CO_2-Mitigation Through Agroforestry Systems

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Abstract: *Agroforestry is a very important option to enhance carbon storage in biomass and soil. Earlier studies in Costa Rica have shown that the amount of carbon stored in tree biomass usually ranges from 3 to 25 t/ha, in some cases up to 60 t/ha. Carbon in soil organic matter may increase by 10 to 60 t/ha if former pure agricultural or waste land is converted agroforestry. In addition, even much higher* CO_2*-mitigation effects may be achieved by*

- *protection of existing forests*
- *reduction of fertilizer and pesticide input*
- *reduction of fossil fuel consumption due to the use of timber or non timber forest products instead of more energy intensive raw materials and*
- *replacement of fossil fuels by biomass.*

Examples are being given on how energy projects like rural electrification can be used to create a market for additional woody biomass from agroforestry plantations. In addition funding for such projects could be made available by "selling" them as climate change mitigation projects.

Worldwide, Houghton et al. (1991) estimated agricultural areas with potential for agroforestry at 356 – 499 Mha. A considerable proportion of this area can be located in India, for sure. The combinations of agricultural land use systems with trees are well known for their potential benefits such as

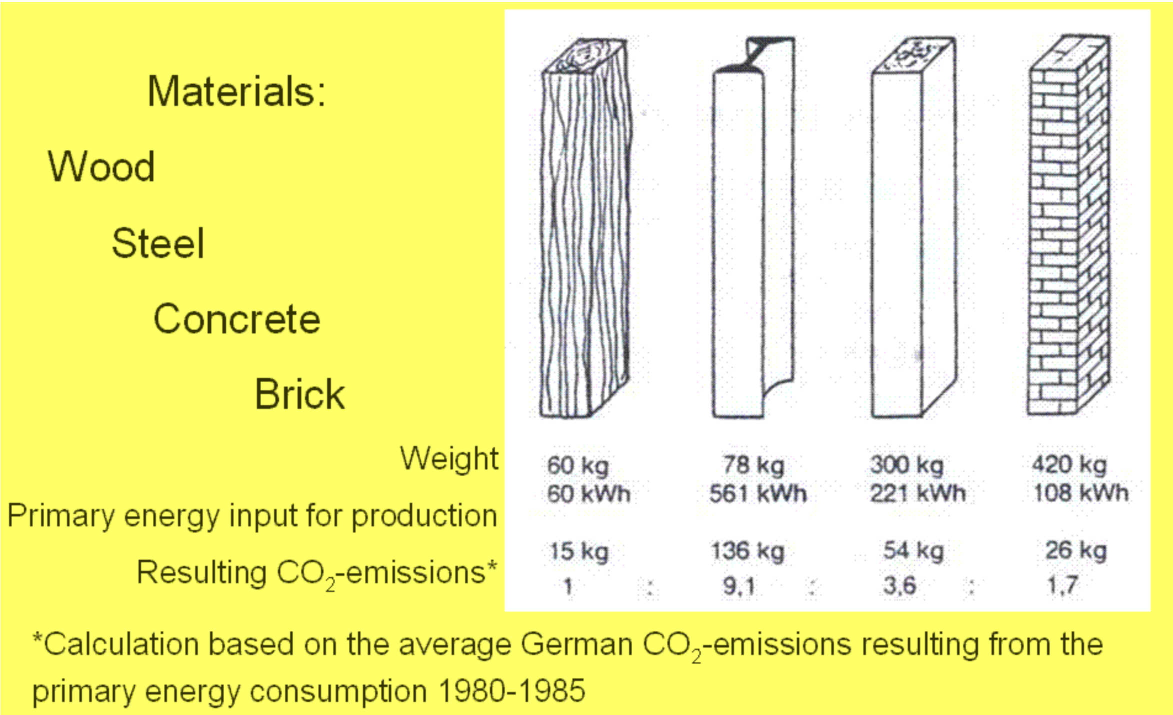
- helping to attain food security
- secure land tenure
- increasing farm income
- restoring and maintaining above-ground and below-ground biodiversity
- acting as corridors between protected forests
- maintaining watershed hydrology.

