Lessons learnt towards sustainable resource loops, and remaining challenges

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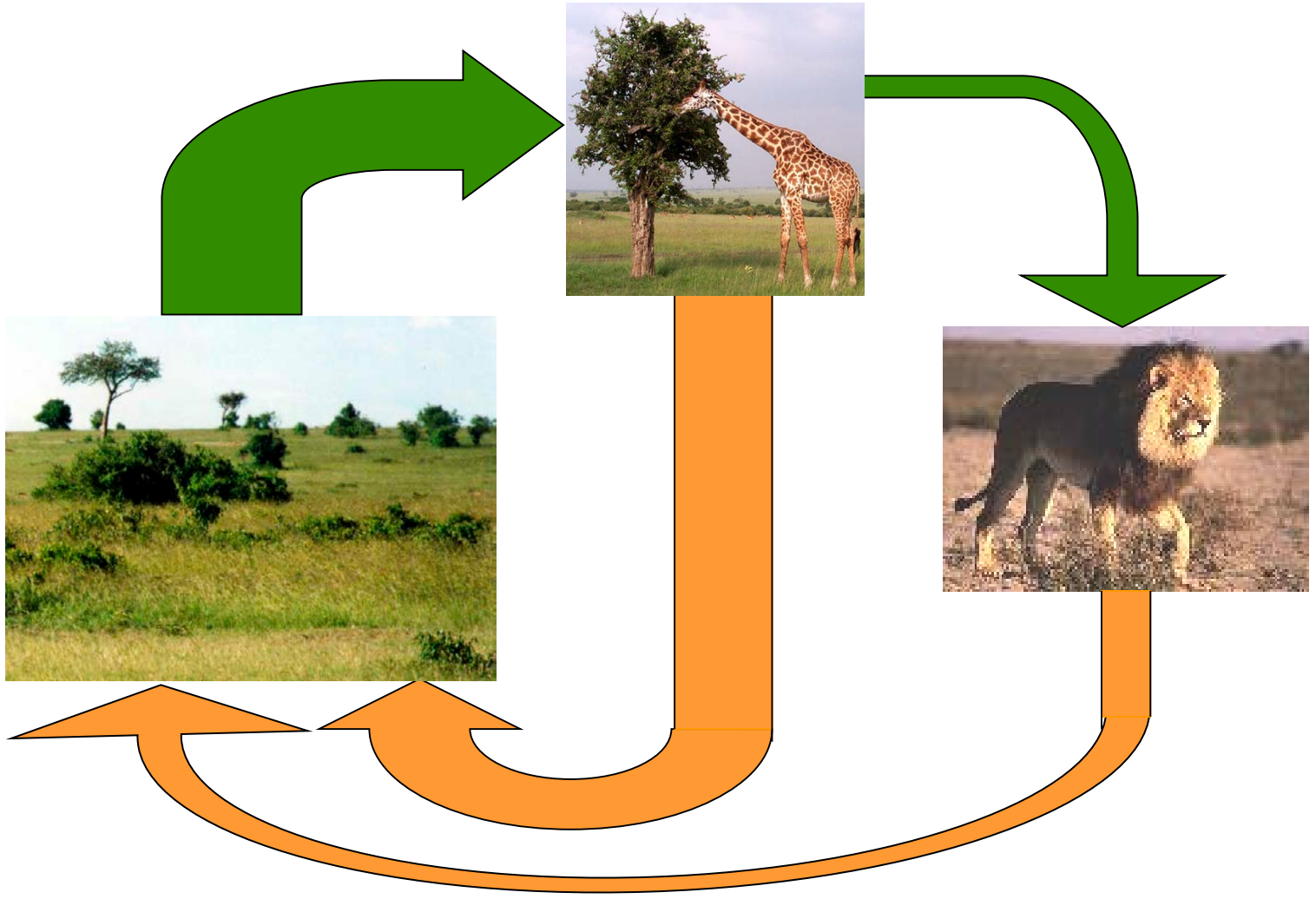
Vision - sustainable loops of nutrients



