Carbon footprint of reed harvesting – Domination of ecological response

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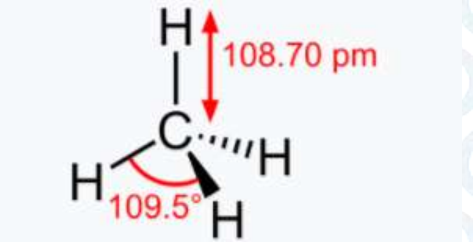
Reed invasions

- Reedbeds are expanding in many places of Europe due to nutrient emissions from agriculture and reduced grazing of lakeshores, common reed being one of the most common species
- Thick reedbeds endanger recreational uses and biodiversity but they can also be a major source of greenhouse gas (GHG) emissions

Figure by Seppo Leinonen


Figure by Ilona Joensuu

Importance of wetlands in methane emissions



- Freshwater ecosystems contribute about 16% of natural methane emissions on Earth making them a substantial source of methane
- Methane is about 20-25 times more harmful greenhouse gas as carbon dioxide -> avoiding methane emissions is an efficient way to mitigate climate change
- Methane concentration has increased by 150% since 1750
- Currently methane accounts for 20% of the total radiative forcing from all of the long-lived and globally mixed greenhouse gases

SYKE

Reedbed greenhouse gas (GHG) emissions

- The emissions from wetlands are also highly variable
- Wetlands are a major carbon sink, with the carbon burial in the sediment of lakes being at the same order of magnitude as ocean sedimentation
- The net emissions of wetlands is a complex issue balancing with CO_2-assimilation and methane emissions

Reedbeds in Finland, photo by Ilona Joensuu

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Methane and carbon dioxide balance of reedbeds

- Reed detritus it is more degradable than many other wetland plants and stimulates emissions from the sediment
- Reed transports also methane from the sediment to the atmosphere: In stands of common reed 62-85% of the methane may be emitted through plants
- On the other hand, roots supply oxygen to the sediment, which reduces methane generation and increases oxidation and increases carbon storage of reed sediment
- Summary: GHG emissions of reedbeds are complex system including **accelerative and decelerative factors**

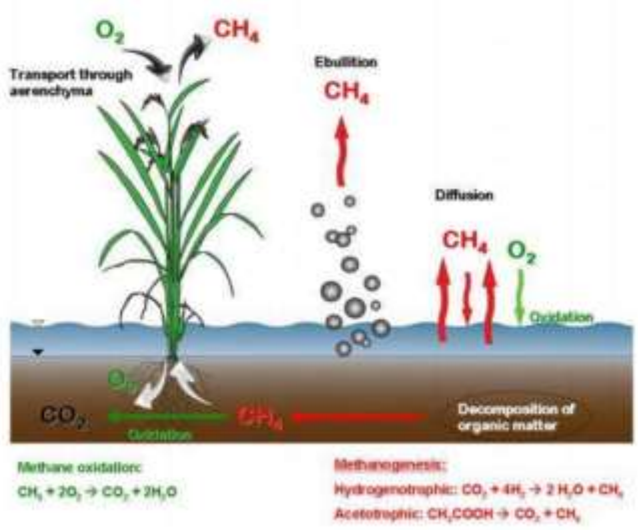

Figure by Ventura 2014

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Reed harvesting

- Reed harvesting is usually done because of recreational reasons in Finland as there is not much uses for harvested reed although reed is widely used in other European countries (energy, construction)
- A common practice is to heap the harvested reeds on the shore and allow them to decompose
- While the use of renewable raw materials seems intuitively beneficial for the environment, assessing its impacts can be complex…

