	0.00055548	0.17793489	-0.0036202	0.00232773
Power for litterfall equation	cm^{-1}	3.42852598	3.52702458	3.55602073	2.23504819	2.74094669
Wood density	kg m^{-3}	580	650	390	600	560
Root tip diameter	cm	0.05	0.05	0.1	0.1	0.1
Max. root length density in layer1-zone1	cm cm^{-3}	3	3	3	3	3
Max. root length density in layer1-zone2	cm cm^{-3}	2.2	2	2	1.5	2
Max. root length density in layer1-zone3	cm cm^{-3}	0.8	0.45	0.45	0.45	0.6
Max. root length density in layer1-zone4	cm cm^{-3}	0.4	0	0	0	0.4
Max. root length density in layer2-zone1	cm cm^{-3}	2.5	2.5	2.5	2.5	2.5
Max. root length density in layer2-zone2	cm cm^{-3}	1.833	1.667	1.667	1.25	1.667
Max. root length density in layer2-zone3	cm cm^{-3}	0.489	0.25	0.25	0.188	0.333
Max. root length density in layer2-zone4	cm cm^{-3}	0.333	0	0	0	0.222
Max. root length density in layer3-zone1	cm cm^{-3}	0.729	0.729	0.729	0.729	0.729
Max. root length density in layer3-zone2	cm cm^{-3}	0.534	0.486	0.486	0.364	0.486
Max. root length density in layer3-zone3	cm cm^{-3}	0.194	0.109	0.109	0.109	0.146
Max. root length density in layer3-zone4	cm cm^{-3}	0.097	0	0	0	0.097
Max. root length density in layer4-zone1	cm cm^{-3}	0.3	0.3	0.2	0.2	0.2
Max. root length density in layer4-zone2	cm cm^{-3}	0.22	0.2	0.133	0.1	0.133
Max. root length density in layer4-zone3	cm cm^{-3}	0.08	0.045	0.03	0.03	0.04
Max. root length density in layer4-zone4	cm cm^{-3}	0.04	0	0	0	0.027
Fraction of roots infected by mychorrhiza	[]	0.3	0.3	0.3	0.3	0.3

Parameters	Units	*S. contorta*	*D. validus*	*G. arborea*	*D. zibethinus*	*A. heterophyllus*
Reduction of constant P by root activity	mg cm^{-1}	0	0	0	0	0
Relative transfer rate for N pool	cm^{-2} day^{-1}	0	0	0	0	0
Relative transfer rate for P pool	cm^{-2} day^{-}	0	0	0	0	0
Max. fire temperature tree can tolerate	°C	75	75	75	75	75
Tree cover efficiency factor	[]	0.5	0.5	0.5	0.5	0.5
Stella inputs						
T_GroResInit		0.0008	0.00031	0.01	0.01	0.01
T_CanBiomInit		0.0001	0.0001	0.0005	0.0005	0.0005
T_WoodBiomInit		0.00013	0.00014	0.0005	0.0005	0.0005
T_HInit	cm	0.36	0.29	0.50	0.86	0.63

Curriculum vitae

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Place of birth	Stuttgart, Germany
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Professional experience

Jun 2006 - present	Research assistant (50%) at Institute of Plant Production and Agroecology in the Tropics / Subtropics, ReGrIn project, West Aceh / Hohenheim[107]
Sep 2002 - present	Associate partner of terra fusca GbR, engineering & consulting[108]
Oct 1999-Feb 2002	Development worker German Development Service (DED) in Pucallpa, Peru. Focus on agroforestry and organic agriculture, institutional development.
1993-1998	Free lance gardening, stage hand at concert and theatre venues
Nov 1994-May 1995	Internships at Weleda S.A., Buenos Aires and Villa Berna, Argentina, and on a smallholder farm in Mérida, Venezuela
1993-1995	Student research assistant (Wihi) at Institute of Plant Nutrition, Hohenheim
Sep1990 - Jun 1992	Apprenticeship landscape gardening incl. tree nursery, Ute Haag GmbH, Stuttgart-Sonnenberg

107 http://www.worldagroforestrycentre.org/sea/projects/regrin/
108 see www.terra-fusca.de for references

Education

Jan 2004 – present (submitted June 2007)	PhD thesis at Institute of Plant Production and Agroecology in the Tropics / Subtropics (Prof. Sauerborn): Soils and carbon sequestration under agroforestry systems in Leyte, Philippines
Higher education Oct 1992-Apr 1998	Studies of agrobiology at University of Hohenheim Major subjects: Soil Sciences, Plant Ecology, Ecotoxicology and Environmental Analytics, Microbiology, Agroecology in the Tropics/Subtropics Diploma thesis: Soils and land use in semi-arid Northeast Brazil (WAVES project)
School education 1979 -1988	Fanny Leicht-Gymnasium, Stuttgart. Specialised courses German, English, maths, history

Trainings and other

Oct-Dec 1999	Trainings in participatory methods and rural appraisal, project management and intercultural communication at DED
Aug 1988-Apr 1990	Civil service: Youth Centre Stuttgart-Vaihingen

Languages	German: Mother tongue English: Fluent Spanish: Fluent Portuguese: Working knowledge
Computer skills	Standard office packages under Microsoft and Linux. Graphics: Photoshop. Statistics: SPSS, Sigma, SAS, Minitab. Modelling: WaNuLCAS, FALLOW, PCRaster

Carsten Marohn
Stuttgart, June 2007

Erklärung

Hiermit erkläre ich, die vorliegende Dissertation selbständig angefertigt, nur die angegebenen Hilfsmittel benutzt sowie wörtlich oder inhaltlich aus anderen Quellen übernommene Stellen als solche gekennzeichnet zu haben.

Carsten Marohn Stuttgart, im Juni 2007