Partly due to these effects, agroforestry is also a very important option to mitigate climate change by enhancing carbon storage in biomass and soil. Earlier studies in Costa Rica have shown that the amount of carbon stored in tree biomass usually ranges from 3 to 25 t/ha, in some cases up to 60 t/ha (Kürsten, Burschel 1993). More recent studies (Albrecht, Kandji 2003) give even higher number like 12 – 228 (median: 95) t C / ha or 4 – 250 t C / ha (fruit trees – forest plantations after 30 years) (Hooda et al. 2007). The values strongly depend of the kind of agroforestry system and on the accuracy of biomass measurements. The latter are especially difficult for root biomass.

Kürsten and Burschel (1993) pointed out that in addition to the carbon storage in biomass, soil and wood products (if applicable), also some other effect have to be taken into consideration. The most important one in some cases can be the protection of nearby forest stands due to the sustainability of the agroforestry system which makes new forest clearance unnecessary (= avoided deforestation). Depending on the biomass of these stands this might result in avoided CO_2-emssions of up to 1000 t/ha.

Further CO_2-emssions can be avoided by the substitution of fossil fuels by bio fuels produced in a sustainable way with a more or less closed carbon-circle. A lesser known option to reduce CO_2-emissions is the substitution of (mainly building) materials with a high energy input in the manufacturing process by wood. This shall be explained in more detail here:

As a simple example, Burschel and Kürsten (1992) had calculated the CO_2-emissions resulting from the production of different pillars of 3 m length designed for the same load of 20 kN based on the energy consumption for their manufacture. Picture 1 clearly demonstrates the advantages of wood, especially if compared to steel: The energy needed to produce a pillar that carries the same load is nine times higher for steel than for wood. Energy consumption usually is associated with emissions of CO_2 and other negative environmental impacts (maybe coal mining, SO_2-emissions, cooling water consumption etc.). That means if you chose a material with a lower energy input (= embodied energy) at the same time you reduce environmental problems resulting from entire production process.



Picture 1: Comparison of different pillars of 3 m length designed for the same load of 20 kN

These ideas can also be applied to bamboo. In a recent study in India Vengela et al. (2007) have successfully tested trusses for school houses or industrial buildings made from bamboo (14´- 18´ long) according to British standards (as Indian standards are lacking). The bamboo trusses were 50% less expensive than comparable steel trusses. In terms of embodied energy bamboo girders might be even better than sawn timber. Bamboo also offers many other possibilities to substitute other raw material: Recently a corrugated roofing board was presented at the Indiawood fair, which could be a substitute for corrugated metal sheet. Other DUROSAM®-products offer further applications in the furniture, construction and building sector and they are even said to be "better than wood" (AB Composites 2008).

Another option might be girders from laminated veneer lumber (LVL). In India, there are many factories converting logs from small poplar and eucalyptus plantations and agroforestry systems into veneer to make plywood from it. The veneer sheets could be used for the production of LVL-girders with a very high strength, while the weight is less than half of the respective steel girders. Having these possibilities of "material substitution" in mind, one can argue that an Eucalyptus plantation should not be compared with a natural forest but with an ore mine from an ecological point of view. The environmental impact of production and processing of wooden building products is generally much smaller than in case of using metal or plastic. This has been proven in many studies in Germany, in the US and in other states.

For India such studies have not yet been performed, but the results most probably will be not that much different.

A last and mostly least important CO_2-mitigation effect of agroforestry systems is the reduction of the need for agrochemical inputs. Firstly the application of (energy intensive) fertilisers can be reduced because the tree roots are capable of recycling nutrient from lower soil horizons to the mulch layer and by this reducing the losses. Secondly even spraying of pesticides might be reduced due to a higher ecological self regulation of the mixed agroforestry systems.