Photos by Ilona Joensuu and Pasi Korpelainen

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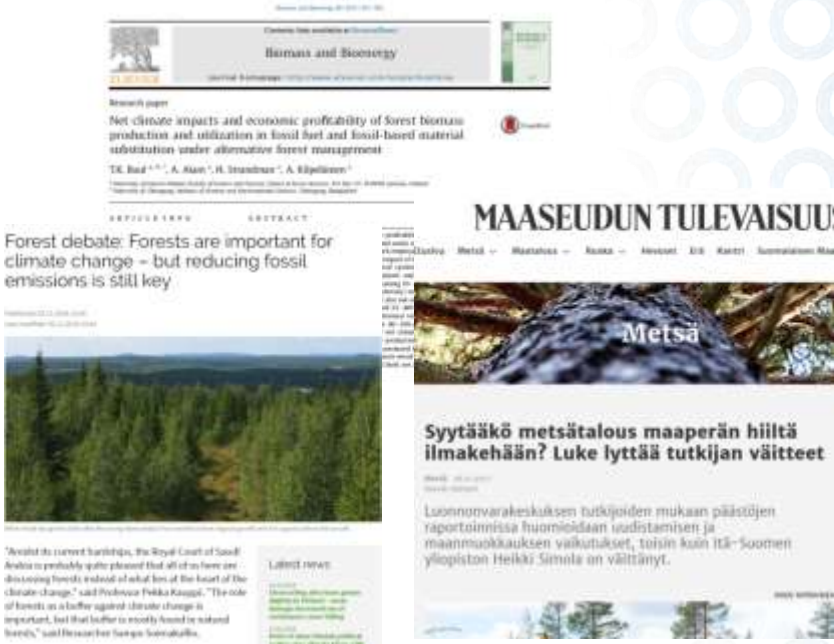
Environmental life cycle assessment (LCA)

- Environmental life cycle assessment (LCA) is often used to assess environmental impacts of a product
- Focus is usually on technosystem, but studies on ecosystem response is available on forest/forestry carbon balance
- Forest carbon emissions has been under an active discussion but no LCA studies on reedbed harvesting is available



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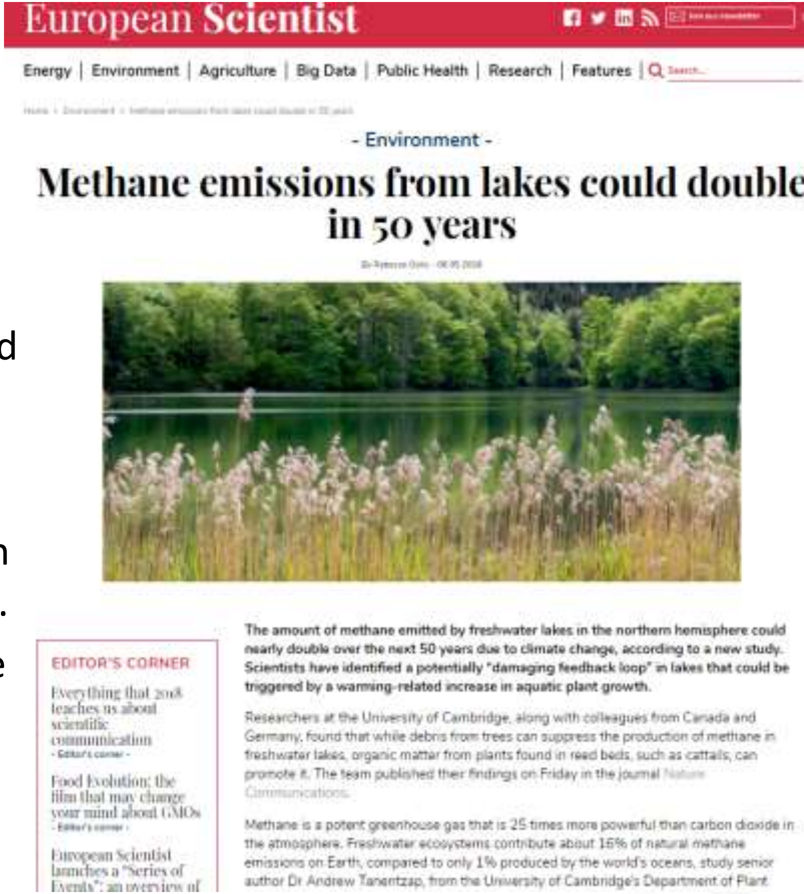
Reedbed emissions are highly relevant in climate change mitigation

