Pulp and paper mill sludge as soil improving material

From factory to the fields

Kimmo Rasa
Research manager, senior scientist, PhD
Production systems / Biorefineries and bio-based fertilizers

Foto: Erkki Oksanen

Content

- Circular bioeconomy
  - Optimized material cycles
- Concept – pulp & paper industry side streams
  - Fiber sludge
  - Nutrient and carbon recycling
- Research activities
- Main results & Impact
- Future perspectives

© NATURAL RESOURCES INSTITUTE FINLAND

Lukes´s Research Programs

Profitable and Responsible Primary Production

- Technologies and operational models in primary production
- Profitable agriculture and food system
- Productive forests

Circular Bioeconomy

- Optimised material cycles
- Added value and new products
- Transition to circular bioeconomy

Climate Smart Carbon Cycle

- Productive soil
- Smart land use
- Carbon neutral society

Adaptive and Resilient Bioeconomy

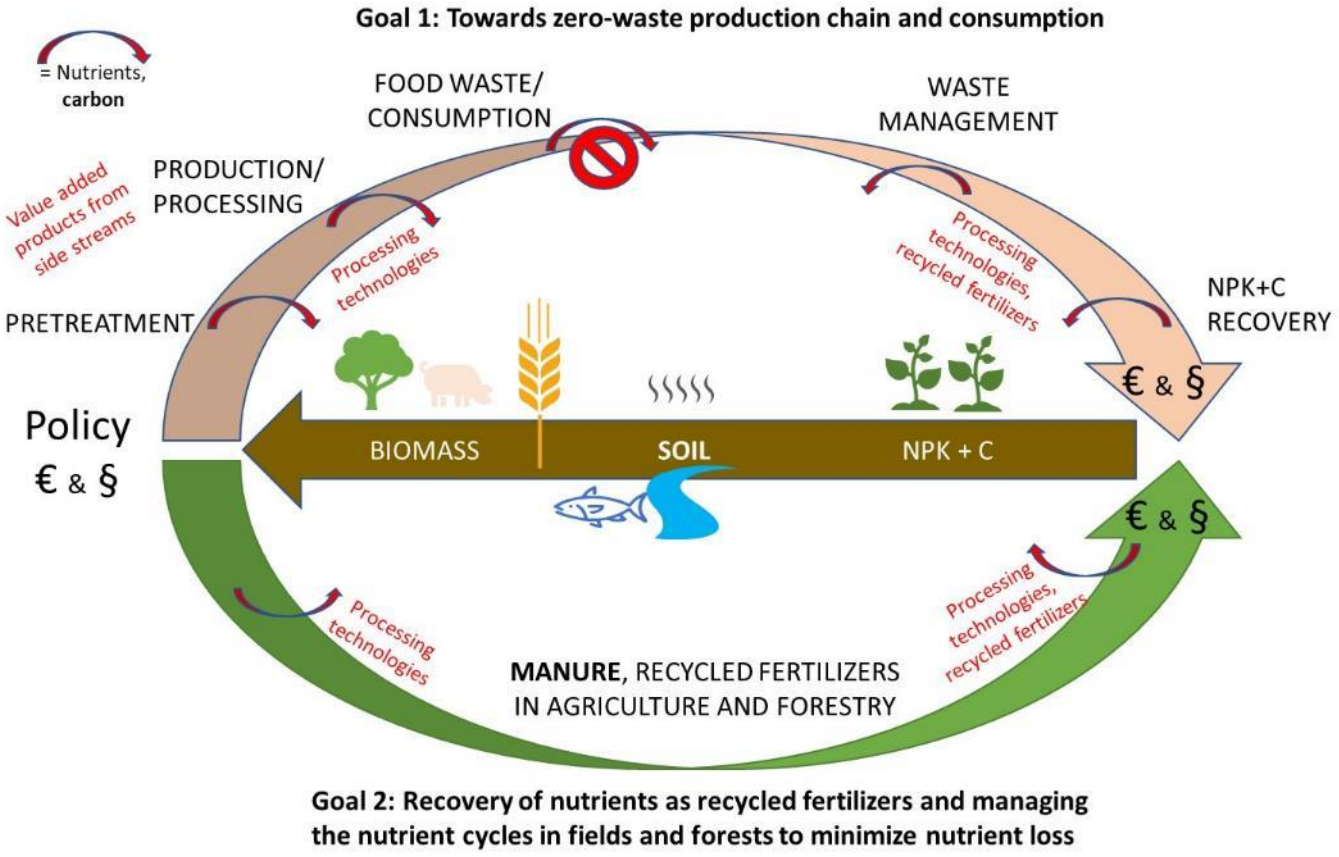
- Diversity and coexistence
- Ecosystem services
- Damage agent management
- Resilient society

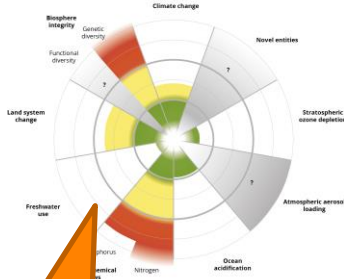
Genetics and breeding

Policy and governance

Optimized material cycles

Operational environment



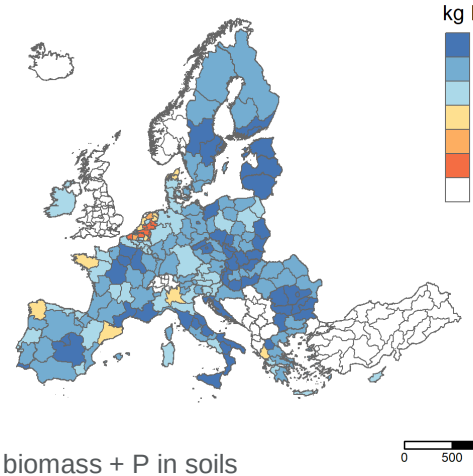


Planetary boundaries
Agricultural water protection
Carbon sequestration
Availability, price
Food security
Self sufficiency