Environmental Engineering group

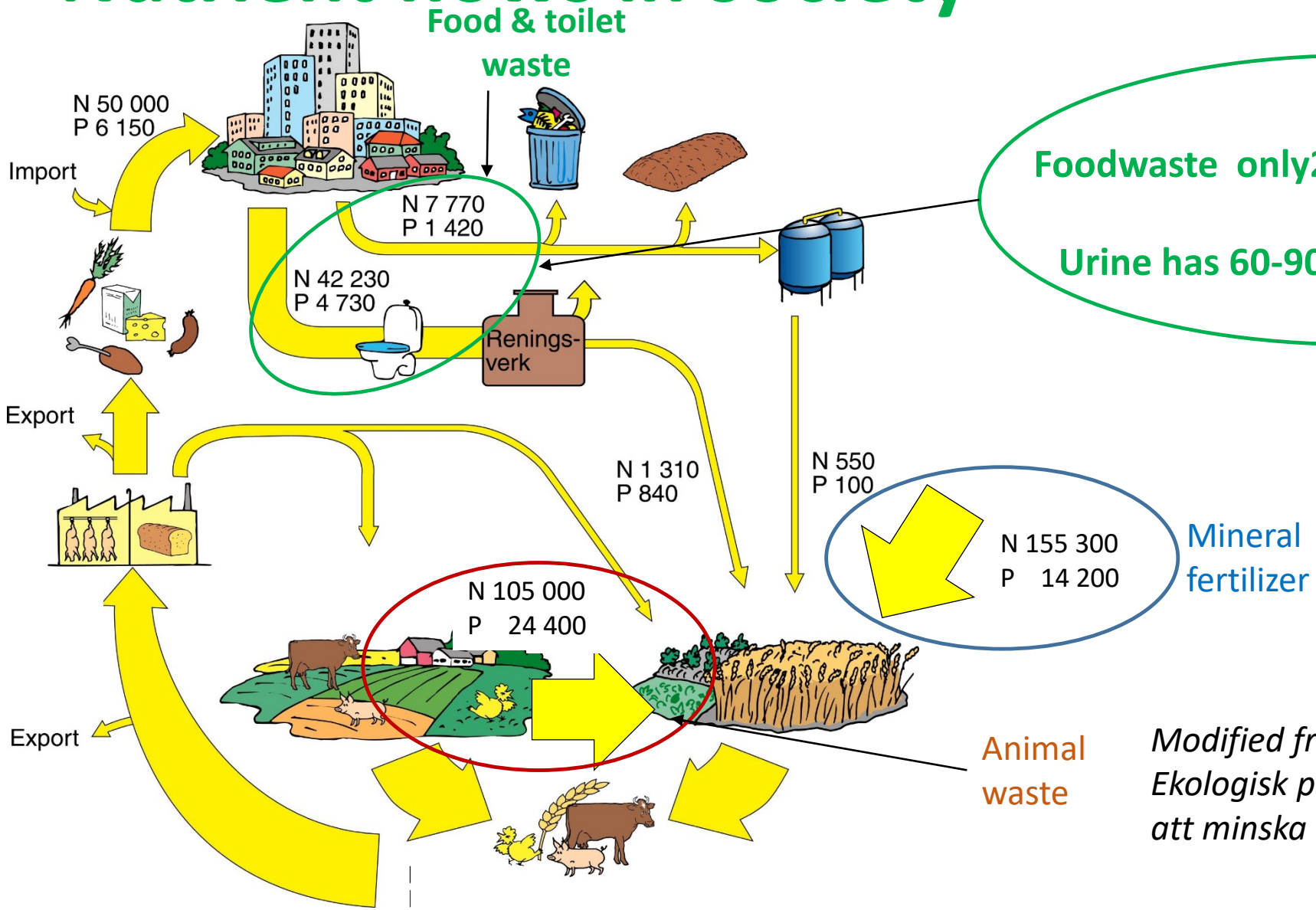
Vision

Safe use of the resources in food chain related waste (manure & crop residues, toilet & food waste).

Our task

To improve the knowledge on safe and efficient systems for using the resources in toilet & food waste, in manure & crop residues

Nutrient flows in society



Foodwaste only20-30% of toilet waste

Urine has 60-90% of toilet nutrients

Modified from: Wivstad et al. 2009. Ekologisk produktion – möjligheter att minska övergödning.

Food waste composting – large scale

- **Start up tricky**:
  pH <6.5 & temperature >46°C

  → Inhibited - halted process

  Sundberg. 2005; Sundberg et al. 2004.

  → Bad odour

  Sundberg et al. 2013.