- GFG emissions of reed harvesting needs to be quantitatively assessed
- Topic is even more relevant if climate change increases methane emissions from the lakes in the future
- Short term field tests indicate, that mechanical reed removal increases GHG emissions of marshes (Martin and Moseman-Valtierra 2017) but also s studies suggesting that reed invasion increases methane emission has been demonstrated (Martin and Moseman-Valtierra, 2015; Mueller et al. 2016).
- Our aim was to demonstrate the significance of the ecological processes in an LCA of reed biomass harvesting, and to compare various options for including ecosystem processes in the system boundary



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Methane emissions from lakes could double in 50 years

EDITOR'S CORNER

Everything that 2018 teaches us about scientific communication

Food Evolution: the film that may change your mind about GMOs

European Scientist launches a "Series of Events": an overview of

The amount of methane emitted by freshwater lakes in the northern hemisphere could nearly double over the next 50 years due to climate change, according to a new study. Scientists have identified a potentially "damaging feedback loop" in lakes that could be triggered by a warming-related increase in aquatic plant growth.

Researchers at the University of Cambridge, along with colleagues from Canada and Germany, found that while debris from trees can suppress the production of methane in freshwater lakes, organic matter from plants found in reed beds, such as cattails, can promote it. The team published their findings on Friday in the journal Nature Communications.

Methane is a potent greenhouse gas that is 25 times more powerful than carbon dioxide in the atmosphere. Freshwater ecosystems contribute about 16% of natural methane emissions on Earth, compared to only 1% produced by the world's oceans, study senior author Dr Andrew Tanentzap, from the University of Cambridge's Department of Plant

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Study setup

- In this case-study it was assumed that harvesting took place during late summer above waterline with an amphibian harvester (truxor)
- The functional unit of the study was a hectare of harvested lake
- The product system included the processes for harvesting and heaping the reed with a truxor
- The decomposition in the heap was considered to be a static pile composting unit
- In this setup no reed use for energy etc. are considered

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Uncertainty and sensitivity analysis

Uncertainty and sensitivity analysis is used in LCA to interpret the results

1. Parameter uncertainty is evaluated by changing each parameter and observing (i.e. amount of methane emitted by reedbed after harvesting)
2. Scenario uncertainty is evaluated through comparing sets of broader assumptions about the foreground and background systems (e.g. increased or decreased growth after reed harvesting)

(3. Calculation rule uncertainty relates to issues where there are several options on how to model or estimate a part of the system (related to LCA methodology how the emissions are allocated))

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Table 1. Sources of parameter uncertainty considered in the study. (UF = uncertainty factor). Referenc are provided in the text.

Subset	Parameter	Unit	Median	UF	Range
Operations	Reed yield	kg/ha	5000	1.6	3125-8000
	Work rate of cutting	ha/h	2	1,6	1.25-3.2
	Blade replacement	g/ha	68	5	14-340
	Equipment lifetime	months	40	1.5	27-60
	Fuel consumption	kg/h	1.8	1.2	1.5-2.2
Heaping	Share of rapid decomposition	%			60-100%
	Methane emissions	g/kg dry matter	3	4	0.7-10
Lake ecology	Methane emitted with reed	kg/ha	210	2	105-420
	Methane emitted without reed	kg/ha	9	1.4	6-12
	Emissions increased by cutting	%	15	1.5	10-23%
	Total NPP of reedbed	t d.m./ha*	14	1.5	9-21

*tonnes of dry matter/ hectare

Reedbed response scenarios on harvesting

- (C1), it was assumed that since the methane is produced from plant biomass, a removal of biomass would decrease methane emissions in a linear proportion. Therefore, methane emissions were reduced using the ratio of removed reed to total NPP (all three of which were uncertain parameters)
- (C2) reed harvesting was considered to increase methanogenesis and gas transport from the sediment to the atmosphere by an uncertain amount (10-23% described in the parameter uncertainty section)
- (C3), it was assumed that a properly timed cutting could reduce the reed stand sufficiently for another vascular plant to colonize the area. This would result in reduced emissions for a period of time or for indefinitely

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Allocation of emissions

- In A1 scenario the reed harvesting is burdened by the methane emissions of the producing ecosystem, therefore, reed harvesting is clearly a major emission source attributed to human activities (carbon footprint 5.172 t CO_2 eq/harvested hectare).
- A2 scenario the reed harvesting is seen to cause a land use transformation which reduces emissions and therefore this is credited to the product system (similar to some cases of tree harvesting from forest systems) and will lead into climate change mitigation (net climate change impact reduced by 5.934 t CO_2 eq/harvested hectare).
- In both cases the impact of the ecosystem methane emissions on the carbon footprint is so large, that it overrides the other uncertainties, resulting in net emissions or reductions in all simulation runs for the given calculation rule.