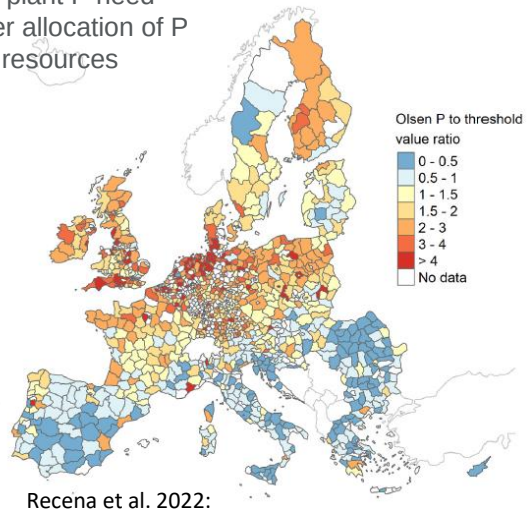
CIRCULAR BIOECONOMY
LUKE

Recyclable nutrients vs. need of fertilizers (case phosphorus)

- It is possible to cover 86% of P demand in EU by optimizing the recycling of P from food processing, manure, wastewater, and municipal solid waste
    - Location of biomass-based nutrients
    - Soil nutrient status and plant nutrition
- 72% of croplands and 57% of grasslands not P-responsive
- → circular bioeconomy solutions are needed to reallocate phosphorus resources on continental scale
- The main constraint are
    - The logistic required to transport biobased fertilizers with low nutrient concentration
    - Technologies to increase nutrient content in the products



P in biomass + P in soils vs. plant P need =better allocation of P resources



Recena et al. 2022: https://doi.org/10.1016/j.jclepro.2022.134749

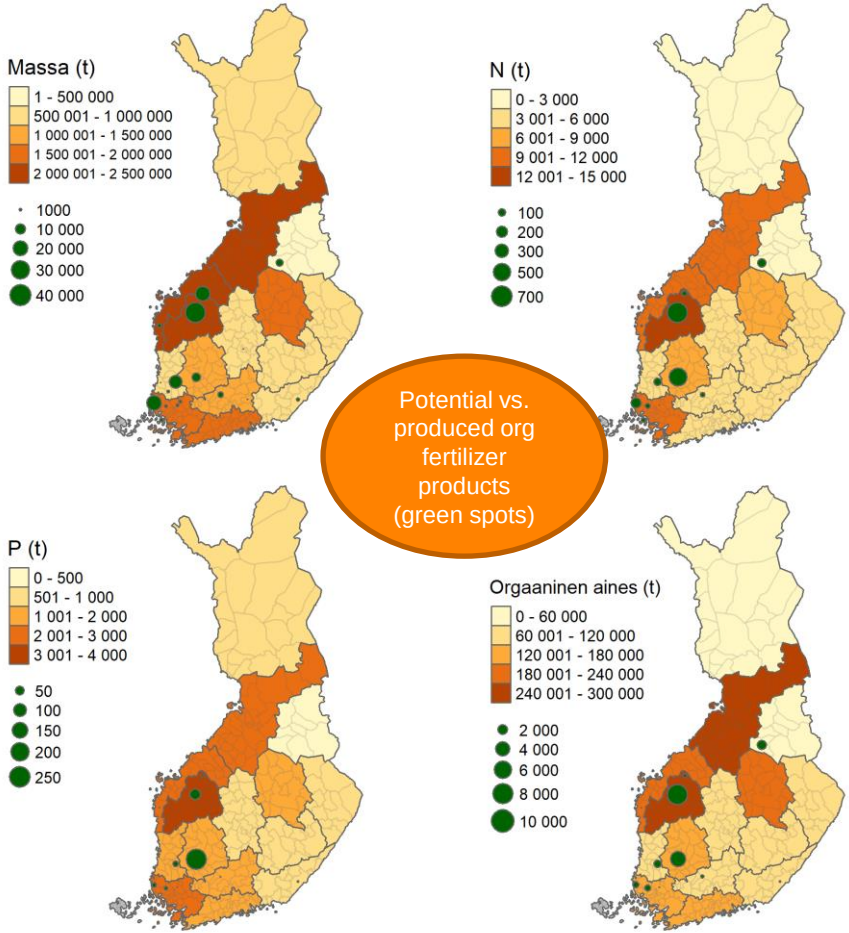
Coordinator: Kari Ylivainio, Luke

Luke © NATURAL RESOURCES INSTITUTE FINLAND

Fertilizer products:

Organic fertilizer products

- Of the potential **less than 2 %** is nationally processed to organic fertilizers
- Regionally specific characteristics
- **Great potential** for circular bioeconomy-based solutions

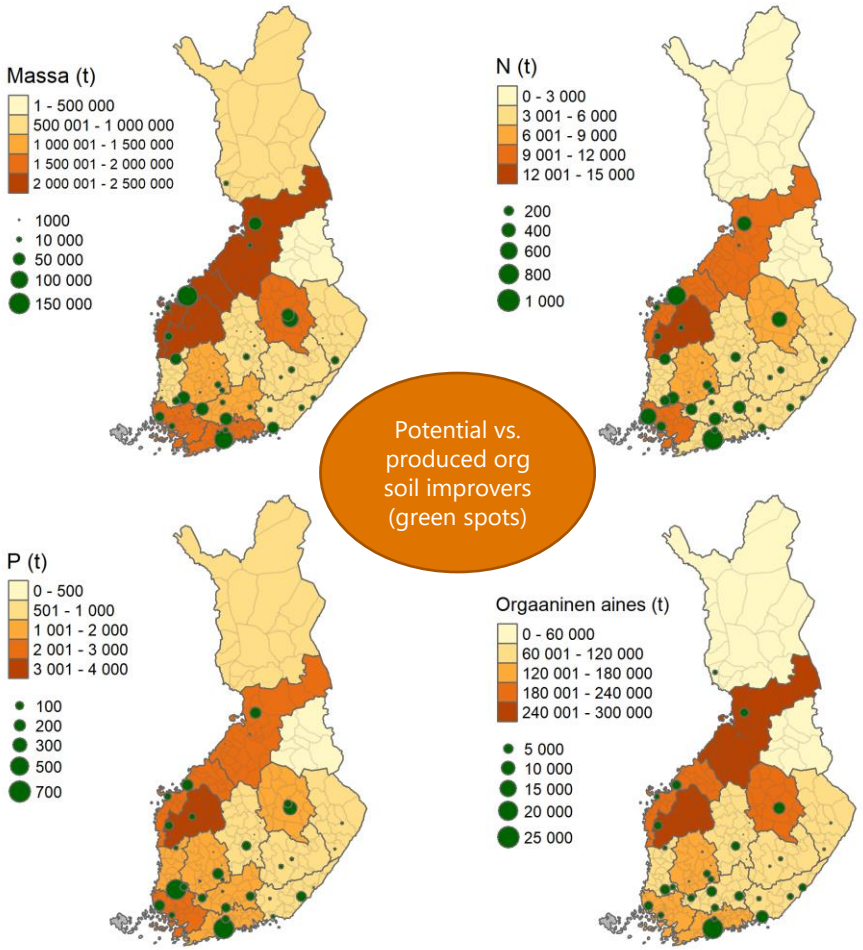


© NATURAL RESOURCES INSTITUTE FINLAND

Fertilizer products:

