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A SUSTAINABLE WOODY BIOMASS PRODUCTION SYSTEM FOR TROPICAL PEATLANDS

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SUMMARY

To develop a sustainable woody biomass production system for use in tropical peatlands, we have begun studies to evaluate the potential reduction in CO_2 emission that results from peat conservation, develop appropriate planting techniques, evaluate carbon sequestration as a result of reforestation, and develop a value-added system for the utilization of tropical peat swamp tree species. To do so, we used *Melaleuca cajuputi* Powell, an extremely flood-tolerant tree species, as the major target species. The preliminary outcomes have let us propose a sustainable woody biomass production system for tropical peatlands at a 200-ha scale.

KEY WORDS: tropical peatlands, reflooding, CO_2 emission, tree plantations, woody biomass utilization

INTRODUCTION

Peatlands that were formerly huge CO_2 sinks are now turning into huge sources of CO_2 in response to drainage of the land to support socioeconomic development and the resulting fires when the peat dries; more than half of this CO_2 emission is occurring in Southeast Asia (Joosten and Couwenberg, 2008). It is therefore important to find ways to develop peatlands without increasing the emission of greenhouse-effect gases. Tree plantations may be a good choice because they require relatively minor human inputs and provide a good source of income. However, the establishment of tree plantations in peatlands as a source of wood fibre can potentially increase CO_2 emissions. Because peat decomposition depends strongly on a site's water regime, and increases as a peatland dries, it can be reduced if we can establish a production system that is applicable under flooded conditions. *Melaleuca cajuputi* is a good choice for such a system because it is a native species that grows well under flooded conditions. To develop a feasible and sustainable biomass production system for tropical peatlands, we started a research project in 2008 at an experimental site in a developed peatland in Nakhon Si Thammarat, Thailand. The project comprises four research themes: (1) development of a CO_2 emission model and evaluation of the potential CO_2 emission reduction by peat conservation, (2) development of planting techniques for degraded peatlands and assessment of carbon sequestration, (3) development of a comprehensive utilization technology for woody biomass, and (4) design of a sustainable woody biomass production project under flooded conditions for use in tropical peatlands. In our presentation, we will outline the progress of our project to date and will discuss future tasks.

ESTABLISHMENT OF A CO_2 EMISSION MODEL AND EVALUATION OF THE POTENTIAL REDUCTION OF CO_2 EMISSION BY PEAT CONSERVATION

By monitoring CO_2 emission in the field and the response to changes in environmental conditions using laboratory soil column experiments, we will develop a prediction model for CO_2 emission and use it to evaluate the potential reduction in CO_2 emission that results from peat conservation.

CO_2 emission from tropical peat soils under fluctuating water regimes

The water level in developed tropical peatlands often fluctuates widely because of the loose water management. Because the belief that CO_2 emission increases as the water level decreases is based on discontinuous field measurements under a range of water level conditions, the response of CO_2 emission from peat soils to fluctuating water levels is not yet fully understood. To better understand CO_2 emission under fluctuating water levels and use this knowledge to establish a model for prediction of CO_2 emission from peat soils, we established a long-term automated monitoring system (Fig. 1) for CO_2 emission in an oil palm field in Nakhon Si Thammarat, Thailand. CO_2 emission was measured using the closed-chamber method.

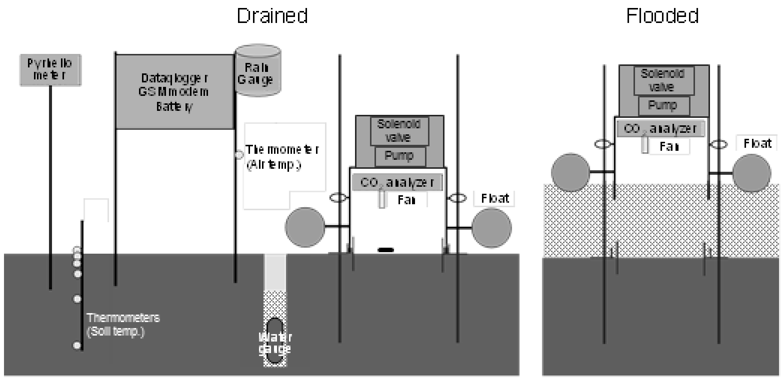

Figure 1. Schematic diagram of the automated monitoring of CO_2 emission from tropical peat soils. Left: drained conditions. Right: flooded conditions.

