Sustainability of residuals recycling on forested land

General issues

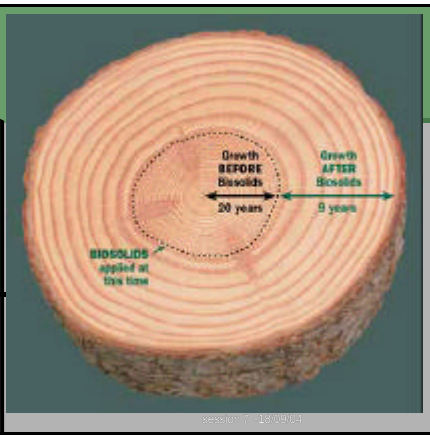
- world population and wastes increase
- need for integrated waste and natural resource management
- soil protection (EU strategy)
- expansion of forest plantations (+2% / yr)
- importance of forest environmental functions

how sustainable is the foret alternative for residuals recycling?

Why recycling on forested land ?

- permanent vegetation cover
- non food chain context
- favorable soils properties
- nutrient deficiency
- degraded and organically poor sites
- increased wood production

Potential benefits



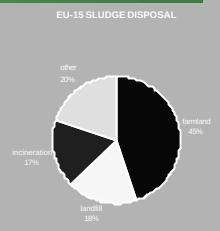
Potential risks

Types of residuals

- treated wastewaters
- sludge (sewage. pulp and paper..) and biosolids
- ash / bio-ash from wood or peat combustion
- composts and green wastes
- other bio-wastes from the agrofood industry

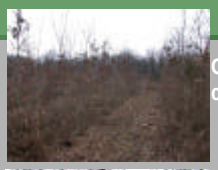
Context for waste recycling on forested land

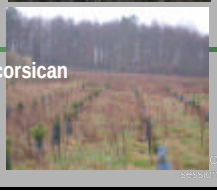
- regulatory framework
- global waste strategy
- recycling on farmland
- environmental lobbying
- forest ownership
- presence of plantation forests



examples of forest sites


Adult poplar plantation


Oak coppice


Young corsican pine


Pine stand

Application in pine forests


Landes site / low -rate applications (3 T MS / ha /yr)

What do we know?

- effects on tree growth, nutrition and soils
- characteristics and behaviour of waste materials
- fate of some contaminants (metals)

- most experiments under high application rates
- limited research on forest-based recycling systems compared to agriculture

Young plantation applications early 1970's

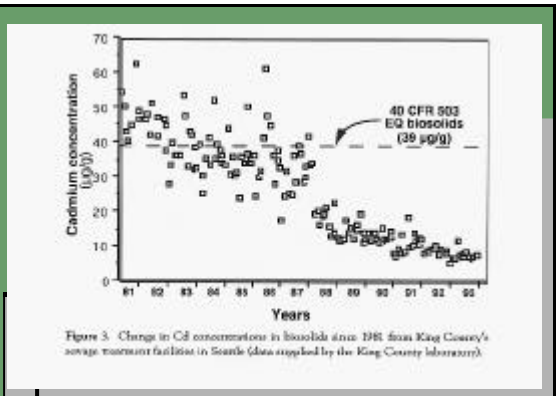


Figure 3. Change in Cd concentrations in biosolids since 1981 from King County's sewage treatment facilities in Seattle (data supplied by the King County laboratory).

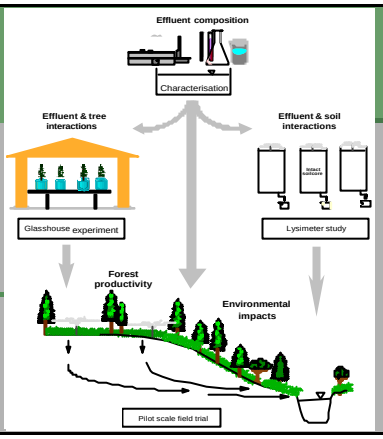
Current issues and research questions

- environmental sustainability
  - effects on ecosystem functioning and biodiversity
  - fate and effects of contaminants (metals, trace organic..)
- economic viability
  - evaluation of environmental services
  - risk assessment
- social acceptability
  - public perception
  - participatory dialogue

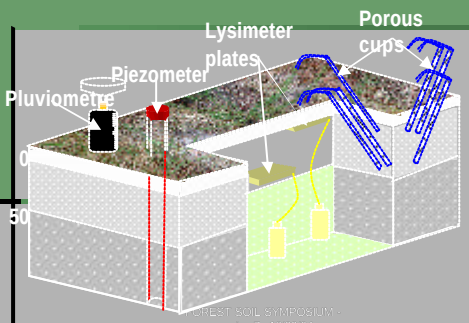
Methods

Integrated experimental approaches ...