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Uncertaintly analysis

- the uncertainties are somewhat reduced for scenarios C1 and C2. At the same time, the benefits of emission reductions from the lake are reduced to an extent, where it is not certain whether the harvesting results in net emission savings (demonstrated by the confidence interval crossing the x-axis in Figure 1).
- C2 in particular, harvesting was assumed to stimulate lake emissions, but this is partially offset by the carbon storage in the reed heaps. Depending on the assumptions made on either parameter, the harvesting can be seen as a net emitter or as a carbon sink.

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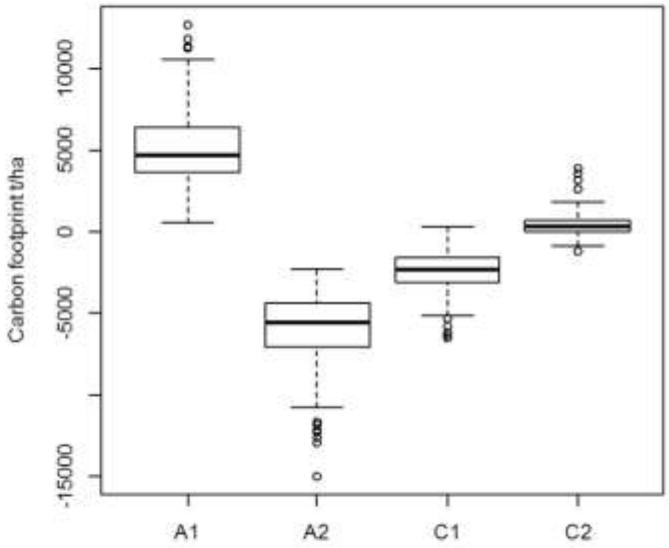
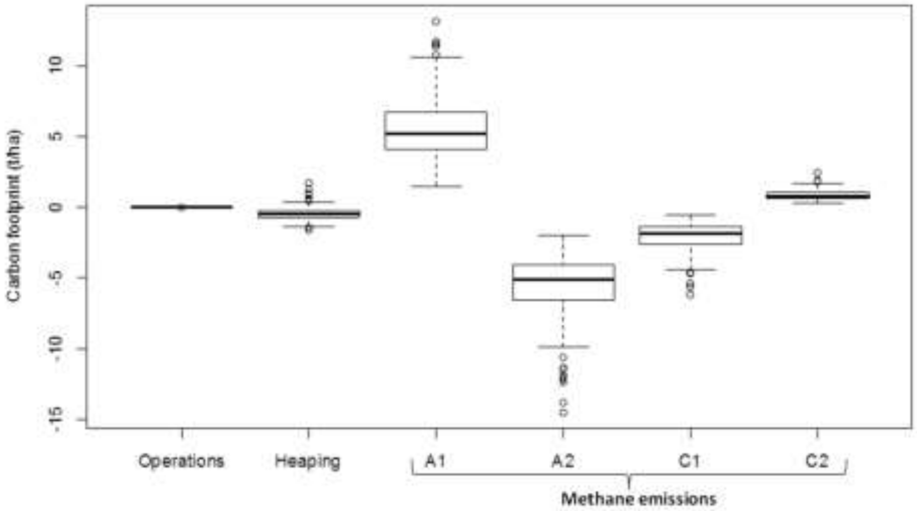
Influence of time-frame

- The uncertainty is further increased by the differing time frames of methane emission and carbon storage.
- Since methane is short lived, some authors have concluded that in the long term carbon accumulating in reedbeds would offset the methane emissions (Brix et al. 2001).
- On the other hand, the long term accumulation may not be relevant for climate mitigation as it has been considered as an urgent target