CO_2 emission fluctuated diurnally in response to temperature fluctuations. The temperature dependency of CO_2 emission differed among the water level conditions. CO_2 emission was small under flooded conditions and increased as the water level decreased. CO_2 emission was suppressed under extremely dry conditions; however, these conditions greatly increase the risk of peatland fires, which would release large quantities of CO_2.

Establishment of a soil column study system to measure the responses of CO_2 emission to temperature and water level changes

We developed a soil column system to analyze the responses of CO_2 emission to changes in water level following the temperature-profile dynamics observed in the field (Fig. 2). CO_2 emission was measured using the open-chamber method. The response of CO_2 emission to changes in the water level was similar under variable and constant temperature conditions, suggesting that the average value can be used as a temperature parameter in the prediction model. We will examine whether CO_2 emission is suppressed under the extremely dry conditions that are sometimes observed in the field. In addition to the soil column experiments, we will examine the variability of potential CO_2 emission rates from a range of sites with thin peat soils, where diffusive resistance is not the limiting factor for CO_2 emission. Combined with the outcomes of long-term monitoring in the field, these data will help us develop an improved model for the prediction of CO_2 emission under fluctuating water conditions.

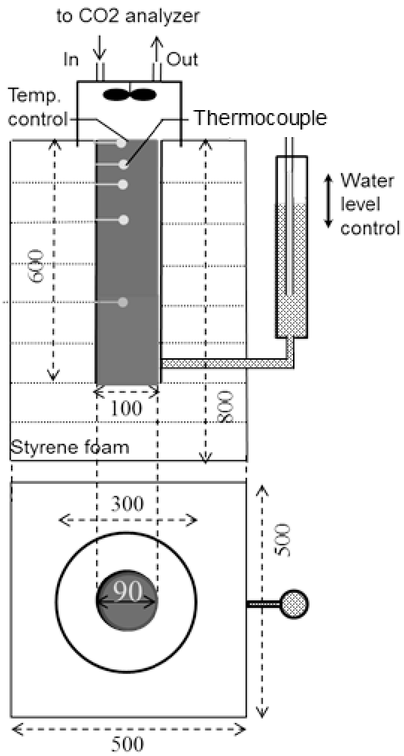

Figure 2. Design of the soil column experiment system. All dimensions are in mm.

DEVELOPMENT OF PLANTING TECHNIQUES FOR DEGRADED PEATLANDS AND ASSESSMENT OF CARBON SEQUESTRATION

We will develop planting techniques suitable for use under flooded conditions. Based on data from previously established plantations, we will develop prediction equations to estimate the woody biomass production of *Melaleuca cajuputi* grown in tropical peatlands.

Development of nursery techniques for plantation establishment in peat swamps

There has been little research to develop standard techniques for the production of seedlings for use in tropical peat swamp plantations. Seedling nursery conditions will be a crucial factor in plantation success because these conditions will determine the seedling traits, and these traits will greatly affect seedling performance after planting.

Flood pretreatment to harden the seedlings

The effectiveness of flood pretreatment was examined by raising seedlings under flooded conditions for several months before planting using ten species that are potentially suitable for peatland plantations. Some of the species showed better post-planting survival after this pretreatment. Because there were no negative effects and the seedlings were easy to handle, this pretreatment may become a standard technique for the production of seedlings for planting in peat swamps.

Production of M. cajuputi *seedlings for planting in peat swamps*

Wild seedlings that were nursed for several months have been used to establish *M. cajuputi* plantations in peat swamps, but the success rate in the nursery has been low. To improve the production *of M. cajuputi* seedlings, we established a system for seedling production from seeds by sowing the seeds directly in pots that are kept in a flooded bed (Fig. 3). The larger seedlings produced by this method showed better post-planting survival, probably because the taller seedlings were submerged for a shorter period during the rainy season, when the water depth reaches 1 m.

Figure 3. The production system for *Melaleuca cajuputi* seedlings. Seedlings were grown under flooded conditions.