Organic soil improvers (digestates, composts)

- **5.5% of the potential** is nationally processed to organic soil improvers (e.g. composts, digestates)
- Organic soil improvers produced yearly 1 061 000 tons
- Main operators are Jepuan Biokaasu Oy (Ostrobothnia), HSY (Uusimaa), Gasum Oy (many locations), Soilfood (Kaakkois-Suomi) →



Luke ©NATURAL RESOURCES INSTITUTE FINLAND

Concentration and recovery of nutrients and carbon

High moisture content biomasses

- Digestates
- Slurries
- Wastewaters etc.

Separation

- Screw-press
- Vibrating screen
- Decanting centrifuge

Liquid fraction

Dry fraction

Consentration

- Membrane filtration

Liquid fertilizer products

Nutrient rich slurries

Low moisture content biomasses

- Composts
- Crop residues etc.

Drying

- Infra-red belt-dryer

Grinding

- Hammer mill
- Knife mill

Recipe development & Pelletizing /Granulation

- Pelletizer
- Disc granulator

Dry soil amendments

Granular fertilizer products

© NATURAL RESOURCES INSTITUTE FINLAND

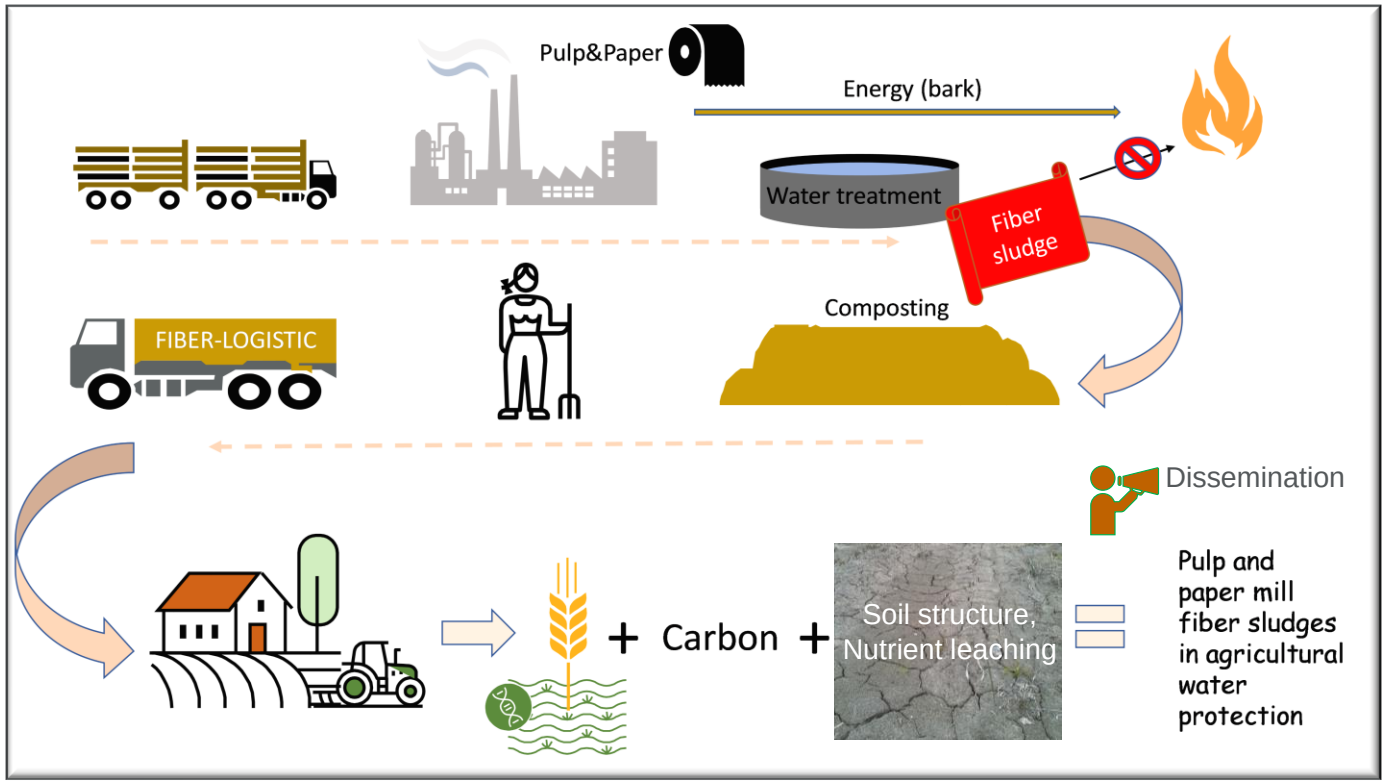
P&P industry sludges as soil improving material

From factory to the fields

P&P Industry

Business, Circular bioeconomy

Farmers & Environment



P&P industry organic side streams

- 420 000 Mg dry matter annually (Dry matter ~30-35%)
- Quality varies depending on factory settings, process and feed stock
- CPMS&LPMS: phosphorus, nitrogen and cadmium content must be considered when applied
- Fiber Sludge is poor in nutrients, “short fibers”