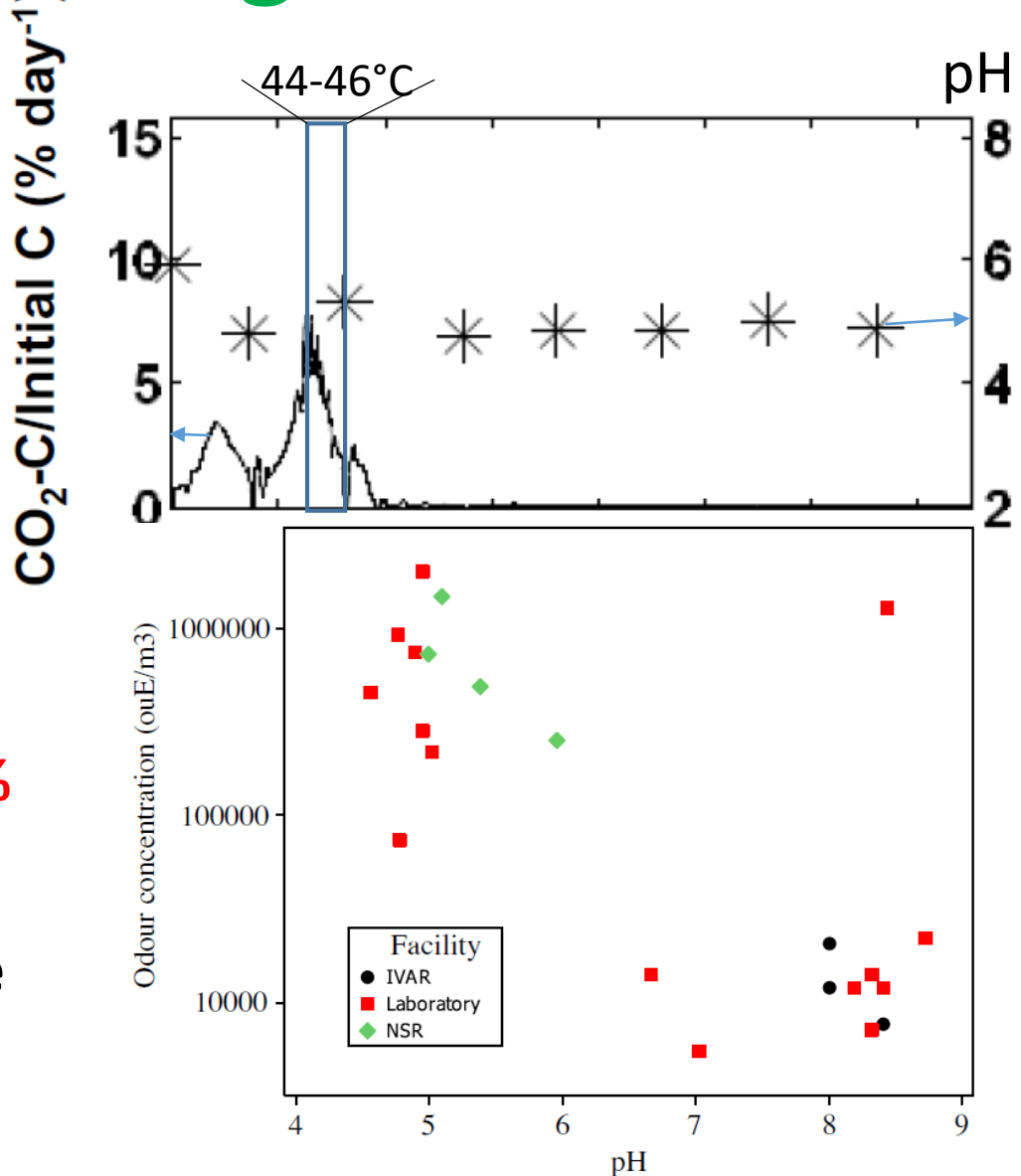
- **CH_4 emissions increases with water content**

  → 1000 times as moisture from 43% to 66%

  Ermolaev et al. Manuscript

- **N_2O emissions generally decreases with moisture**

  Ermolaev et al. Manuscript.