Estimation of CO_2 sequestration by peat swamp forests

To determine whether it is acceptable to convert developed peatlands into forests, it's necessary to develop a reliable method for the estimation of biomass growth and CO_2 sequestration by these forests. This provides an indication of the potential environmental impact of this form of management and an indication of whether this management will be sustainable. We evaluated biomass production in a 15-year-old *M. cajuputi* plantation forest (3072 trees ha^{-1}) established in a swamp area where the surface peat has decomposed and the underlying acid-sulfate soil is exposed.

Estimation of stand biomass of M. cajuputi

Stand biomass and its increment were estimated based on the size of all trees in the stand and allometric equations for the relationship between tree size and mass obtained from sample trees. Above- and below-ground biomass were estimated to be 134 and 35 Mg ha^{-1}, respectively. Debarked stem biomass and bark biomass were estimated to be 101 and 12 Mg ha^{-1}, respectively.

Estimation of the net primary production of M. cajuputi *forest*

Based on the stand biomass, the biomass and the net primary production (NPP) of fine roots, the mass of litter, and the decomposition rate of leaves and fine roots, we estimated the stand NPP for 15 years as 324 Mg ha^{-1}. Assuming a 50% carbon content in the biomass, the amount of CO_2 fixed and sequestered in the forest during the 15 years was 108 Mg C ha^{-1}, which represents a rate of 7.2 Mg C ha^{-1} $year^{-1}$, which indicates a moderately high ability to fix CO_2 even under these adverse soil conditions.

DEVELOPMENT OF COMPREHENSIVE UTILIZATION TECHNOLOGY FOR WOODY BIOMASS

Our project will also develop technology for full utilization of the above-ground biomass of *M. cajuputi*. Wood from other peat swamp tree species will also be examined.

Utilization of biomass from *M. cajuputi* plantations

We calculated the number of logs and the log volume per hectare for each top-end diameter class in a 15-year-old *M. cajuputi* plantation based on the measured tree size distribution and a stem-taper equation. The oven-dried biomass of logs and bark were estimated to be 92.3 and 10.2 Mg ha^{-1}, respectively; 95.4% of the logs were small (less than 14.5 cm in top-end diameter) and were therefore unsuitable for use in plywood production. *Melaleuca cajuputi* wood has moderate to high density (0.63 g cm^{-3}), and good surface hardness and painting properties. Thus, logs larger than 8.5 cm in diameter can be used to produce laminated board for use in flooring and furniture. Logs smaller than 8.5 cm or larger than 14 cm in diameter can be used to produce particle board and plywood, respectively.

Production of wood-based panels using *M. cajuputi* wood

Wood-based panels were manufactured from *M. cajuputi* wood (Fig. 4). The lathe veneer and lamina had good cutting performance, but showed warping and cracking under the conventional drying process. The drying performance was improved by pre-pressing the wood to reduce surface shrinkage. The modulus of elasticity values of the plywood, laminated board, and particle board were 9.6, 10.8, and 1.7 GPa, and the modulus of rupture values were 98, 163, and 18 MPa, respectively. These mechanical properties are comparable to those of other widely used hardwood products available in the study area.

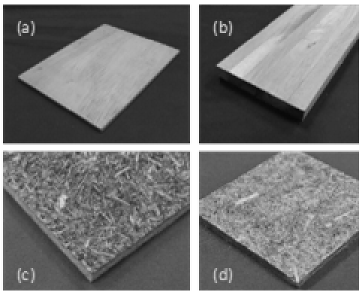

Figure 4. Wood materials made from *Melaleuca cajuputi* biomass: (a) plywood, 6 mm thick, using aqueous polymer-isocyanate (API) adhesive;(b) laminated board, 20 mm thick, using API; (c) particle board, 10 mm thick, using citric acid adhesive; (d) bark board.

Advanced utilization of woody biomass of peat swamp tree species

We evaluated the mechanical properties, chemical composition, and decay resistance of the following peat swamp species to determine their potential as plantation species: *Vatica pauciflora*, *Alstonia spathulata*, *Syzygium kunstleri*, *Syzygium longiflorum*, *Syzygium oblatum*, *Syzygium polyanthum*, *Ploiarium alternifolium*, *Campnosperma coriaceum*, and *Fagraea fragrans*. The wood of *A. spathulata* has a density of 0.18 g cm^{-3} and is suitable for use as a shock absorber or heat insulator. *Syzygium kunstleri* and *P. alternifolium* have a density of 0.9 g cm^{-3} or more and are suitable for use in fine furniture and musical instruments. *Vatica pauciflora*, *S. kunstleri*, and *F. fragrans* have rich extract for exterior use.

