Pulp and paper mill fiber sludges in agricultural water protection

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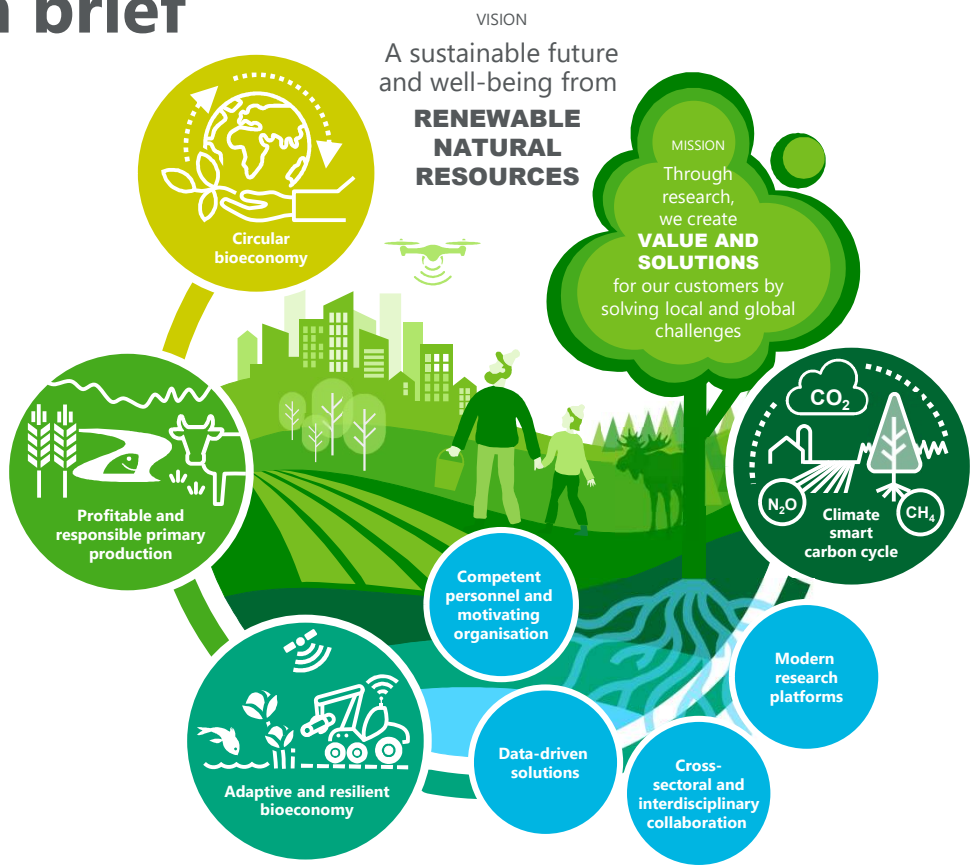
Luke in brief