Home composting

- **CH_4 emissions low**
  - also at high moisture content
  - mix seldom or not at all.
- **N_2O emissions** continuous

→ Be lazy & use compost quickly

Ermolaev et al. 2014; Ermolaev. 2015

Faecal waste composting

- **Temperatures >50°C possible** (WHO requires >1 week)
- **Startup challenge – energy & water critical**
  - **→ add food waste!**
  - **→ insulate compost reactor**
  - **→ compost experience and understanding!**
- **Quick & good sanitization possible**

Vinnerås et al. 2003; Niwagaba. 2009; Niwagaba et al. 2009a; Niwagaba et al. 2009b

Urine diversion – urine diverted at source – efficient and simple technology

- **Can recycle ~80% N, ~60% P and K in household wastewater**
  Jönsson et al. 2005; Ek et al. 2014.
- **Urine - unique complete biofertilizer** high plant availability, easily applied & low heavy metals
  Jönsson et al. 2000; Jönsson et al. 2005
- **Technical challenge - Blockages** – avoided by maintenance
  Jönsson et al. 2000; Kvarnström et al. 2006
- **Socioeconomic challenges**
  -Urine handling systems lacking
  -**Acceptance**
  - toilet supply
  McConville et al. 2017

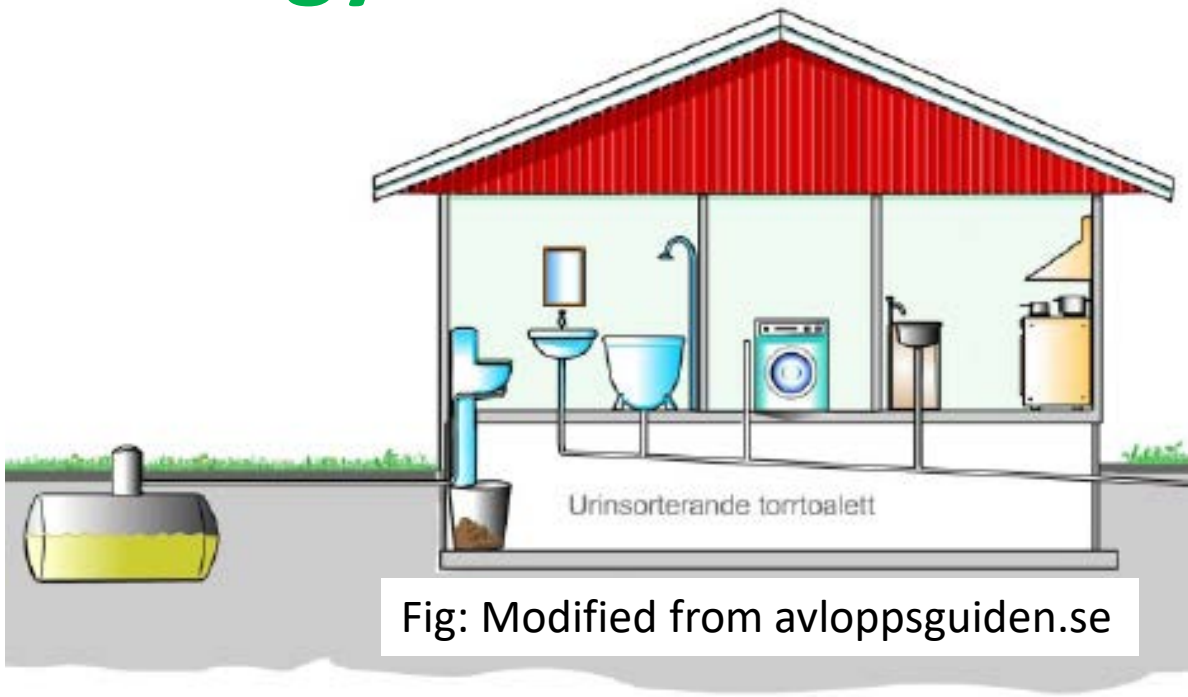
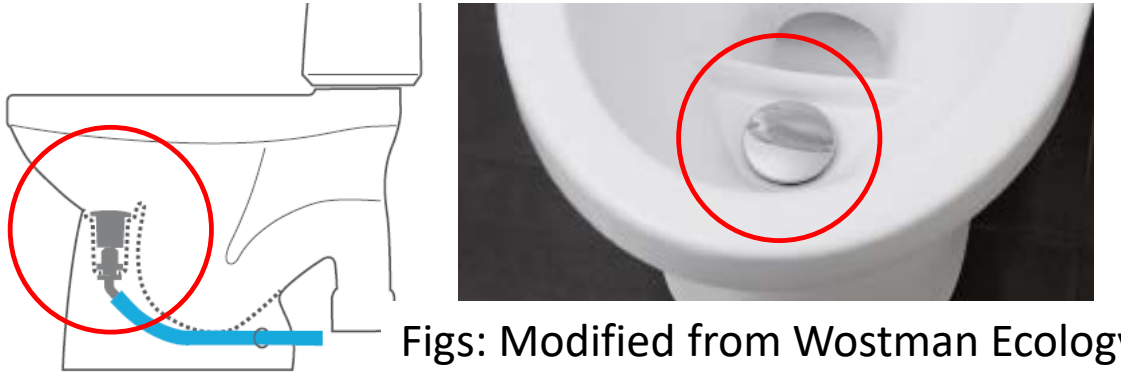