- Microcosms and lysimeter studies
- dose-response forest trials
- small scale pilot studies
- long-term monitoring sites
- social surveys
- -....



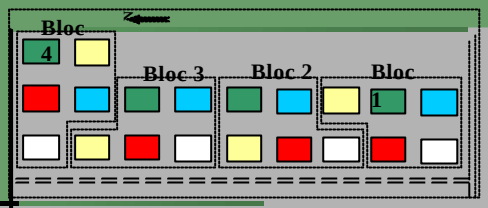
In-situ lysimeter



Lysimeter equipment

Zero-tension lysimeter

Experimental site

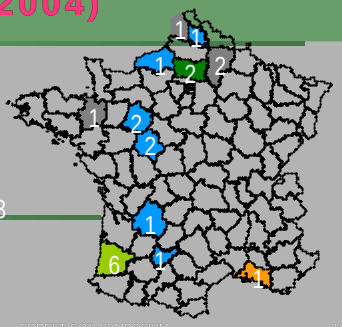


- control
- liquid sludge
- composted sludge
- dehydrated sludge
- limed dehydrated sludge

Dose 6TDM/ 2 years
20 plots of 780 m²,
20 m width buffer zone
4 blocks
80 trees/plot

French experimental network (2004)

- AFOCEL
- INRA
- IDF
- ONF
- CG-13, Univ-13



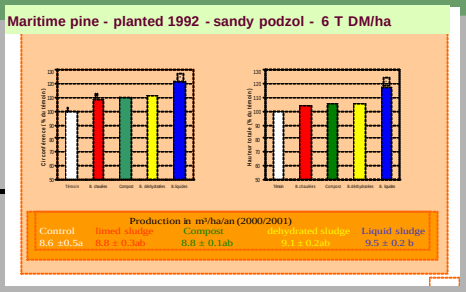
Residual materials
Soil types
Tree species
Silviculture regimes

Case study results

- limited increase in tree growth
- improved nutritional status
- accumulation of MTE in soils surface
- changes in biodiversity
- effects on understory

Effects on tree growth

Maritime pine - planted 1992 - sandy podzol - 6 T DM/ha

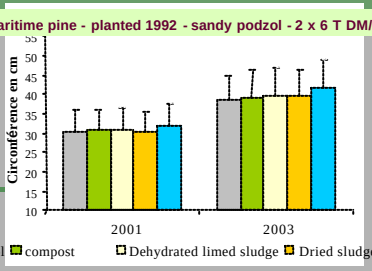


Production in m³/ha/an (2000/2001)

Control	limed sludge	Compost	dehydrated sludge	Liquid sludge
8.6 ±0.5a	8.8 ± 0.3ab	8.8 ± 0.1ab	9.1 ± 0.2ab	9.5 ± 0.2 b

Effects on tree growth

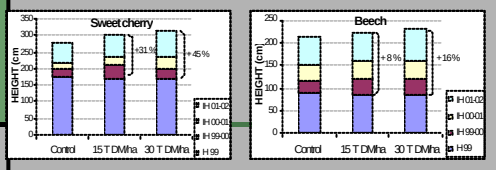
Maritime pine - planted 1992 - sandy podzol - 2 x 6 T DM/ha



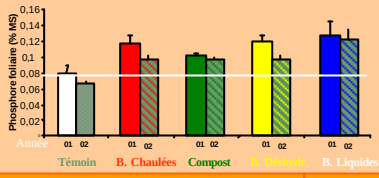
control | compost | Dehydrated limed sludge | Dried sludge | Liquid sludg

AFOCEL project of forest application of pulp and paper sludge: first results after 3 years

- a positive and limited effect of pulp and paper sludge on height growth of young broadleaf trees plantations

