Harvest to Harvest

Recovering Nitrogen, Phosphorus and Organic Matter via New Sanitation Systems for Reuse in Urban Agriculture

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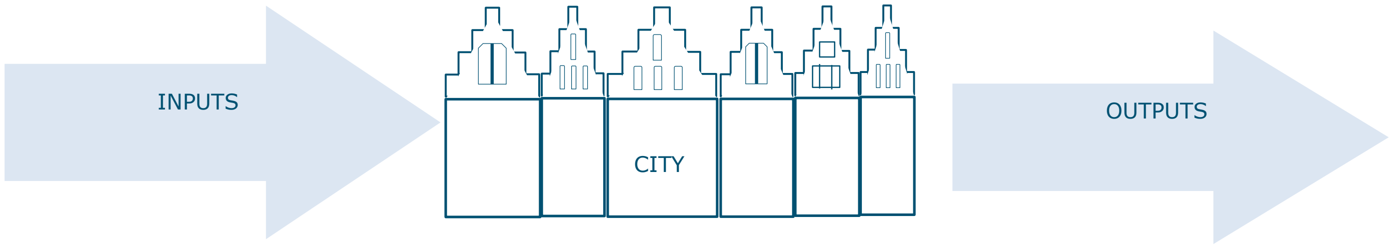
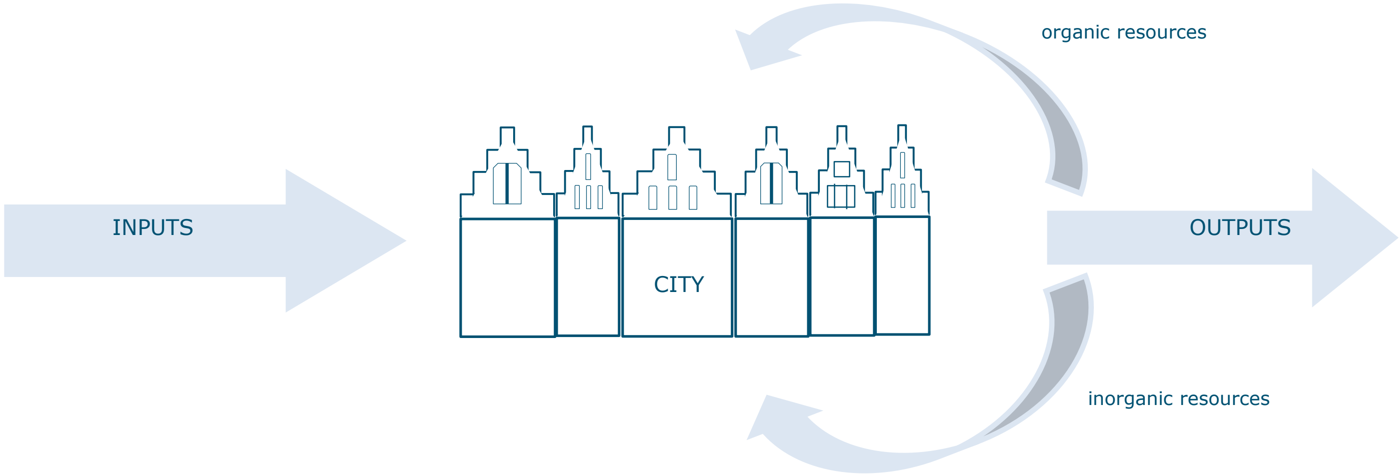
Cities: the problem



- More than half of the world’s population
- Hotspots for resource conversion
  - High quality inputs; Low quality outputs
- Linear metabolism

Cities: the solution



- Opportunity: link resource flows between urban functions (ie. Residential, commercial, industrial)
- Match input-output flows
- Circular metabolism

Urban Agriculture + New Sanitation

Urban Agriculture New Sanitation

Local food provisioning
Community health
Employment
Temporary land-use
Reusing waste

Decentralized
Source separated
Small-scale infrastructure
Reduce water use
Resource recovery

Demand: nutrients, water, and energy

Supply: nutrients, water, and energy

Focus and Objectives

- Nutrients: Nitrogen (N), Phosphorus (P), and Organic Matter (OM)
- Rotterdam, the Netherlands
- Domestic waste and wastewater
- Quantity and quality of demand and supply

Objective 1: To determine appropriate systems for the recovery of nutrients and organic matter from urban residual streams for reuse in urban agriculture.