Fig: Modified from avloppsguiden.se



Figs: Modified from Wostman Ecology AB

Blackwater – source separated

- **Recycling potential ~85-90% N, P and K in household wastewater**
  Jönsson et al. 2005; Ek et al. 2014.
- **Complete biofertilizer**
  high plant availability (urine)
- **Ammonia sanitized by urea addition**
  Fidjeland et al. 2015.
- **Pharmaceutical dose – a problem?**
  - Pesticide doses ~1000 times larger
    Jönsson et al. 2013
  - Similar amounts as with sewage sludge &
    Simple simulation shows negligible risk
    Levén et al. 2016;

  → Probably socially but not for health or environment!

Urine & blackwater NPK ratios fit crop removal

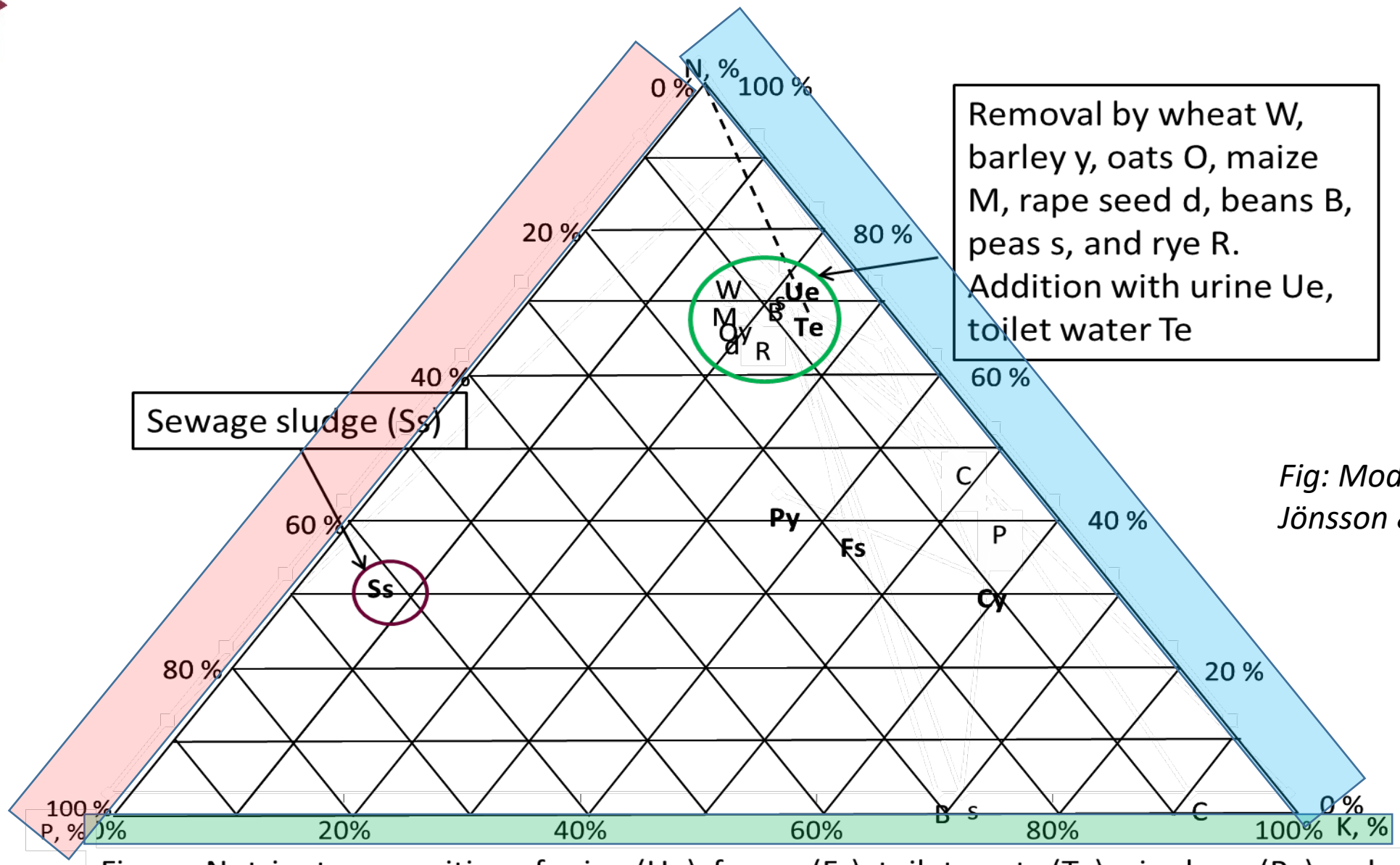


Fig: Modified from Jönsson & Vinnerås. 20

Figure. Nutrient composition of urine (Ue), faeces (Fs), toilet waste (Te), pig slurry (Py) and cattle slurry (Cy), sewage sludge (Ss) and nutrients removed by crops.

Greywater

- **Small flows of N & P**
- **BOD_5:N:P 100:5:0.8**

  Jönsson et al. 2005; Ek et al. 2014

  → Near optimum for activated sludge treatment
  → Source separation improves WWTP performance

  Wilsenach. 2006; Wilsenach & van Loosdrecht. 2003

  → Treated on site, risk of serious pollution is low

- **Charcoal and filters have high capacity**
- **Treated greywater is a reliable source for irrigation**

  Dalahmeh. 2013; Dalahmeh et al. 2014; Dalahmeh et al. 2016

Environmental effects - blackwater separation

