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Scientific cooperation to fight international challenges – Short rotation coppice development for the provision of firewood and hydrothermal carbonization of water hyacinth for hydrochar production in Myanmar

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Introduction

Due to a still growing need for firewood and construction timber, the pressure for utilization on Myanmars remaining natural forests is steadily increasing. Furthermore, water hyacinth (*Eichhornia crassipes*), one of the most invasive species worldwide, is becoming more and more of a challenge in valuable ecosystems of Myanmar like the Inle-Lake.

The overarching goal of this project therefore is, to build international networks and cooperation that specifically address these challenges, by linking scientists and young researchers of both countries, active in the field of short rotation coppice (for an utilization as firewood to decrease pressure on natural forests) and hydrothermal carbonization (as one possible way to gain positive value from fighting water hyacinth, i.e. production of hydrochar for combustion and/or fertilizer for short rotation coppice plantations from the process water).

Short Rotation Coppice (SRC) in Myanmar

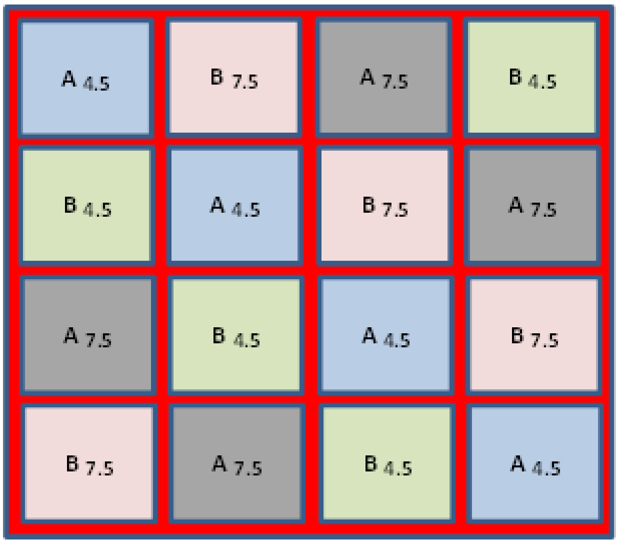
Together with the Forest Research Institute in Yezin, Myanmar, a short rotation coppice plantation for firewood was established on fallow land in the Saiya Reserved Forest, Yetarshay Township, Taunggoo District to gain experience on suitability, growth and yield of native fast growing tree species. Plantation establishment was carried out in August 2016, in cooperation with staff from the local Forest Department.

The following variants were established in the SRC plantation site in Saiya Reserved Forest and will be analyzed in the following years (table 1):

Tab. 1: Variations of Plantation Design

Species Name	Local Name	Rotation Period	Spacing	No. of trees	Abbrev.
Senna siamea	Mezali	4 years (Fuelwood)	4.5 ft x 4.5 ft	121	A 4.5
Senna siamea	Mezali	4 years (Fuelwood)	7.5 ft x 7.5 ft	49	A 7.5
Samanea saman	Thinbaw - Kokko	4 years (Fuelwood)	4.5 ft x 4.5 ft	121	B 4.5
Samanea saman	Thinbaw - Kokko	4 years (Fuelwood)	7.5 ft x 7.5 ft	49	B 7.5

Each variant has 4 replications. The size of the plot for each variant is 2,025 sq ft (188 sq m) and the distance between the plots is 7.5 ft (2.3 m). As two different spacings were adopted, the total number of trees in the plot with a spacing of 4.5 ft is 121 trees (11 x 11 trees) while the number of trees in the plot with a spacing of 7.5 ft is 49 trees (7 x 7 trees) respectively. The total area of the plantation is 0.44 ha including buffer stripes of 2.4 m in width around the site. The layout of the plantation is shown in figure 2.



A = *Senna siamea*,
B = *Samanea saman*,
4.5 = spacing of 4.5 ft between trees,
7.5 = spacing of 7.5 ft between trees

Fig. 2: Layout of the demonstration site

Before planting, the area was clear-felled. Only a few individuals of economically important trees species like *Xylia xylocarpa* (Myanmar name: Pyinkado), *Pterocarpus macrocarpus* (Myanmar name: Padauk) were left on the site. Soil samples were collected and the physical and chemical properties were analyzed at the Soil Lab of the Forest Research Institute in Myanmar.
Soil condition on the site was generally found to be sandy soil with a soil pH of 5.34 to 7.16. Nutrient contents such as nitrogen and phosphorus were very low and soil organic matter was medium for plant growth (table 2).

Tab. 2: Soil conditions of Saiya Reserved Forest, Yetarshay Township, Taungoo District

Soil depth	pH	Total N %	Ava. P %	OM %	Texture		
					Sand %	Silt %	Clay %
0-10 cm	5.40 – 6.89	0.013 – 0.01	0.00004 – 0.00022	1.56 – 6.35	51 – 91	2 – 27	3 – 33
40-50 cm	5.34 – 7.16	0.011 – 0.106	0.00005 – 0.00050	1.82 – 4.70	44 – 89	5 – 33	3 – 31
80-90 cm	5.35 – 6.69	0.013 – 0.107	0.00003 – 0.00024	2.60 – 7.19	37 – 91	2 – 42	3 – 36

For the establishment of the plantation, common Myanmar tree species were used: on the one hand *Samanea saman* (Jacq.) Merr. (Myanmar name: Thinbaw-kokko), a large deciduous tree that is used as a medicinal plant in Myanmar. It grows well naturally along the roadsides as a shade tree in various parts of Myanmar. On the other hand, *Senna siamea* (Lam.) (Myanmar name: Mezali) was planted, a medium-sized tree providing edible leaves and flower-buds. It grows wild and also is planted in warmer parts of Myanmar.

