Memo: Report on bus ticket[1] no. B1
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Typha for Bioenergy

Definition of the problem

Typha is a type of reed that covers large parts of the Senegal river. Two dams have been constructed limiting the natural fluctuations of the river and providing an opportunity for Typha to establish itself permanently along the shores. Because of the extensive Typha growth irrigation canals are blocked, the local population has difficulty accessing the river, fishing has become impossible, and health problems arise from still water. In the last few years possibilities have been evaluated to remove the Typha in order to utilise it for charcoal production. Mechanical removal of Typha is costly and is not a sustainable option unless the cost of removal can partly be recovered by selling (energy) products.

Questions

Describe the possibilities to set up production chains for solid biofuels from Typha for export. Discuss:

What is required in order to establish a sustainable and continuous production of solid biofuels?
Describe the harvesting system and calculate at what cost Typha can be harvested and delivered to the shore.
Describe the composition of Typha as is relevant for the conversion into biofuels
Compare local use of the biofuel to export of the biofuel
Evaluate Typha as a feedstock in two scenario's: - capex paid from aid funds – Capex has to be repaid from bio-fuel delivery.

1. Approach

First a description is made of the situation in the Senegal River basin and the role that Typha plays as a pest. Then the important aspects of a Typha to biomass energy production chain are discussed, from harvest to utilisation as a biofuel. A discussion of the most important issues is followed by conclusions and recommendations. Along the way the specific questions as described above are answered.

2. Description of Typha situation in the river basin

The Senegal river basin and Typha

The Basin of the River Senegal lies in four countries, Guinea, Mali, Mauritania and Senegal, as shown in figure 1. In this river two dams have been constructed to provide electricity, irrigation, drinking

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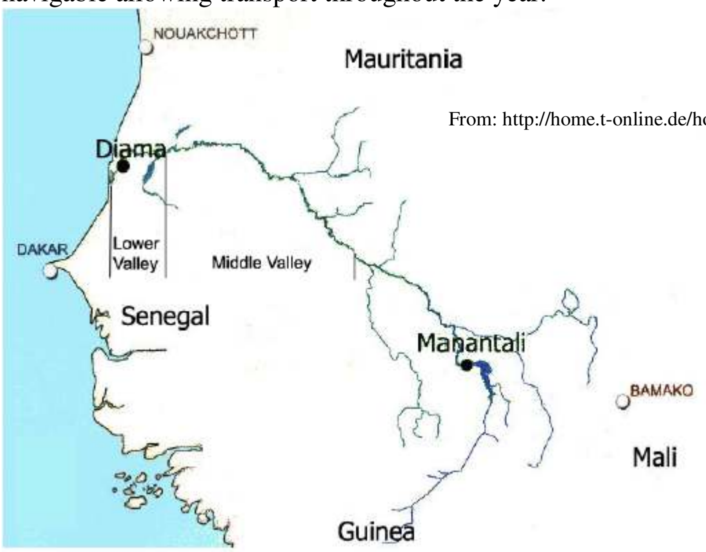
water and to prevent sea water incursion (see Kolff and Pieterse for more information). The system provides irrigation water for some 250.000 ha of farm land. The dams provide 800 GW of electricity and drinking water to the capitals of Mauretania and Senegal. The dams have also made the river navigable allowing transport throughout the year.



From: http://home.t-online.de/home/320033440512-0004/typha/kloff.pdf

Figure 1 : Senegal River Basin with the location of both dams

After the construction of the Diama dam in 1985 in the River Senegal (see figure 1) a shallow lake has been formed in the former delta. Lack of stream velocity combined with the effects of eutrophication of the river water due to agriculture located upstream, provides favourable abiotic conditions for several aquatic water plants that can become a nuisance. In the shallower parts along the shore emergent water plants such as reed (*Phragmitis australis*) and the native species *Typha australis* can occur, but also floating water plants such as Salvinia, Pistia and possibly in the future Water hyacinth (lat name) can become a pest under these nutrient rich conditions in still water. Pistia seems to be under (biological) control and currently Typha is the most problematic weed. The lake between the dams is shallow (maximum depth 3 m) making most of the area potential habitat for Typha which requires less than 1.5 m of depth. The salt content has become less than 1.6%, ideal for Typha which requires less than 2% salt.