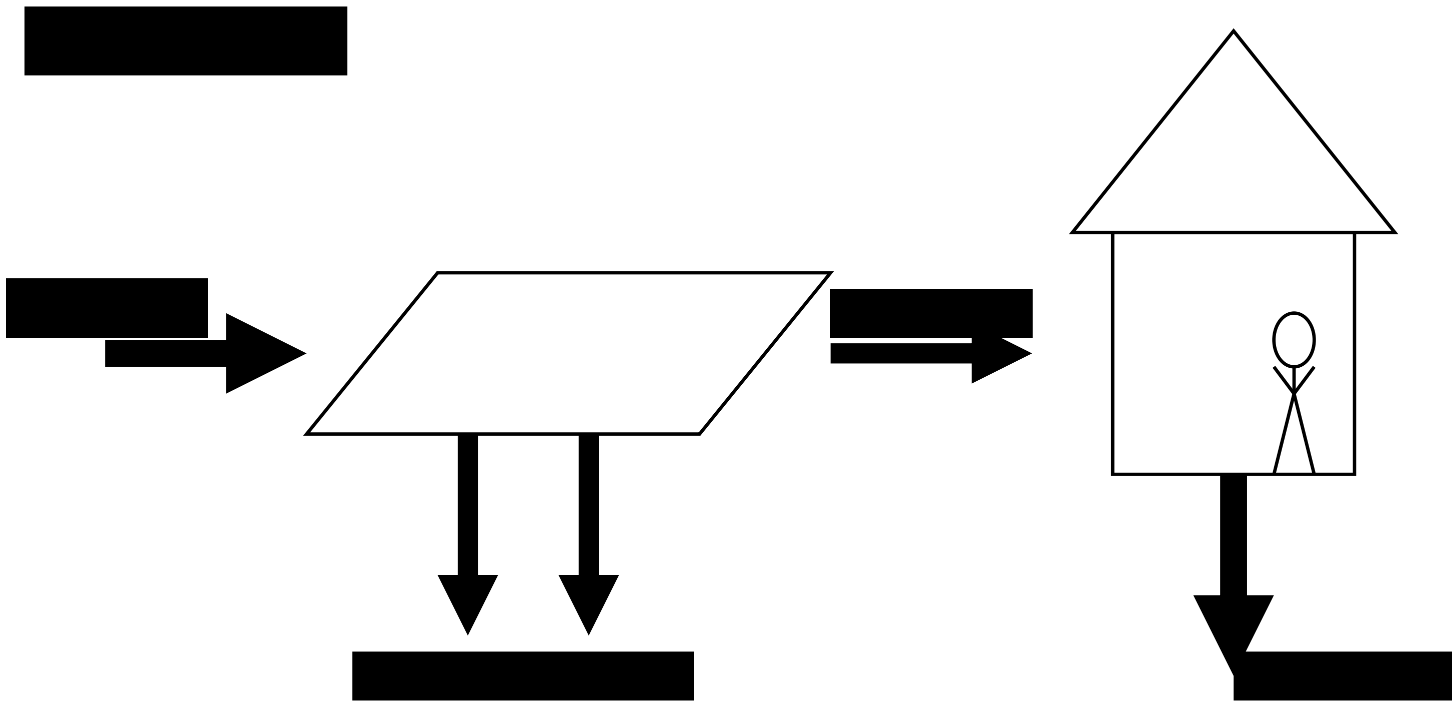
Objective 2: To quantify the degree of self-sufficiency of resource flows of combined urban agriculture and new sanitation systems.

Urban Harvest Approach

- A multi-scale approach
- For sustainable urban resource planning
- To increase resources self-sufficiency
- Via three management strategies
  - Demand minimization
  - Output minimization
  - Multi-sourcing"

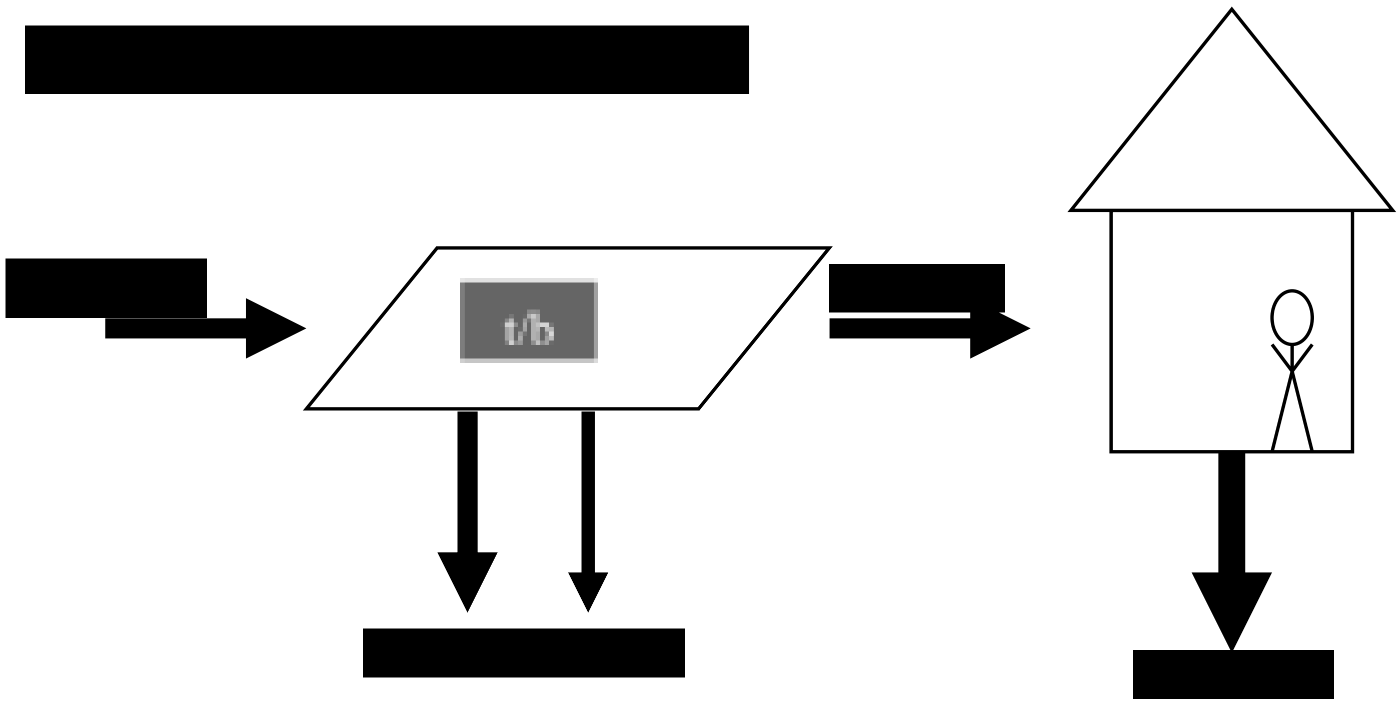
(Agudelo-Vera et. al. 2012)