Melaleuca cajuputi has a high terpene content in its leaves, which provides significant antimicrobial properties, and its paper-like thick bark has properties that also make it a valuable biomass resource. We developed a method to control the volatilization rate of the leaf essential oils in antimicrobial applications. The bark had good compatibility with thermoplastic resins because of its rich hydrophobic content. We developed a bark board (Fig. 4d) and found that it was more durable than wood-plastic board made from wood wastes.

DESIGN OF A SUSTAINABLE WOODY BIOMASS PRODUCTION SYSTEM FOR TROPICAL PEATLANDS

By examining CO_2 emission and costs based on the abovementioned preliminary outcomes, we have proposed a woody biomass production system that appears to be suitable for use in tropical peatlands.

CO_2 emission and cost of woody biomass production

We estimated the CO_2 emission and costs of a 200-ha woody biomass production plantation in tropical peatlands based on an estimate of 20 Mg C ha^{-1} $year^{-1}$ of potential CO_2 emission from drained peatlands. We found that reflooding the peatland and establishment of an *M. cajuputi* plantation would potentially decrease CO_2 emission by about 21 Mg C ha^{-1} $year^{-1}$ compared with an oil palm plantation (Fig. 5) and that this saving is much larger than the CO_2 emission caused by plantation establishment. Our preliminary results also suggest that the cost to reduce CO_2 emission using this approach is acceptable. Increasing the resource allocation to the production of laminated board, which produces lower CO_2 emission than the production of particle board, could further reduce CO_2 emission by this production system.

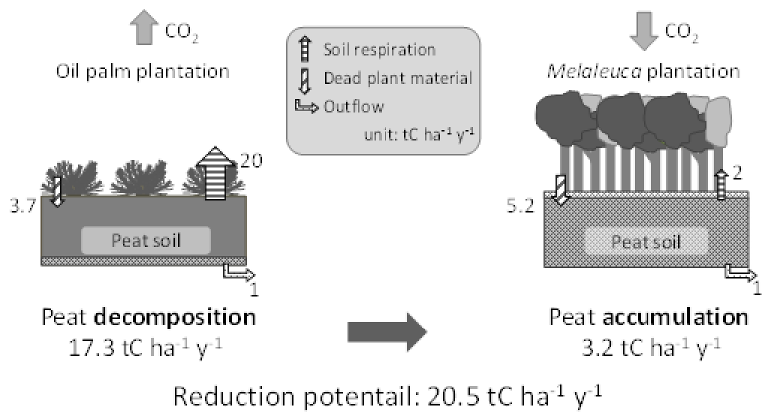

Figure 5. CO_2 emission reduction potential of the *Melaleuca cajuputi* plantation in tropical peatlands.

Effects of reflooding on methane emission

Reflooding of drained tropical peatlands could increase methane emission under anaerobic soil conditions. Because some plants are known to convey methane from the soil into the atmosphere, *M. cajuputi* could potentially increase methane emission if this species is planted after reflooding. We therefore evaluated the methane efflux from the soil surface, from a submerged surface, and from the stem surface of *M. cajuputi* trees using the closed-chamber method.

Methane emissions from the submerged surface were less than 0.2 Mg C ha^{-1} $year^{-1}$, which is similar to or lower than the emission under drained conditions. The enhancement of methane emission by reflooding is therefore unlikely to negate the potential CO_2 emission reduction effects of reflooding. Methane efflux from the stem surface of *M. cajuputi* trees was detected, but at sufficiently low levels that it seems likely to have little impact on the overall emission reduction permitted by reflooding.

CONCLUSIONS

Our preliminary results have demonstrated that the production of woody biomass under flooded conditions is a potentially interesting option for the sustainable utilization of tropical peatlands. Further studies will be carried out to refine our preliminary estimates and develop a production system suitable for use at a practical scale.

REFERENCES

Joosten, H. and Couwenberg, J. (2008). Peatlands and carbon. In F. Parish *et al*. (eds.), *Assessment on peatlands, biodiversity and climate change: Main report*. pp. 99-117. Global Environment Centre, Kuala Lumpur, and Wetlands International, Wageningen.