After planting, surviving individuals will be counted and heights and diameter at breast height (dbh) of these individuals will be measured. These measurements will be repeated every six months in order to assess growth performance of species in dependency of the different spacings.

The continuous monitoring of such plantations will be implemented using UAV observation platforms and methods of airborne photogrammetry and photogrammetric point-clouds to quantify the above ground biomass on regular annual repetition to detect change over time.

Water hyacinth for Hydrothermal Carbonization

In addition to the short rotation coppice plantations, a large sample of water hyacinth was harvested and transported to Germany, to do basic tests on its suitability for hydrothermal carbonization in a lab scale, as well as in larger technical scale.

For this study, large quantities of water hyacinth were needed. Around 500 kg of fresh plants were collected from various points in the Inle-Lake. These plants were sundried for 5 days, raking them regularly to ensure a thorough removal of the moisture, allowing for easier transportation and better tolerance to storage.

Hydrothermal carbonization tests were conducted in the laboratories of the Eberswalde University for Sustainable Development, using a Büchiglas autoclave. Another test was performed in a large scale, in the facilities of the company AVA-CO2 in Karlsruhe, using 25 kg of dry biomass and a sulfuric acid solution in an unstirred batch reactor.

The products from this last test were analyzed: for the hydrochar, heating value, ash content and elemental composition were determined. For the process water, elemental analysis and dissolved organic carbon were determined.

As a result, it can be said that hydrothermal carbonization of the water hyacinth leads to an increase in the carbon content of the solid phase from 39.9 to 47.4 % (see table 3), as well as a decrease in oxygen content (hydrogen content remains similar throughout the process). This suggests that, while some degree of carbonization was achieved in the process, it was not complete, possibly due to the reaction conditions (short reaction times, heterogeneous conditions in the reactor, etc.).

Heating value still showed a marked increase after the process (30 % higher), similar to wood, which indicates this hydrochar has potential as a substitute for firewood. A comparison with the results obtained for the process water shows that while a majority of the carbon and nitrogen from the plants remains in the hydrochar, chlorine and sulfur are more evenly distributed in both phases. Still, the relatively high concentration of many elements and substances present in this process residual water suggests it could find a use as a liquid fertilizer.

Tab. 3: Main parameters of water hyacinth and hydrochar

Parameter	Water hyacinth	Hydrochar
Carbon (wt %)	39.9	47.4
Hydrogen (wt %)	4.47	4.59
Nitrogen (wt %)	1.11	1.48
Sulfur (wt %)	0.35	0.31
Oxygen (wt %)	31.1	26.1
Chlorine (wt %)	1.6	0.91
Ash (wt %)	21.5	19.2
HHV (MJ/kg)	14.43	18.64

In the coming months, further, much more detailed analysis will be done to improve reaction conditions of the hydrothermal carbonization and to therewith improve the properties of the final products for a later utilization as hydrochar and fertilizer.

Further activities

In order to monitor floating biomass and assess the abundance and quantify *Eichhornia crassipes* and similar floating macrophytes on the Inle Lake in Myanmar a multi-sensor approach combining different remote sensing classification methods and sensors (MODIS and Landsat 7-ETM) was successful in detecting temporal spatial patterns and sizes of floating biomass on the Inle lake (Mund; Murach & Parplies 2013).
A times series change detection based on Landsat imagery from 2000 to 2011 focusing on the spatial extent of sparse floating biomass on the Inle lake shows a range from 250 ha to 1,300 ha of floating biomass on the Inle Lake with large scale spatial variations with no significant trend over 10 years but a peak of more than 3,000 ha in 2002.

The spatial–temporal classification shows four peaks of floating biomass abundance in 2000, 2002, 2007-08 and 2011 with a high periodicity but no significant correlation to the variability of dense floating vegetation. The lack of intra-seasonal classification results limits the probability to identify any seasonal periodicity of water hyacinth abundance on the Inle Lake, yet.

The calculated average volume of dense floating vegetation on the Inle Lake has been estimated to an amount of approximately 18,000 t/DM/y (DM = dry matter). The calculated results of annual dry matter biomass based on empirical DM biomass quantifications from literature show a very high inter annual variability and a similar high seasonality which has not been subject of this study.

The results from the Inle Lake research area need to be further verified based on high to very high resolution imagery or other image segmentation and object identification classification methods due to adverse classifications effects of floating garden vegetation along the lake shores.

The quantified and harvestable biomass can be used further as a permanent source for bioenergy or a resource for chemical processes, such as hydrothermal carbonization, converting biomass into an alternative energy source (hydrochar) or into solid or liquid fertilizer

Conclusions and Outlook

Beyond BMBF funding, it is planned, to intensify the cooperation in additional joint research and development activities – a sound basis could already be laid in this first phase of the current project.

Further research and development regarding growth and yield of short rotation coppice shall be done, presumably with an extended scope, including especially agroforestry systems. Modified reaction conditions and their influence on the properties of the final products will be analyzed in additional lab tests in Eberswalde and Montevideo to further improve possibilities for an efficient utilization of water hyacinth in small- and medium scaled industrial processes.

Neighboring disciplines, especially GIS and remote sensing, e.g. for the monitoring of plantations or to estimate future expansion of water hyacinth shall be included more intensively.

References

Mund, J.-P., Murach, D. and A. Parplies (2014): Monitoring and Quantification of Floating Biomass on Tropical Water Bodies. In: Vogler, R., Car, A., Strobl, J. and Griesebner, G. (Eds.) (2014): GI_Forum 2014. Geospatial Innovation for Society.