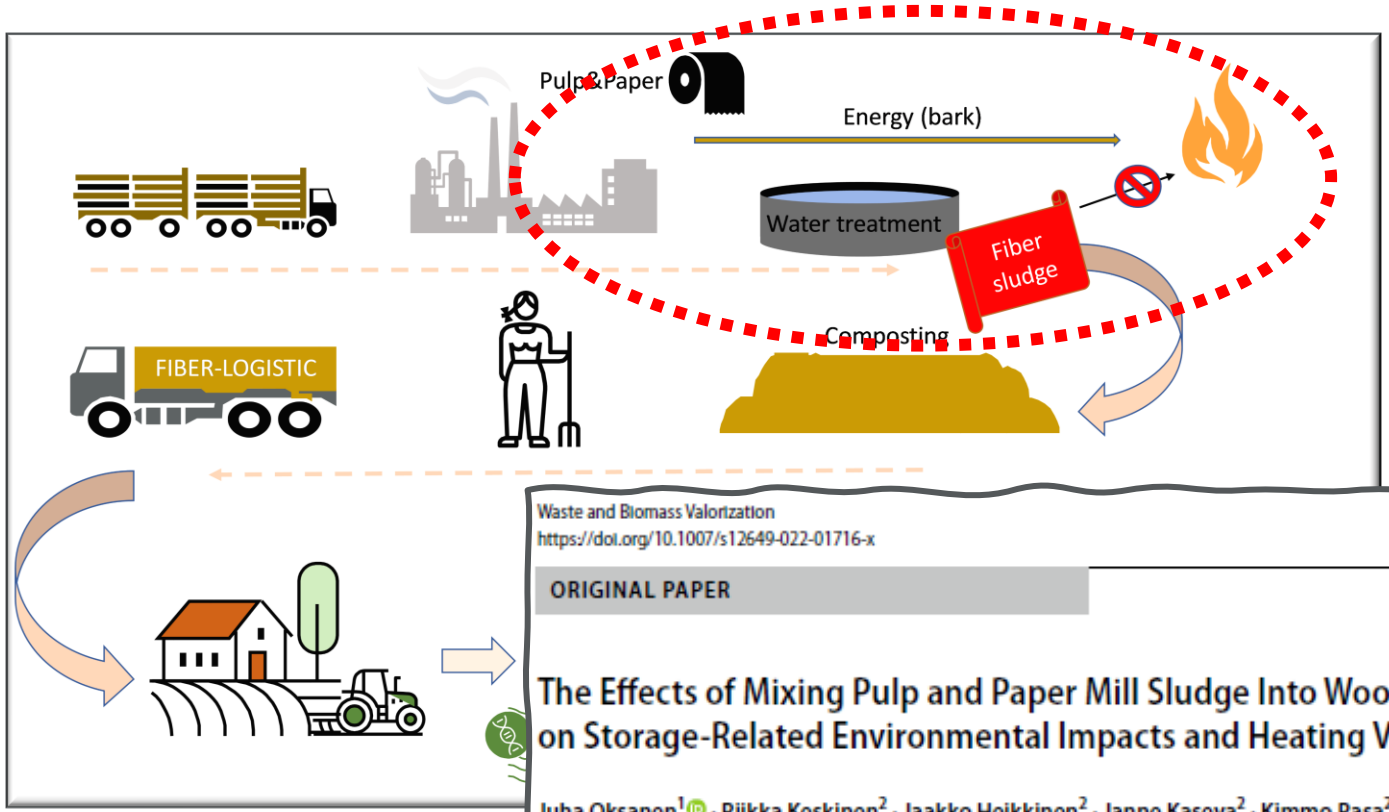
	Units	CPMS (composted)	LPMS (Lime Stabilized)	FS (cellulose)
C	%	35.1	34.8	34.9
Ash	%	35.9	33.2	34.8
pH		7.9	8.0	8.7
Tot N	g kg^{-1}	9.5	9.8	0.5
Sol N	g kg^{-1}	1.6	1.3	0.0
Cd	mg kg^{-1}	0.96	0.60	0.01

Paper 1: Sludge in factory, effect on heating value

P&P Industry

Business, Circular bioeconomy

Farmers & Environment



Waste and Biomass Valorization
https://doi.org/10.1007/s12649-022-01716-x

ORIGINAL PAPER

The Effects of Mixing Pulp and Paper Mill Sludge Into Wood Bark on Storage-Related Environmental Impacts and Heating Value

Juha Oksanen[1] · Riikka Keskinen[2] · Jaakko Heikkinen[2] · Janne Kaseva[2] · Kimmo Rasa[2]

Paper 1: Sludge in factory, effect on heating value

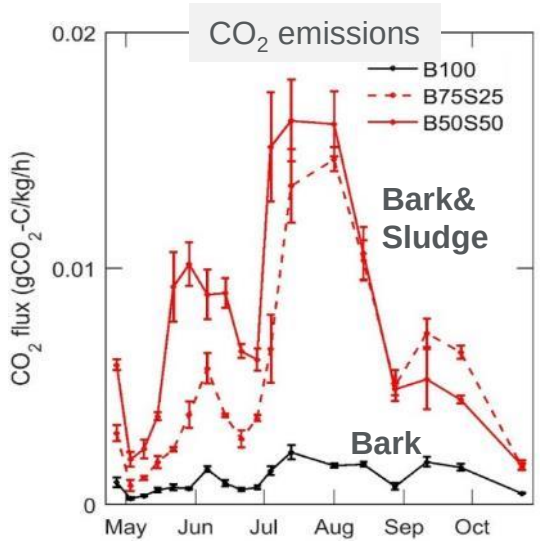
Motivation

- Impact of sludge on heating value of bark + Environmental impacts
- Is there benefits if alternative approach for sludge disposal is to be adopted?

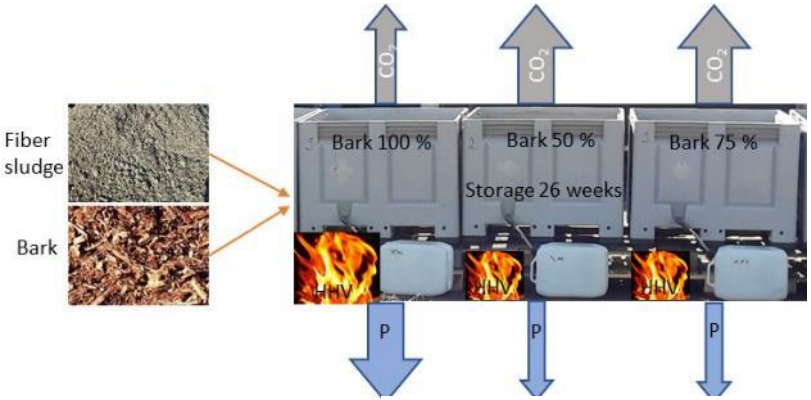
Results

- Bark and sludge stored together → microbial decomposition
- Co-storage of sludge and bark led to loss of energy
- Larger amounts of inorganic elements released