Problems associated with Typha

The proliferation of Typha leads to many problems including:

- Clogging of irrigation canals
- Bird pests ("Roodbekwevervogel") invading rice areas: birds find refuge in the Typha
- Reduced access to water for villagers
- Impediments to fishing
- Reduced water quality
- Water borne diseases such as Bilharzia and Malaria
- Air pollution because villagers burn above water parts of Typha
- Weed problems in rice growing areas because of Typha seeds blowing into rice fields

Area and biomass potential of Typha
Typha now covers some 140.000 ha of shallow water and wetland areas that were formed due to dam construction. In figure 2 a map is shown of the area with an indication of the Typha proliferation and density. The dry matter density of Typha varies with soil type, water depth and availability of nutrients. Yield estimates for Typha range from 6 to more than 20 tonnes of dry matter per ha. Overall a productivity of 6 to 8 tonnes of dry matter should be expected (van Kooten, pers comm.). The current area of 140.000 ha is expected to be reduced to some 30.000 to 40.000 ha due to several measures that will be part of a large World Bank project partially financed by the Dutch government (van Kooten, pers comm.). The proposed measures include (van Kooten, pers comm.; Scharloo and Drost, pers comm.):
Construction of small levies (dams) to reduce wet and inundated areas, this essentially reduces the area of the lake and thus the area where Typha can grow.
Dredging inlets to irrigation canals to a depth of 2 to 3 m, thus preventing growth because Typha needs water shallower than 1.5 m to grow.
Similarly the access of villages to the water can be dredged deeper to prevent establishment of Typha, thus giving the villages better access to the water.
Making small levies allowing selected areas to dry out from which Typha can subsequently be removed or eradicated after which the water is returned again
Mechnical removal of Typha

The remaining 30.000 ha of Typha would then be available for continuous sustainable exploitation making it possible to establish commercial production of Typha products. One idea is to rent out this area for commercial exploitation for charcoal production (pers comm.. van Kooten). At a yield of 6 to 8 tonnes of dry matter this would potentially yield 180.000 to 240.000 tonnes of dry matter per year.

The most important factor to determine the feasibility of such a scheme will be the cost of harvesting, drying and transporting Typha to a processing facility and the sustainability and continuity of the Typha growth.

Harvesting and drying of Typha
In order to utilise Typha an effective harvesting and transportation system has to be devised, which can be difficult:
“La difficulté majeure réside dans la coupe, le ramassage et le transport d’une biomasse importante dans un environnement aquatique qui complique singulièrement les choses” (Dieng, 2002). (The main problem is the harvest, the handling and the transport of biomass in an aquatic environment which much complicates things).

Harvesting Typha for eradication or for sustainable use requires very different approaches. For sustainable use special equipment has to be used and specific measures have to be taken (Hellsten et al., 1999; Henning, 2002):
The emergent Typha plants should be cut 20 cm above water level (to maintain air exchange with the lower parts of the plant). If plants are cut too short Typha may die down creating anoxious conditions (because of decaying plant material) and associated pollution problems together with a reduced ability for re-growth.
Plants should be cut at senescence to maintain sufficient reserves for re-growth in rhizomes but before seeds are spread.
One harvest per year.

The cost of harvesting

On the cost of harvesting Typha little information can be found. A wide range of equipment is available but costs are never given. From a study on aquatic weed management coordinated by the Royal Dutch Tropical Institute, it was concluded that a mowing boat costing 75 000 US$ could only cut 1 hectare in 35 hours (Hellsten, 1999). Henning gives more optimistic estimates, indicating some 15 mowing boats or 15 amphibious mowing vehicles would be needed to harvest 100.000 tonnes of dry biomass. If we assume the investment cost of such a vehicle is 75.000 US$, mowing equipment would cost more than 2,25 million US$ for 30 machines harvesting 200.000 tonnes of biomass (dry basis) from 30.000 to 40.000 ha per year. Operational cost is not given. If we assume other costs to be 2 x the machine costs and a 10 year operational live the cost would be: 2,25 x 3 = 6,75 million US$ for harvesting 10 x 200.000 tonne of biomass = 2 million tonnes of biomass. This means 3,40 US$ per tonne dry matter harvesting costs.