125 M€
Turnover

73 M€
Budget funding

52 M€
External funding

25
Locations in Finland

HQ in Helsinki

Present in 12 campuses with universities, research institutes and polytechnics

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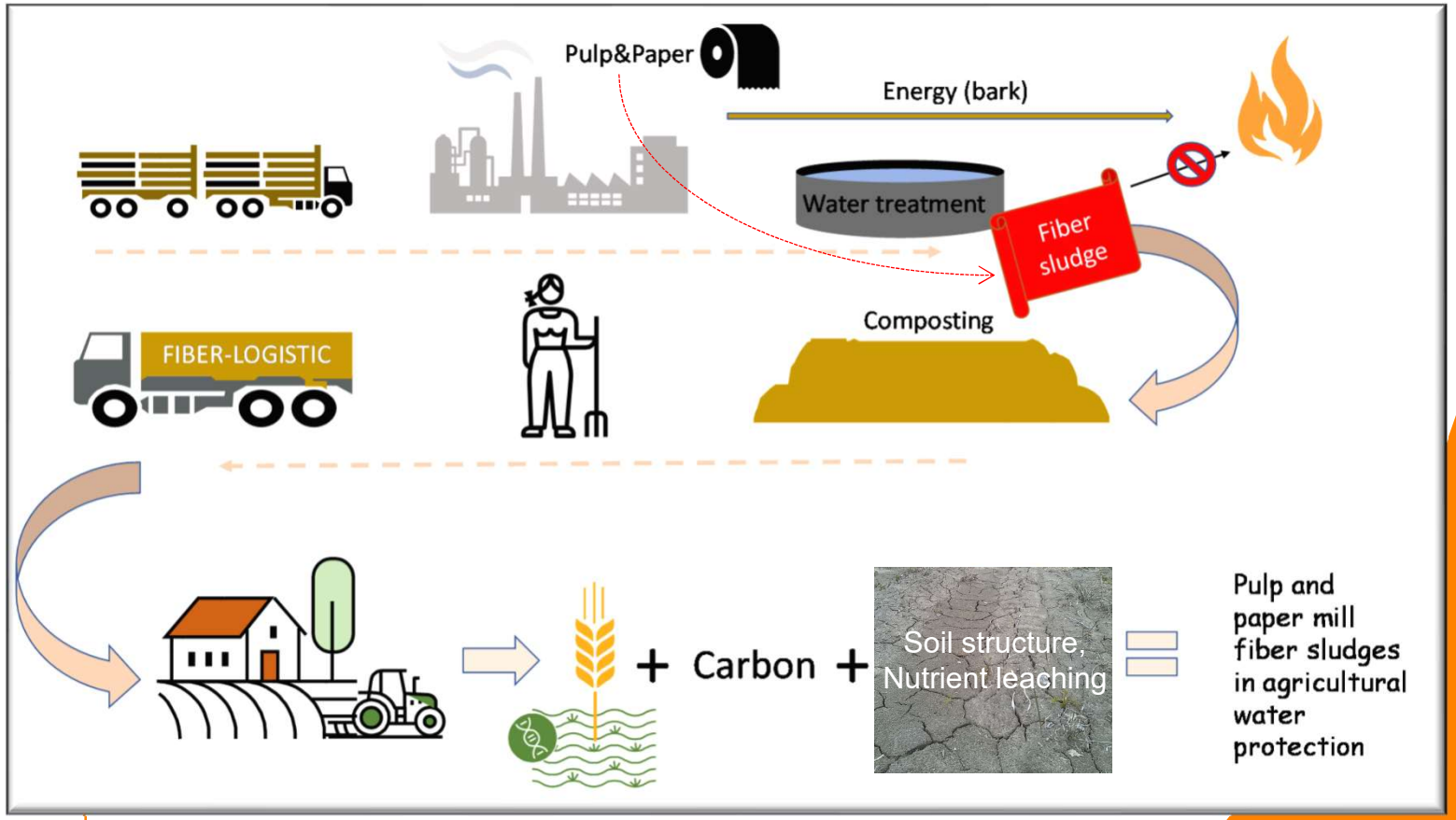
1288
Employees

46 research professors
622 researchers

We are one of the four Statistical Authorities in Finland.

9.3.2021

Fiber sludge - from factory to farm



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4-year data published

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

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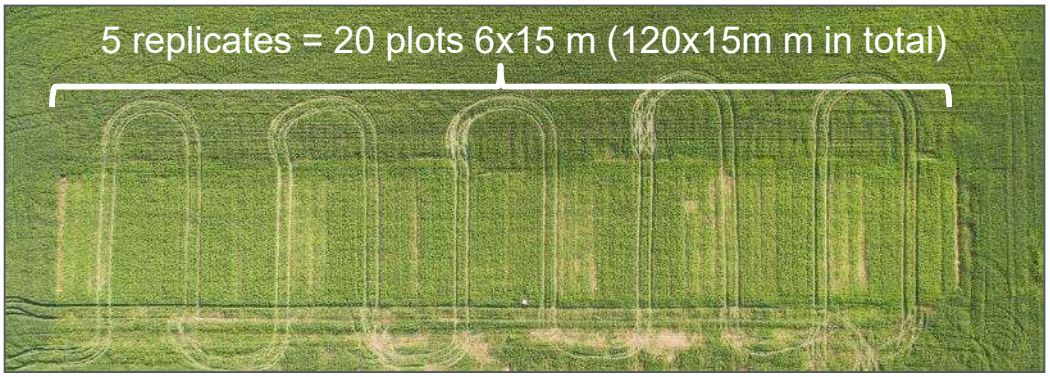
Field experiment at Jokioinen