→ Green light, data supported need to find alternative usage for sludges



GHG-emissions



Leaching water quality

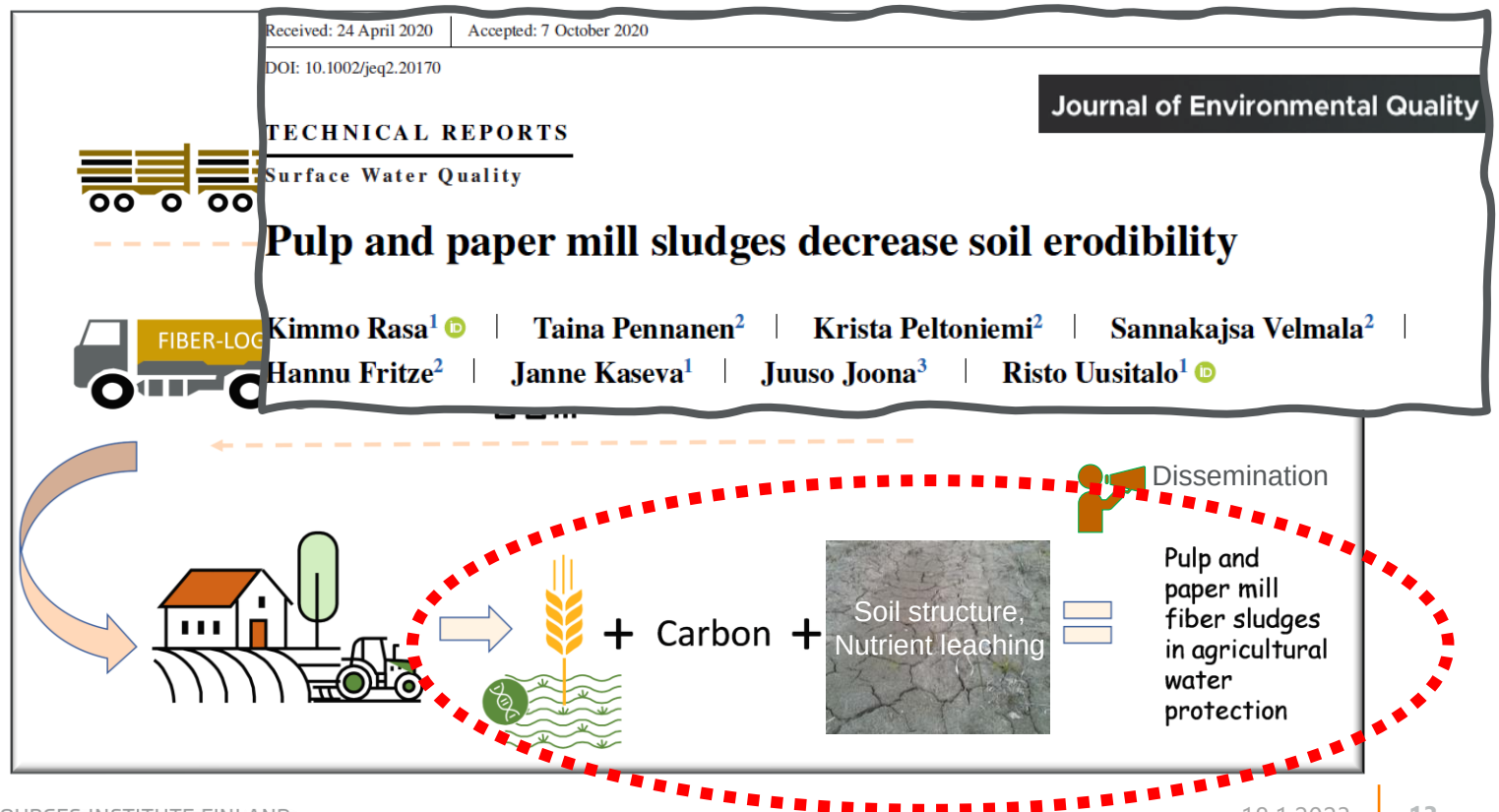
Luke © NATURAL RESOURCES INSTITUTE FINLAND

Paper 2: Sludge degrease soil erodibility

P&P Industry

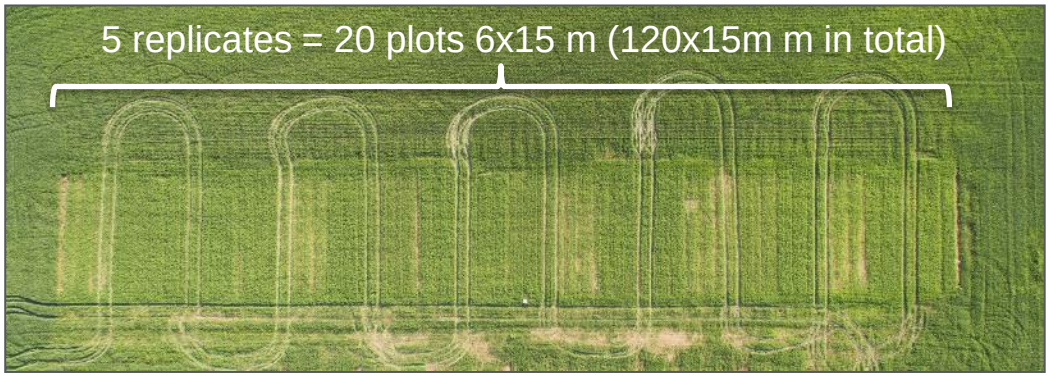
Business, Circular bioeconomy

Farmers & Environment



Field experiment at Jokioinen

- Established at autumn 2015
  - Composted pulp mill sludge (CPMS)
  - Lime-stabilized pulp mill sludge (LPMS)
  - Fiber sludge (FS)
    - From pre-clarifier of cardboard machine process water
  - Unamended plots served as the control



Fotos: Jaakko Heikkinen

© NATURAL RESOURCES INSTITUTE FINLAND

Soil amendments

- Fiber sludge nutrient poor
- CPMS&LPMS: phosphorus, nitrogen and cadmium content must be considered when applied
- Current practice ~40 t ha^{-1}