One of the main objectives of the Word Bank project (mentioned above) is to identify mowing options for Typha (pers comm. Van Kooten; perscomm Scharloo and Drost).

A problem seems to be that most aquatic plant harvesting machinery and harvesting systems are geared towards eradication and not yet towards sustainable production. An alternative may be to use areas, within levies, that can be dried out periodically for harvesting Typha after which the area is flooded again (van Kooten). This will certainly make harvesting less costly as it can be done with conventional equipment such as sugarcane or rice harvesting equipment.

Drying

Drying of biomass can be problematic in tropical areas. Fortunately the Senegal river area mostly has a desert climate with low rainfall (approximately 600mm per year) and a very low humidity most of the year (20 to 30 % humidity, pers comm. Van Kooten). Therefore biomass can be air dried to 80% dry weight in less than 10 hours (Henning, 2002). It is necessary to create a large area for drying within the boundaries of levies. The area needed for drying the biomass would be limited as

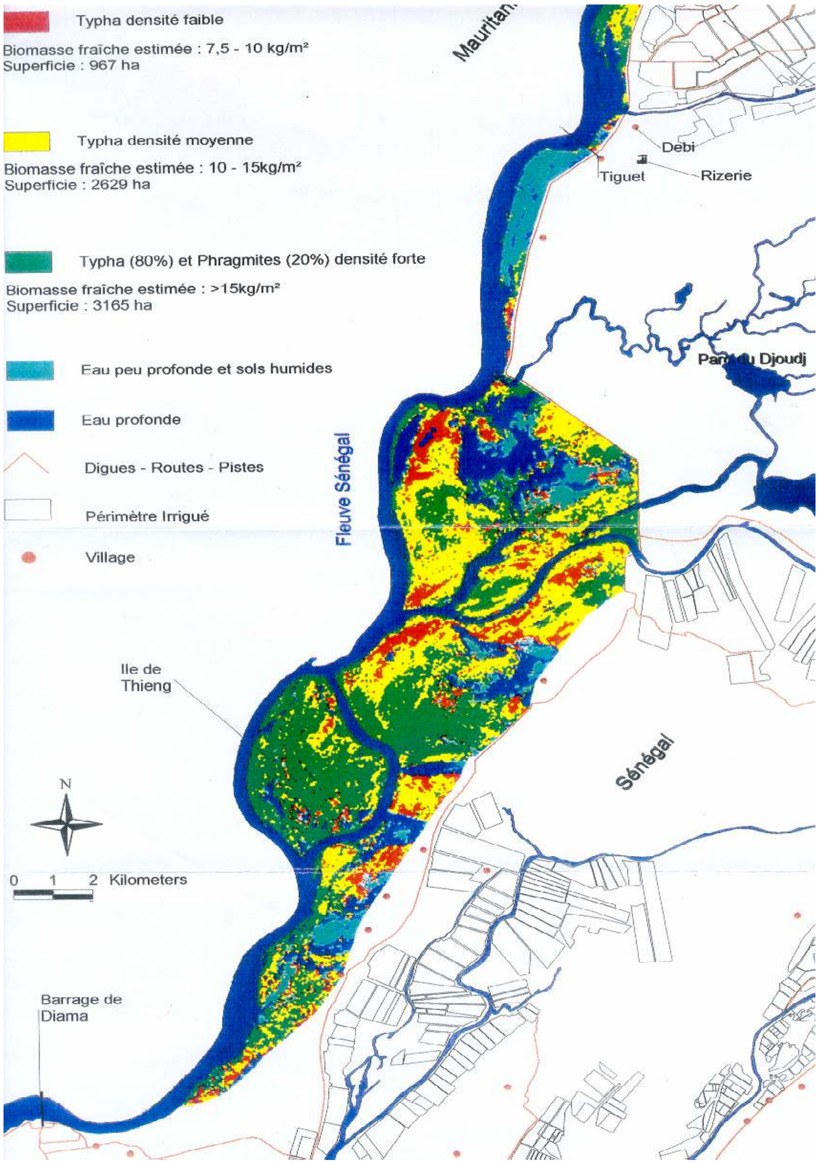


***Figure 1**. Typha cover and density in the Senegal river (Figure OMVS, SOGED, AGRER)*

Composition and utilisation options for Typha

Composition of Typha

Typha is an aquatic plant that is rooted in the soil. The composition of plant material will depend on factors such as plant type and soil type, but there are many more. A quick search of composition data of Typha did not yield much relevant information. The only data found on Typha composition (on internet) refer to Duke, 1983 and only apply to North America:

Whole plant	Dry matter basis
volatile matter	71,6 %
ash	7,9 %
fixed C	20,5 %
C	43,0 %
H	5,3 %
O	42,5 %
N, S, Cl	0,8 %
Undefined rest	8,4 %
Energy content:	16,3 - 17,8 MJ / kg
Leaves	
dry matter	16 - 24 %
carbohydrates	38 - 48 %
raw protein	7 - 12 %
Lipids	1,5 - 3,5 %
raw fiber	30 - 39 %
Minerals	6 - 18 %

It is possible to speculate on the composition of Typha based on soil type. The delta soils will often contain heavy clay, leading to a higher ash content than on sandy soils. Furthermore it is known that the water of the lake has elevated salt concentrations and there are salt containing soil layers (van Kooten pers comm.) this means that higher Cl and K and Na loads (Na and K reduce melting point of the ash, complicating thermal conversion). It is not difficult to leach out these components but this increases processing costs.