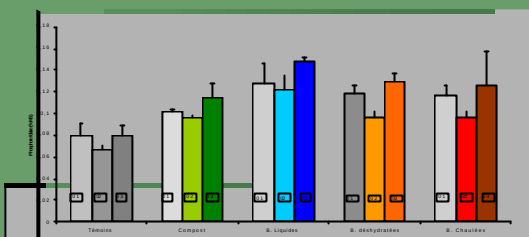


Effects on nutritional status



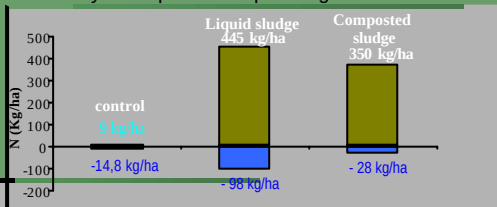
	Azote (% MS)		K, Mg et Ca
Année	*2001*	*2002*	
Témoins	1.1a	1a	
B. Chaulées	1.3a	1.1a	
Compost	**1.2a**	**1.2a**	Pas d'effet
B. Déshydratées	1.3a	1.1a	
B. Liquides	**1.3a**	**1.4b**	

Nutritional status (P)



Nutrient leaching

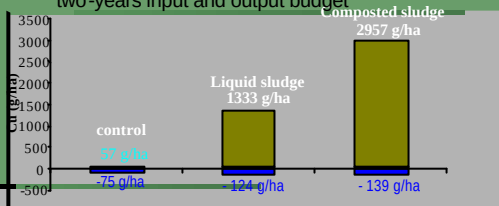
two-years input and output budget



(initial N pool in topsoil (0-20 cm) = 1085 kg/ha)

Metal accumulation (Cu)

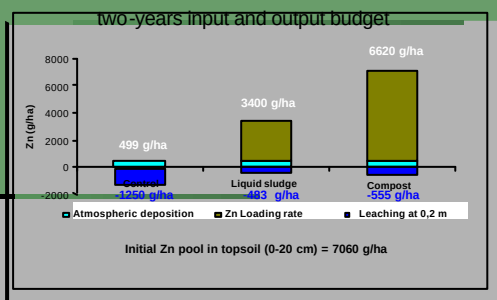
two-years input and output budget



(initial pool in topsoil (0-20 cm) < 3240 g/ha)

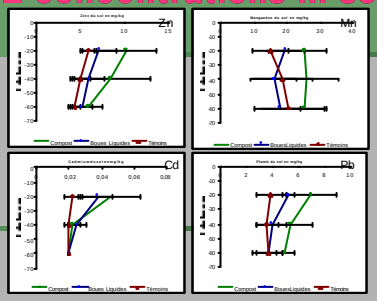
Metal accumulation (Zn)

two-years input and output budget



Initial Zn pool in topsoil (0-20 cm) = 7060 g/ha

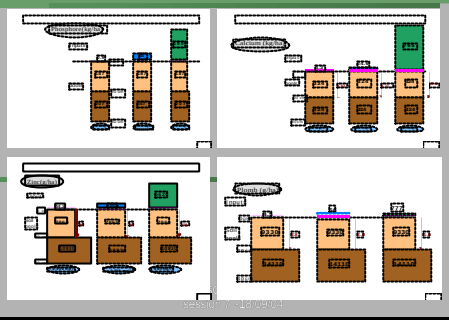
MTE concentrations in soils



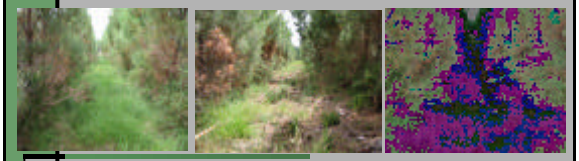
Concentration profile in soils two years after composted and liquid sludge applications

Inputs - outputs

Inputs (atmospheric, liquid and composted sludge) and soil pools (0-0,2 / 0,2 - 0,4) of Ca, P, Pb, Z



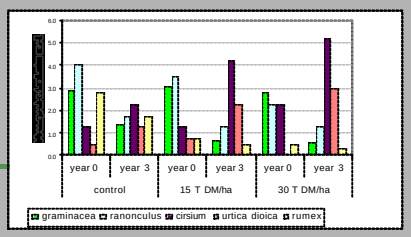
Understory response



Liquid sludge (2.89 T/ha) | Control (0.98 T/ha) | Composted sludge (1.67 T/ha)

AFOCEL project of forest application of pulp and paper sludge: *first results after 3 years*

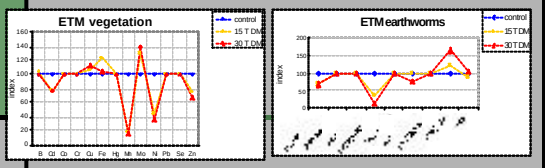
Change in composition of understory vegetation