Median values of 6 systems analyses 2010-

+**Saved primary energy** (-26%*), largely due to N recycled, not removed.

+**Decreased GHG emissions** (-38%*), largely due to N recycled, not removed.

+**Decreased eutrophication** (-29%*)

+**Increased recycling** of N, P, K, S etc. & organics

* *Median of values given by Kärrman et al. 2012, Remy. 2010, Spångberg et al. 2014, Tervahauta et al. 2013, Vidal. 2014, Wittgren et al. 2011*

Environmental effects – urine diversion

Median values of 5 systems analyses 2010-

+**Saved primary energy** (-41%*), mainly due to N recycled, not removed

+**Decreased GHG emissions** (-25%*), mainly due to N recycled, not removed.

+**Decreased eutrophication** (-26%*)

+**Increased recycling** of N, P, K, S etc.

* *Median of values given by Kärrman et al. 2012, Remy. 2010, Spångberg et al. 2014, Tervahauta et al. 2013, Wittgren et al. 2011.*

Which nutrients are best to recycle?

Meat meal (MM), Blackwater (TB), Urine (TU), Digested foodwaste (DF), Composted mussels (MC) or Acidified Mussels (MA)

Table 4. *Organic fertilisers studied in* ***Papers I-IV*** *compared with the reference scenario, with use of chemical fertiliser. + = ≥20% better, - = ≥20% worse, 0 = <20% difference*

Scenario	MM	TB	TU	DF	MC	MA
Primary energy use	-	+	+	-	+	+
GWP	+	+	+	-	-	0
Potential eutrophication	-	-	-	-	-	0
Potential acidification	0	-	-	-	-	-
Cadmium	0	-	+	-	+	0

Spångberg. 2014;

Summary
source separate and recycle urine and faeces!!