Sludge	Moist t ha^{-1}	Carbon t ha^{-1}	P-tot kg ha^{-1}	N-sol kg ha^{-1}	N-tot kg ha^{-1}	Cd g ha^{-1}
CPMS	52	8	45	211	34	21
LPMS	51	9	53	30	32	16
FS	72	8	2	1	1	0.2

Luke © NATURAL RESOURCES INSTITUTE FINLAND

Rainfall simulation test

- Soil susceptibility to erosion and nutrient mobilization
- 30x40 cm soil monoliths taken to laboratory
- Simulated rain applied for 5 h d^{-1} on two consecutive days at an intensity of 5 mm h^{-1} (=25 mm d^{-1})
- Percolation water samples were collected and analyzed
- Procedure repeated each spring 2016-2019 (published)

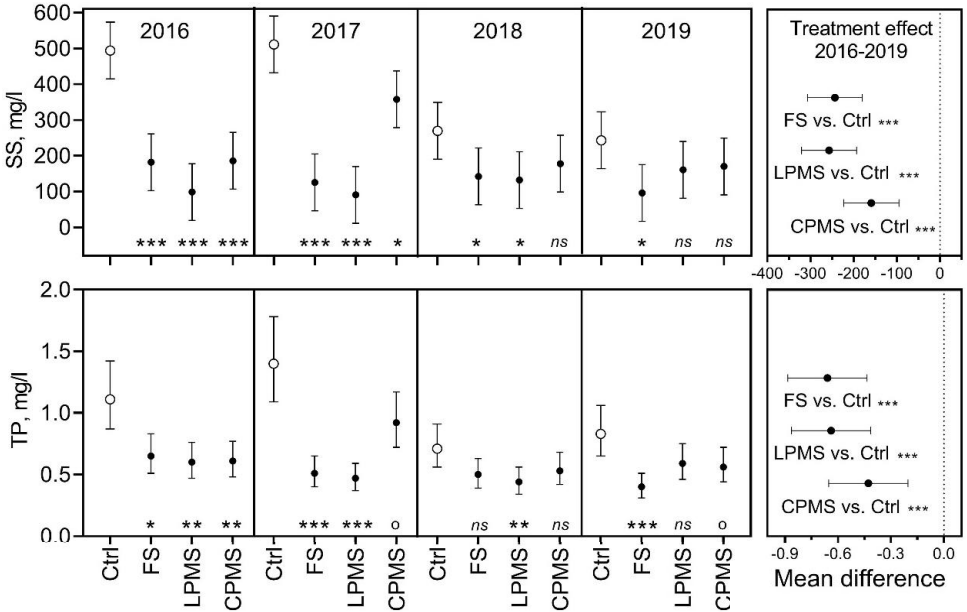
Tractor driven auger

Intact soil monolith

Rainfall simulator

Suspended solid (SS) and total phosphorus (TP)

- All products reduced SS and TP over 4-year period
- Reduction of SS in 1st year >60% and in 4th year >30 %
- Gradually subsiding effect over time
  - → Need for reapplication?
- Dissolved reactive P not affected by treatments



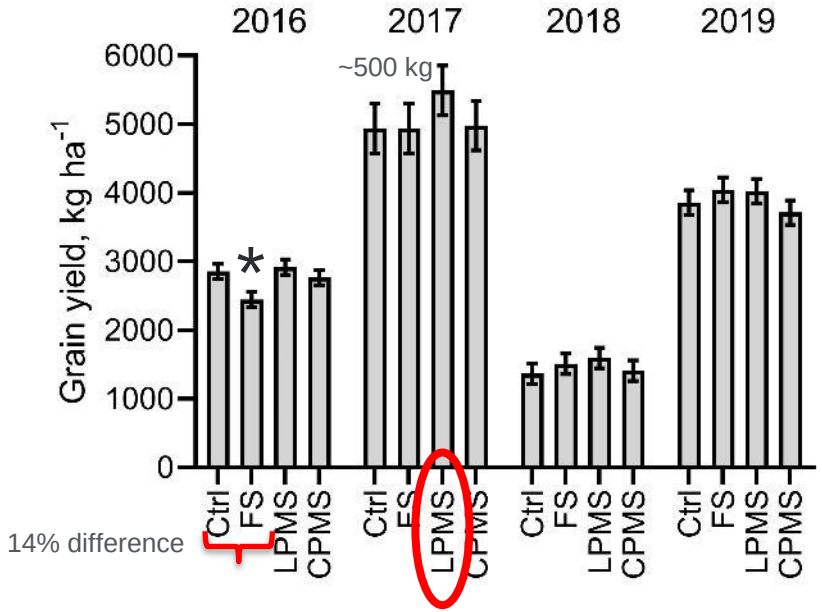
Soil carbon content

- No clear increase in soil carbon content after 4 years
  - Composted pulp mill sludge resulted in highest C %
  - More detailed studies and advanced study methods used!
- Liming effect, pH increased 0.2-0.6 pH Unit
- No effect on soil Cd content

Treatm.	C %	p	EC mS cm^{-1}	p	pH	p	Cd mg kg^{-1}	p
FS	**2.34**	0.767	**0.87**	<.0001	**6.81**	<.0001	**0.16**	0.984
LPMS	**2.40**	0.388	**0.83**	<.0001	**6.69**	<.0001	**0.16**	0.611
CPMS	**2.50**	0.053	**0.71**	0.001	**6.40**	0.005	**0.17**	0.558
CTRL	**2.32**		**0.61**		**6.25**		**0.16**	

© NATURAL RESOURCES INSTITUTE FINLAND

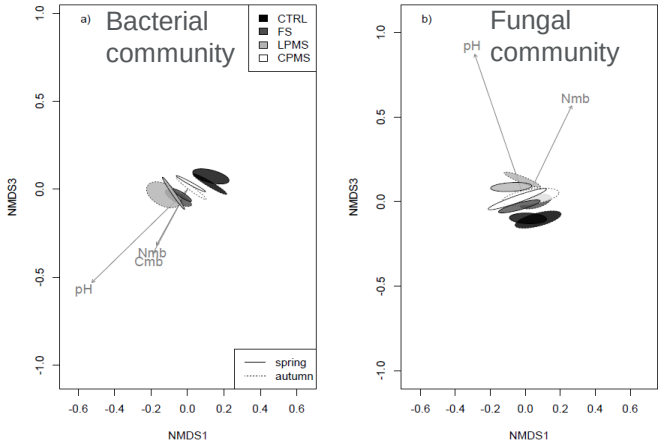
Fiber treatments had minor effect on yields



© NATURAL RESOURCES INSTITUTE FINLAND

Soil microbes 3 year after amendment

- The amendments increased basal respiration in spring and microbial biomass in autumn
- The amendments clearly changed the fungal and bacterial community composition
- *Sebacinales* ~300-700% increase
  - Indicator for less intensive land use typical in organic farming
- *Funneliformis mossae* ~200% increase
  - Arbuscular mycorrhiza fungi, nutrient uptake
- *Tetracladium marchalianum* ~230% increase
  - Fungi, efficient aggregator
- **Positive association** but no direct evidence that microbiological activity explains improved soil stability!