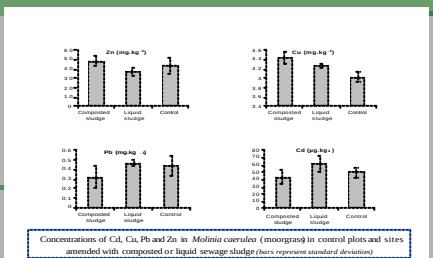
AFOCEL project of forest application of pulp and paper sludge: *first results after 3 years*

low levels of MTE in the vegetation and in the earthworms

but the assimilation depends on the element

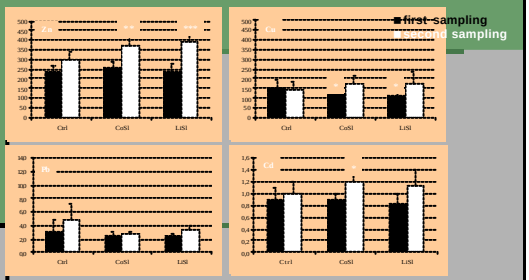


Transfer of MTE in vegetation



Concentrations of Cd, Cu, Pb and Zn in *Molinia caerulea* (moorgrass) in control plots and sites amended with composted or liquid sewage sludge *(bars represent standard deviation)*

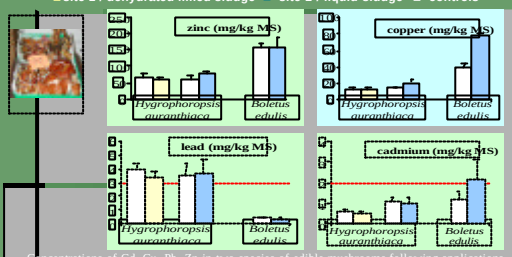
Transfer of MTE to snails



Concentrations (µg.g⁻¹ dry mass) of Cd, Cu, Pb and Zn in whole soft body of *H. aspersa* snails exposed to non amended soil (Ctrl) or soils amended with composted (CoSl) or liquid (LiSl) sewage sludge. *, ** and*** indicate group(s)significantly different from control with $p < 0.05$, $p < 0.01$ and $p < 0.001$ respectively.

transfer to edible mushrooms

■ site 1 / dehydrated limed sludge ■ site 2 / liquid sludge ■ controls



Concentrations of Cd, Cu, Pb, Zn in two species of edible mushrooms following applications of sewage sludge in maritime pine stands in SW France
(bars represent standard deviation - red line for European limits for cultivated mushrooms)

Conclusive remarks

after 4 yrs (2 x 6 TDM)

- improved tree nutrition and increased biomass
- changes in soil surface and pH
- accumulation phase for all MTE
- leaching of nitrogen
- changes in understory diversity
- limited transfer in mushrooms and vegetation
- acceptability for liquid and composted sludge

General conclusions

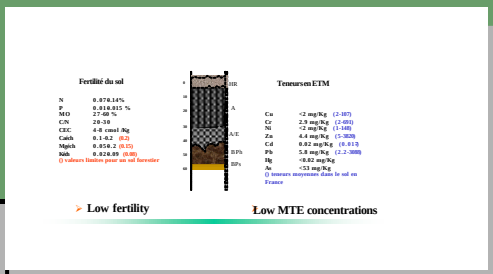
- field of scientific interest at interfaces between disciplines
- evolving issues (contaminants) and societal questions (forest environmental functions)
- requires better co-ordination of research efforts between countries
- develop integrated experimental approaches
- need to improve linkages between bio-wastes, soil protection and renewable energy strategies

Characteristics of sludge/Ychoux

Parameter	*Compost*	*Liquid*
pH_{water}	6.67	6.63
Dry matter (%)	48.10	2.37
N (%DM[a])	2.10	6.70
P (%DM)	1.11	2.96
K (%DM)	0.62	1.23
Ca (%DM)	4.46	1.64
Mg (%DM)	0.32	0.62
Fe (%DM)	1.69	0.36
Cd ($mg.kg^{-1}$) *10*	0.89	1.53
Cu ($mg.kg^{-1}$) *1000*	172	227
Ni ($mg.kg^{-1}$) *200*	34.5	18.8
Pb ($mg.kg^{-1}$) *800*	45.3	37.5
Zn ($mg.kg^{-1}$) *3000*	386	704

[a] DM: dry matter *b/ threshold concentration in sludge*

Characteristics of soils



➢ Low fertility

Low MTE concentrations