- 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

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

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 (+2020)

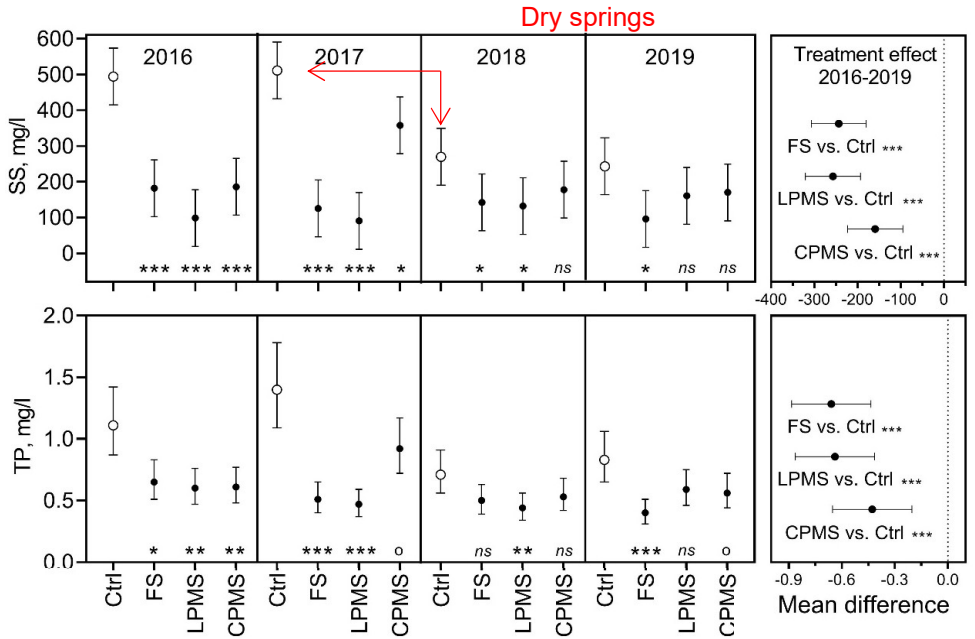
Tractor driven auger

Intact soil monolith

Rainfall simulator

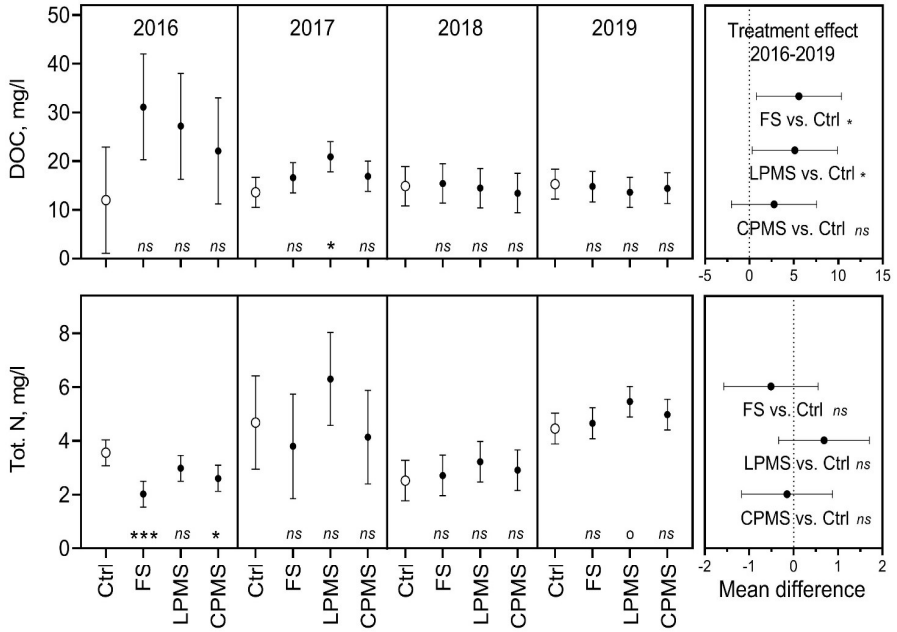
Suspended solid (SS) and total phosphorus (TP)