It can be concluded that it is likely that Typha from Senegal will have lower quality for thermal conversion due to elevated Na and Cl levels. For other options like charcoal for household use or lignocellulose ethanol production this may be less of a problem.

Utilisation options for Typha:
Currently several options for using Typha plant material are being considered including:
Compost for local horticulture farms
Many other uses can be found from paper making to construction material, food and even medicine (http://www.typha.net)
Energy use of which charcoal production has been most extensively investigated.
Charcoal production appears to be the most logical and pragmatic route, taking into consideration the large volume of material that has to be dealt with.

The following facts can be found for the production of charcoal from Typha:
It is necessary to have Typha biomass at air humidity of less than 20%

For production of one tonne of charcoal some 3 dry tonnes of Typha is needed (Henning , 2002) which compares favourably to wood.
The only price quoted (Henning, 2002) varies between 55 and 70 FCFA per kg?? (1 Euro is 655.96 FCFA. Thus one tonne of charcoal would cost approximately 100 Euro's. It is not known if the cost of harvest and transport are included in this estimate.
Carbonisation of Typha produces a coal powder that needs to be pressed with a binder (molasses, starch) into briquettes.
The overall (sustainable) yearly production potential of charcoal from Typha based on 200.000 tonnes of dry matter (see above) = 200.000 x 1/3 (conversion to charcoal) = 65.000 tonnes of charcoal.

Thus Typha can provide up to 15% of the charcoal demand of Senegal (more than 400.000 tonnes according to GTZ data. (pers comm. van Kooten)). The demand for charcoal in Senegal (and in many other African countries) is a threat to forests and forest destruction causes erosion, especially in southern Senegal which has sufficient precipitation (2000mm) for forest. Much effort is given to finding alternative sources charcoal. World Bank and GTZ projects aimed at finding more efficient charcoal production methods are evaluating Typha as a source. Carbon credits for such a project can be obtained as it contributes to less forest destruction in Southern Senegal (pers. comm..van Kooten).