Associated uncertainties



The range of uncertainty in the carbon footprint of reed cutting and removal in four scenarios and calculation rules: **It cannot be stated if reed harvesting increases or reduces GHG emissions, but it has a potential to decrease emissions substantially**



Contribution of life cycle stages to the overall carbon footprint in four methane emission scenarios (A1-2; C1-2). **To increase reliability of assessments, more information on long term methane emissions are needed**

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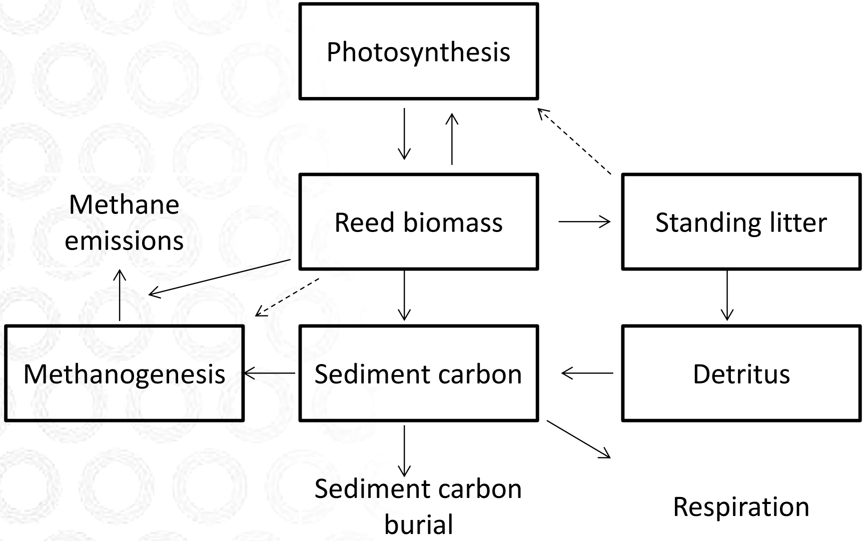
System dynamic model to assess reed harvesting climate change impacts



Carbon is readily decomposed into carbon dioxide through respiration.

The growing reed biomass supplies some oxygen to the root zone, stimulating aerobic degradation

Part of the carbon pool undergoes methanogenesis, which is partially reduced by the oxygen supplied by the reed

As methane concentrations in the sediment increase, methane flows to the water column, where some of it is oxidized by water microbes and the remaining mass is emitted to the atmosphere.

The reed biomass increases the transport rate of methane from the sediment to atmosphere considerably

Part of the sediment carbon is buried into deeper sediments, where it can remain for centuries

The deep burial carbon storage is dependent on the temperatures and residence times in the sediment, making the estimation of burial rates difficult without on-site measurements

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Conclusion

- In order to be fully used in an LCA, the system dynamic model should be made fully quantifiable. A first step in this would be to replace the diagram in the previous slide with a set of differential equations and to construct process submodels for the reed growth and sediment decomposition processes

Response of academic review process on manuscript:
Douple rejection…

Reviewer #1:

”there are major problems in methodology and discussion”

” the results of LCA have not given a novel and instructive statement ”

” should give a meaningful instruction for readers.”

”my recommendation is to reject the manuscript.”

Reviewer #

”climate change is so big a topic, and there are many influence factors exist”

”read community is very complex and many influence factors”

”It is really hard to use an LCA to predict some things”

”no valuable conclusion”

”no valuable data”

I suggest to reject the manuscript.

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What happens next...

- We still believe that topic is relevant and our approach is one of the first structured attempts to model carbon footprint of reed harvesting and to demonstrate associated uncertainties
- Forest and forestry carbon dynamics have been quantitatively assessed in substantial amount of articles (and lot of money is has been allocated to support this type of research), still no consensus…
- Assessment of carbon footprint of reed harvesting deserves more attention
- Collaboration with reedbed ecology experts and LCA analysists is highly needed, but it seems that such collaboration has not established so far

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Thank you for the listeners,
and remember not the get rid of ALL reed…

SYKE

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Measure of a Man

Photo by Pasi Korpelainen

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