- All products reduced SS and TP over 4-year period
- Reduction of SS in 1st year >60% and in 4th year >30 %
- Similar trend in TP
- Dissolved reactive P not affected by treatments
- Springs 2018 and 2019 were very dry, SS concentration in CTRL was halved
  - Gradually subsiding effect of amendments or drying induced improvement of CTRL soil structure?



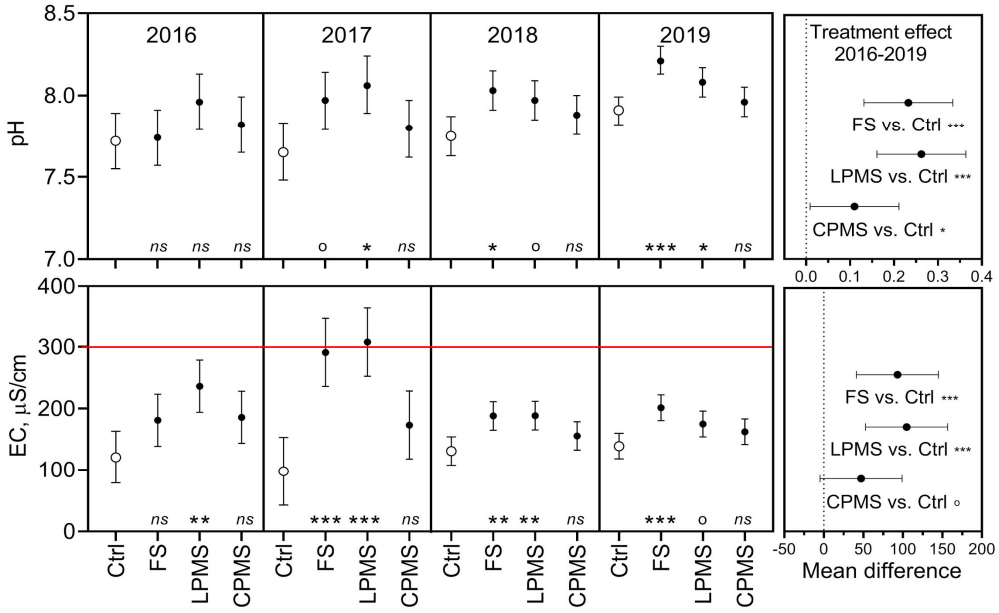
Dissolved organic carbon (DOC) and Total nitrogen (Tot-N)

- DOC concentrations stabilized after the first spring
  - 14-17 t organic matter ha^{-1} was added
- Low Tot-N concentrations coincident with low yield of FS treatment in 1st year
  - Microbial immobilization



Electrical conductivity (EC) and pH

- Increase in percolation water pH in line with soil pH
- EC mostly below 300 µS cm^{-1}
  - In the case of gypsum, water EC >300 µS cm^{-1} promoted aggregate stability and flocculation of clay particles
- Mechanism behind stabilized soil structure?
  - interactions of soil minerals with the added organic matter and microbe-derived compounds