Therefore it has to be concluded that utilization of Typha for charcoal production and local use seems to be the most attractive option compared to exporting the biomass.

3. Discussion and conclusions

The picture that emerges is that the establishment of dams in the Senegal river has led to important benefits such as an end to floods and droughts, a new source of drinking and irrigation water, and a large electric potential. But, these benefits have been less than anticipated and a number of environmental problems have been created. One of the these is the infestation of the large and shallow lake(s) with aquatic weeds. A problem that has to be dealt with. Utilisation of the major aquatic weed Typha that currently covers 140.000 ha in the Senegal river delta for biofuel can only be part of a solution. Other measures such as dredging out the access to villages and irrigation channel entrances will also have to be implemented. It also appears that the importance of fulfilling the main purposes of the watersystem (irrigation water, drinking water, etc) can not be compromised for biofuel production as is illustrated by the quote:
"*Typha* continues to have diverse negative impacts on drinking water, fishing, water-borne diseases and pests, which far outweigh any potential of the plant to combat erosion or be used in manufacturing" (http://pest.cabweb.org/Journals/BNI/Bni23-1/Gennews.htm).

"All profits from Typha will never outweigh the negative impacts. Typha is first of all a pest and not a new resource" (Boubouth et al.,1999).

If Typha is to be exploited on a large scale it will require investments in an infrastructure for harvesting, drying, transport and conversion to a fuel. This investment will have to be repaid requiring a guaranteed continuous supply of Typha. As explained above, harvesting Typha for sustained production requires a different approach than for eradication. Also the quality of the biomass in terms of soil contamination, etc may be less favourable. Therefore we can conclude that a large quantity of Typha can become available from eradication activities, but this quantity is variable over the years and may not be sustainable. For a guaranteed Typha supply as needed to recover investments, some kind of production system will have to be incorporated in the management of the river basin. It may be possible to link the Typha harvesting system to reduce eutrophication (beneficial to the water quality and therefore to the rest of the aquatic ecosystem and water use purposes), which is one of the main causes of the weed problem in the first place. Thoughts exist to eventually rent out some 30.000 to 40.000 ha for Typha production and use as biofuel or for other uses.

Investments in a biofuel production system based on Typha can only be justified if some kind of guarantee can be given of continuous supply if Typha. This seems at odds with goals of eradicating the weed unless Typha production and removal becomes part of the management of the lake such as the reduction of eutrophication.

Harvesting techniques of Typha needed for eradication or sustained production are very different. But it seems well possible that the equipment used to eradicate Typha from certain areas can also be used to harvest, dry and transport Typha in the production system of Typha.

Currently some 140.000 ha of Typha exits in the Senegal river basin. This area should not be seen as all available for exploitation since the main goal is to eradicate Typha in most of this area. Eventually some 30.000 to 40.000 ha of Typha could be used for continuous sustainable production.

It seems quite possible that continuous exploitation of Typha fits in with other management goals such as reduced eutrophication leading to less weed problems in other areas like irrigation channels and benefits other water use purposes (drinking water) and the aquatic ecosystem.

From an investor point of view the cost of continuous production and harvest of Typha for biofuels should probably be compared with growing biomass in the same region in an agricultural setting.

The risk of the investment in conversion and logistics may be reduced by also utilising other biomass residues such as rice straw in the region.

It is interesting to note that a large amount of natural biomass that is essentially available for free is still very difficult to exploit because of logistical problems and uncertainties with respect to the continuity of the supply. It appears that the only way of exploiting the potential sustainably will be by making the biomass removal an integral part of the whole management system.

Further research

Large problem that exists in Africa because of deforestation and erosion due to the increasing demand for charcoal. The process of charcoal production is generally not very efficient. It would be interesting to see if small scale Torrefaction of biomass would produce an acceptable fuel that can substitute charcoal for cooking purposes.

It would be interesting to explore how a Typha biomass production system could be fitted into the management system of the Senegal river and to quantify the potential benefits to the environment (and irrigation, drinking water quality, etc) and the costs at which biomass could then be produced.

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