 © NATURAL RESOURCES INSTITUTE FINLAND

Financial support:
- Finnish Funding Agency for Technology and Innovation (Tekes/Business Finland) and the companies involved in the NSPPulp project: UPM-Kymmene Oyj, Metsä Fibre Oy, Stora Enso Oyj, Biolan Oy, Ekokem Oy, Outotec Finland Oy, Tyynelän maanparannus Oy
- Ravinnekuitu-project (2018-2019), financed by the Nutrient Recycling Pilot Programme (Finnish government key project)
- European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme, grant agreement 818290 (CIRCLES).

4-year data published

Journal of Environmental Quality

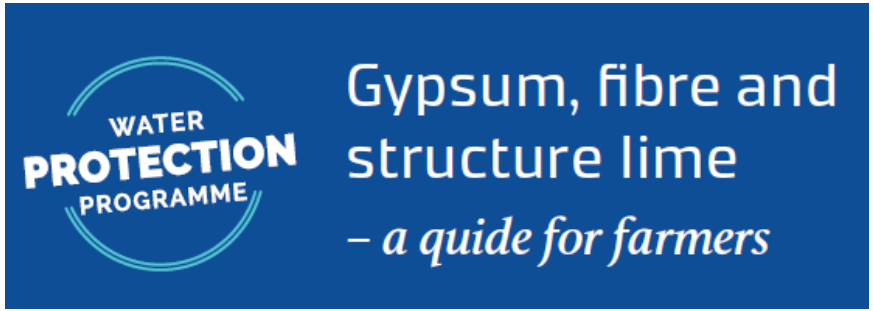
TECHNICAL REPORT | Full Access

Pulp and Paper Mill Sludges Decrease Soil Erodibility

Kimmo Rasa, Taina Pennanen, Krista Peltoniemi, Sannakajsa Velmala, Hannu Fritze, Janne Kaseva, Juuso Joona, Risto Uusitalo

First published: 21 October 2020 | https://doi.org/10.1002/jeq2.20170

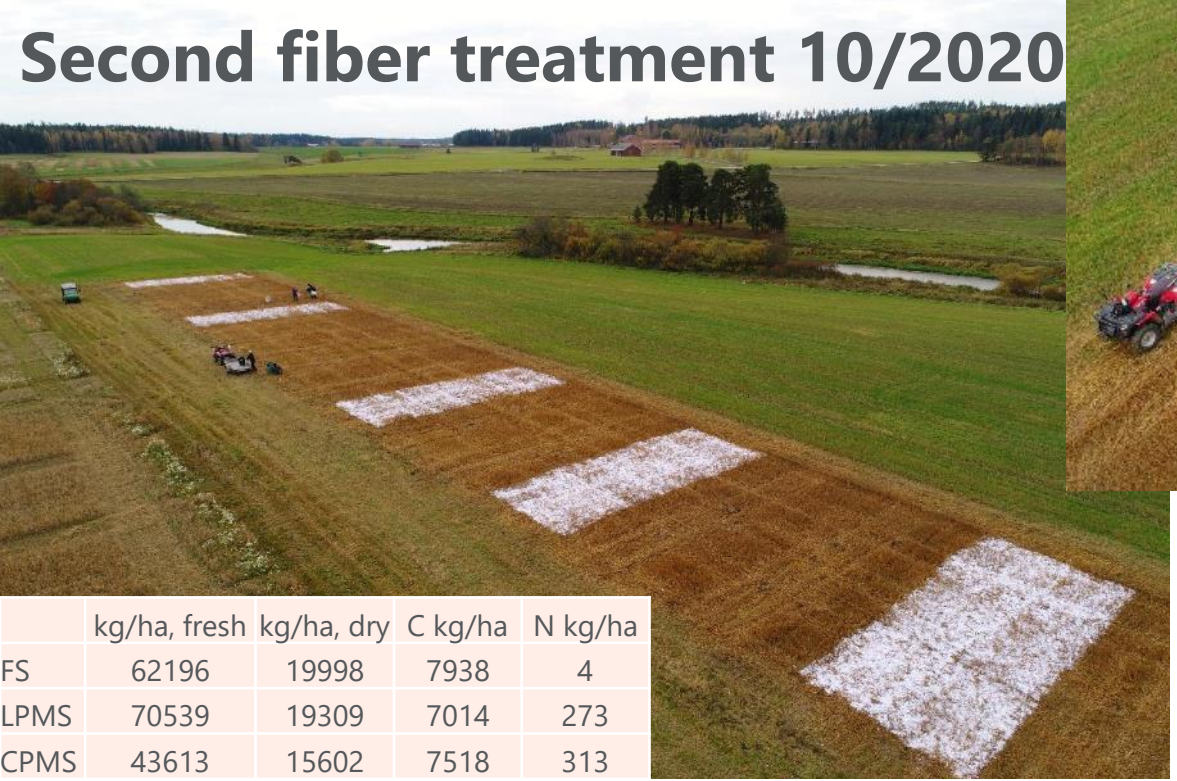
→ Practical Guide for Farmers



Luke
NATURAL RESOURCES INSTITUTE FINLAND

 © NATURAL RESOURCES INSTITUTE FINLAND

Second fiber treatment 10/2020



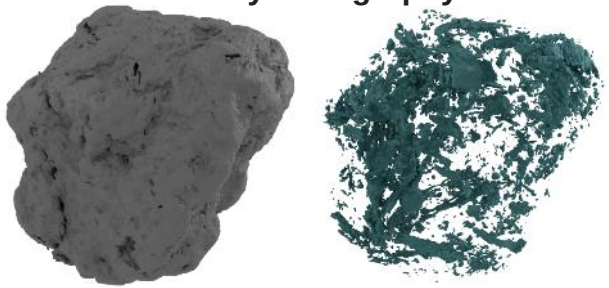
	kg/ha, fresh	kg/ha, dry	C kg/ha	N kg/ha
FS	62196	19998	7938	4
LPMS	70539	19309	7014	273
CPMS	43613	15602	7518	313

- Fiber application repeated after 5 year study period
- Data available for 7 years, 2023 = year 8 → to be published…
- Data in active use, work continues….