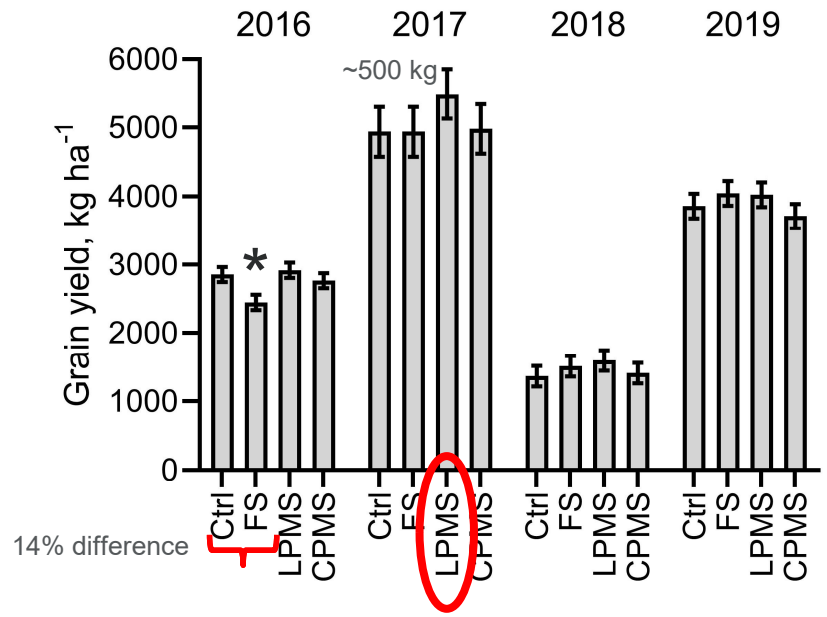


Soil carbon (C%) and cadmium (Cd) content, electrical conductivity (EC) and pH

- No clear increase in soil carbon content after 4 years
  - New sampling 2020, advanced study methods used!
  - Results leans towards fast microbiological decomposition
- Liming effect, pH increased 0.2-0.6 pH Unit
- Slight increase in soil electrical conductivity
- 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**	

Yields

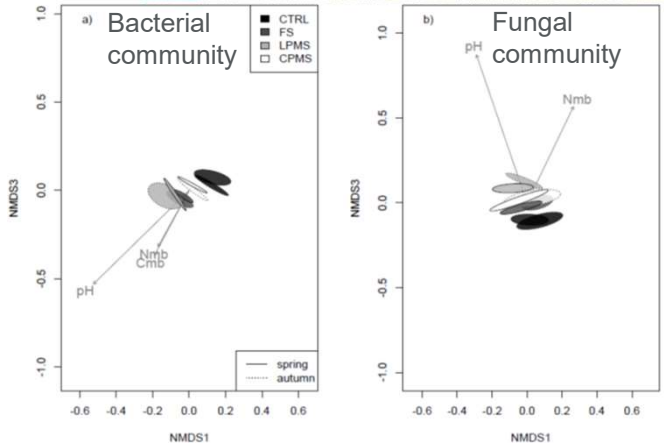


Fertilization

	2016	2017		2018		2019	
	N	N	P	N	P	N	P
CPMS	90	80	-	85	-	85	-
LPMS	90	80	-	85	-	85	-
FS	120	85	10	90	10	90	10
Ctrl	120	85	10	90	10	90	10

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!



Ongoing projects

- KUITU-Project studies CPMS as water protection measure in catchment-scale
  - https://www.luke.fi/kuitu/
  - On-line water quality measurement installed 2019, fiber application at autumn 2021
- Biosfääri-project, fibers in coarse textured soil (2020→)
- Viivi-project, fiber sludge in vegetable production (2021→)
- Maa- ja vesitekniikan tuki ry (2021→)
  - Helium ion microscopy and X-ray microtomography
  - Organo-mineral associations, aggregate 3D structure
- EU-H2020-project CIRCLES
  - Soil microbial communities and activities using new metagenome and metatranscriptome analyses

VESIENSUOJELUN TEHOSTAMIS-OHJELMA

Thank you!

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