Urine and faeces:

- largest urban nutrient flow

Properly treated and recycled urine and faeces:

- gives large environmental gains (energy, GWP, eutrophication)
- decreases risks of pharmaceuticals and hormones
- decreases hygiene risk
- can save money

Remaining challenges

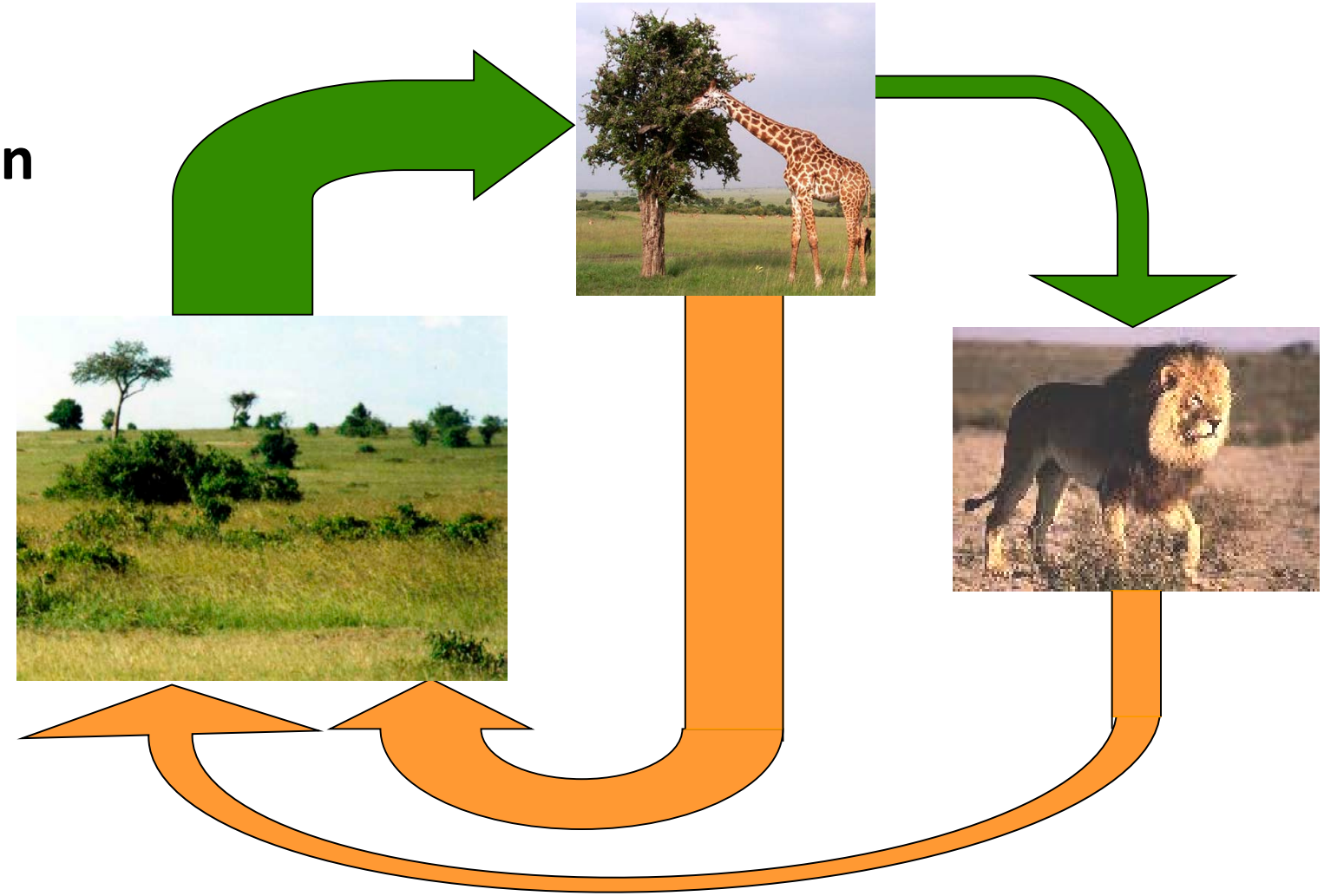
- **Bioeconomic strategy not yet implemented**
  - National recycling goal lacking for both nitrogen and phosphorus!
  - Incentive for recycling wastewater resources low!
- **Convince SLU of our subjects strategic importance!**
- **Safe & efficient recycling systems** that are
  - **socially & legally preferable,** at least acceptable
  - **profitable**, or at least decreases costs
  - **mainly on site**:
    → less need for infrastructure (hardware & laws, organisations etc.)
    → in line with polluter pays principle

Thank YOU for listening, PhD students & researchers for contributions!

Lets all strive towards:

Safe use of the resources in food chain related waste!!

Time for quick questions?



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