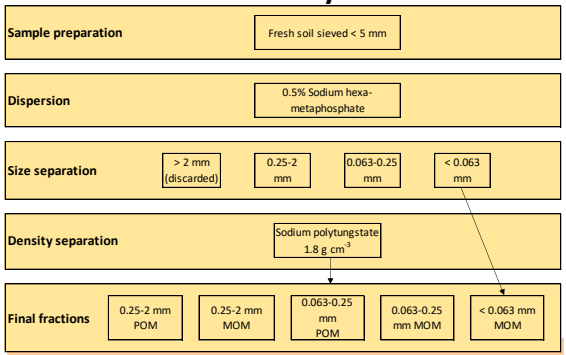
© NATURAL RESOURCES INSTITUTE FINLAND

Ongoing studies

3D pore structure of soil aggregates X-ray tomography



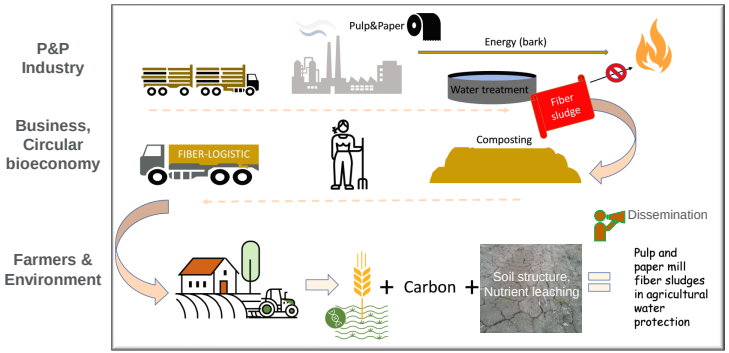
"Tracing wood fiber sludge-derived carbon based on size and density fractions of soils"



Mineral associated organic matter (MOM) is **protected against decomposition**

Fibers in vegetable production and in coarse soils

Life cycle assessment



Comparison of metagenomes and transcriptomes

Tussitaikurit

Catchment-scale experiment

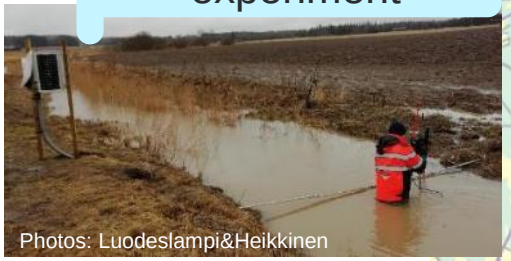
VAIKUTA VESIIN

WATER PROTECTION PROGRAMME

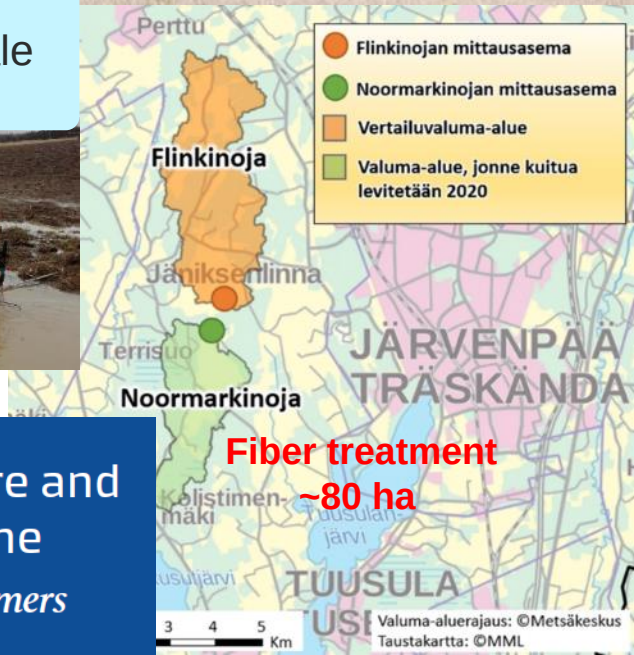
- Two small catchments, other received composted soil impro-vement fibers 2020-2021 ~80 ha
- Fields of 8 farmers located ~ 30 km North of Helsinki
- Water quality measured with automatic sensors since 2019 and it continues at least 2023
- Dissemination, guide for farmers

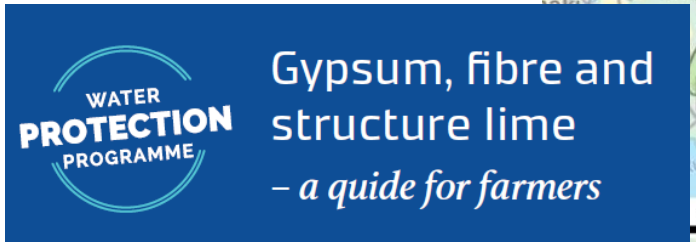
→ Impact on public acceptance, decision making, financial support…

Tuusulanjärvi Catchment-scale experiment



Photos: Luodeslampi&Heikkinen





Thank you!

Luke´s working group: Risto Uusitalo, Taina Pennanen, Sannakajsa Velmala, Krista Peltoniemi, Hannu Fritze, Jaakko Heikkinen, Helena Soinne, Riikka Keskinen, Jari Hyväluoma, Helena Merkkiniemi, Johanna Nikama, Niko Jalava, Tuija Hytönen, Juha-Matti Pitkänen…

CIRCULAR BIOECONOMY
LUKE

Luke
NATURAL RESOURCES
INSTITUTE FINLAND


Luke
NATURAL RESOURCES
INSTITUTE FINLAND