Kürsten and Burschel (1993) summarized all these CO_2-mitigation effect of agroforestry systems in the following table:

Accumulation and Conservation of Carbon Stores	
Trees in Agroforestry Systems	3... 60
Wooden Products	1... 100
Soil Organic Matter	10... 50
Protection of Existing Forests	0...1000
Sum	***(14...1210)***
Reduction of CO_2-Emissions within 50 Yrs	
Energy-Substitution	5... 360
Material-Substitution	0... 100
Reduction of Fertilizer-Input	1... 5
Sum	***(6...465)***
Total	**20...1675**

In spite of all these obvious potential advantages of forestry and agroforestry projects in terms of ecology and CO_2-mitigation they are not really accepted within the framework of the “Clean Development Mechanism” (CDM) under the Kyoto protocol. Main reasons for this are the problems to measure and calculate the carbon flows and to estimate potential “leakages” of the projects. But, as it became obvious on the “Carbon Expo” in May 2007, the acceptance of forestry projects is increasing, especially on the voluntary carbon market. There the positive ecological and socio-economical side effects of such projects make them especially attractive for companies who focus on advertising by funding such projects (Kürsten 2007). So there actually are really good chances to get funding for well managed projects which do not only mitigate climate change but also improve the livelihood of rural villages by planting and using woody plants.

The CO_2-mitigation effect of an agroforestry project might more easily to be calculated and convincing if the tree planting activities are combined with a project for rural electrification. The other way round: To create a financial incentive for tree planting, it could make sense to develop an energy project based on woody biomass.

One starting point for such a project could be the fact that until 2012 all households in India shall have access to electricity. To facilitate this even in remote villages the Ministry of New and Renewable Energy (for details see: http://mnes.nic.in/) is running two programmes: Remote Village Electrification (RVE) Programme since FY 2001-02 and an Outline Plan on Village Energy Security (F. No. 72/8/2004-VESP). If the nearest power line will be at least 5 km from the village, the electrification by means of small hydro power, biomass (gasification or plant oil) or even photovoltaic will be mainly funded by the Government of India. If a village (or a factory!) normally would be connected to the grid, the avoided CO_2-emissions from the "normal" power generation by hard coal can be avoided due to a local biomass based supply. Kumar and Kandpal (2007) give the basic parameters:

- Efficiency of coal based power plants in India: 35%
- Carbon emission factor of coal: 0.0258 kg/MJ
- Calorific value of coal: 20.50 MJ/kg
- Processing energy requirement of coal: 0.07%
- Fraction of carbon oxidized during coal combustion: 92%
- Transmission and distribution loss of electricity in India: 23.2%

A locally managed electricity supply may also result in a higher reliability as it would not suffer from power cuts in the grid.

If such a project should become an "official" CDM-project one has to consider the following aspects (for details see: http://cdm.unfccc.int/):

- Additionality: This would be no problem, if the agroforestry + biomass based electricity is more expensive than grid connection.
- Leakage: Firstly, if the coal based electricity is not used in project area it will be most probably used elsewhere, as total electricity generation in India is always to low. Of course, this is an argument which hardly can be disproved. So it would be more convincing if the use of biomass would replace an existing diesel supply for the engine. This is anyway about 30% more effective in terms of CO_2-mitigion, as compared to substitution of electricity from coal fired power plants. (Kumar and Kandpal 2007, Singal et al. 2007). Secondly, if biomass for electricity is taken not only from additional trees but from existing sources this will create additional pressure on other resources. This could be avoided by an additional programme for more efficient (gasification) stoves.

If such a project for one reason or the other would not be eligible for CDM it could be offered on the voluntary carbon market where good projects are urgently needed as well.

As a practical example a project in Ranidahra (Chhattisgarh) shall be mentioned ("The Hindu" 08.02.2008): There an electricity plant is powered by Jatropha oil. 600 villagers replace kerosene lamps with electrical light (+ street lights + TV). They have to pay 20 Rs per household monthly (30 Rs with TV). The power plant is owned and managed by villagers. They cultivate Jathropa on wasteland and field boundaries only.

Another idea to make more and efficient use of biomass from new agroforestry systems and thus to create a climate change mitigation project is cofiring of coal and biomass. Hereby a part of the coal in the power plant will be substituted by biomass. This is already being done in Europe and in the US. A recent study in India (Narayanan and Natarajan 2007) showed that a rate of 40:60% was the best to reduce SO_2, NO_x and dust.

To briefly summarize: In India, obviously there are many possibilities to create integrated projects for sustainable land use and energy supply. External funding could be made available for them by offering them as CO_2-mitigation projects on the emerging global carbon market. But, as Pandey (2002) states: There is need to support development of suitable policies, assisted by robust country-wide scientific studies aimed at better understanding the potential of agroforestry and ethnoforestry for climate change mitigation and human well-being.

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