Urban Harvest Approach



(adapted from Agudelo-Vera et. al. 2012)

Urban Harvest Approach

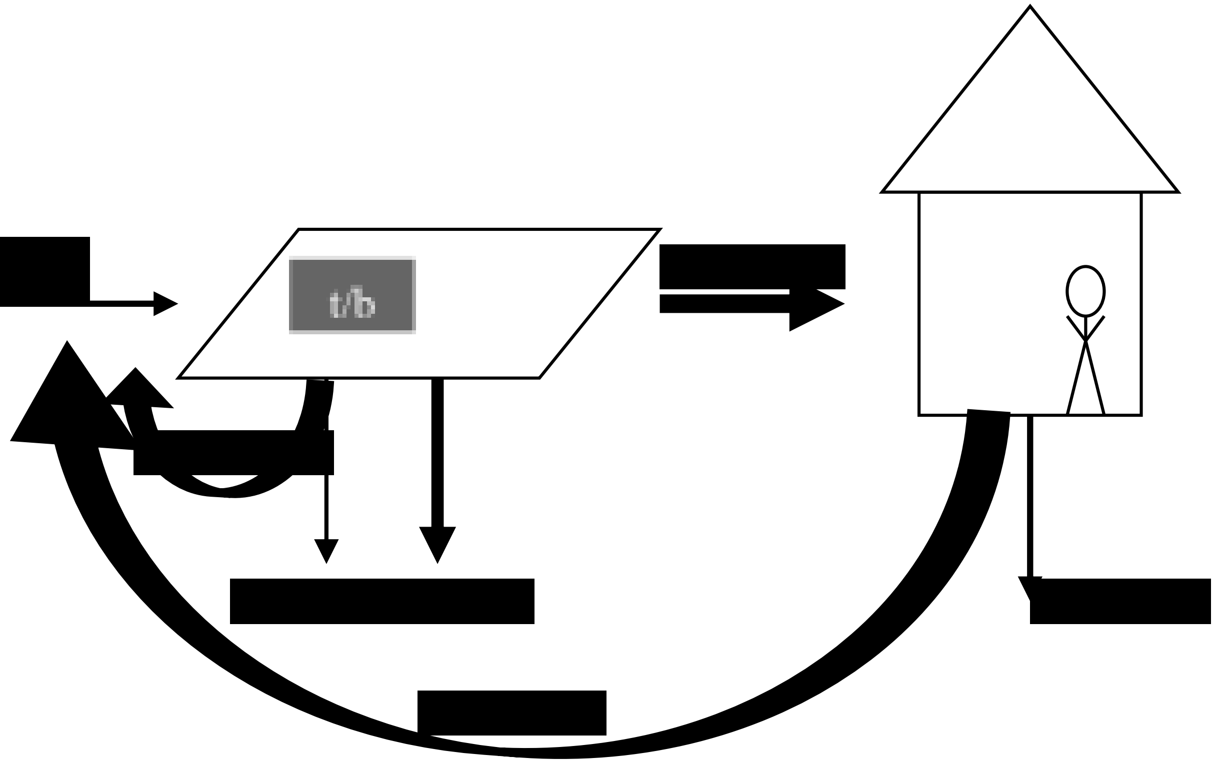


$$MI = \frac{Baseline\ demand\ (D_o) - Minimized\ demand\ (D)}{Baseline\ demand\ (D_o)} * 100$$

(adapted from Agudelo-Vera et. al. 2012)

Urban Harvest Approach

2) Output Minimization



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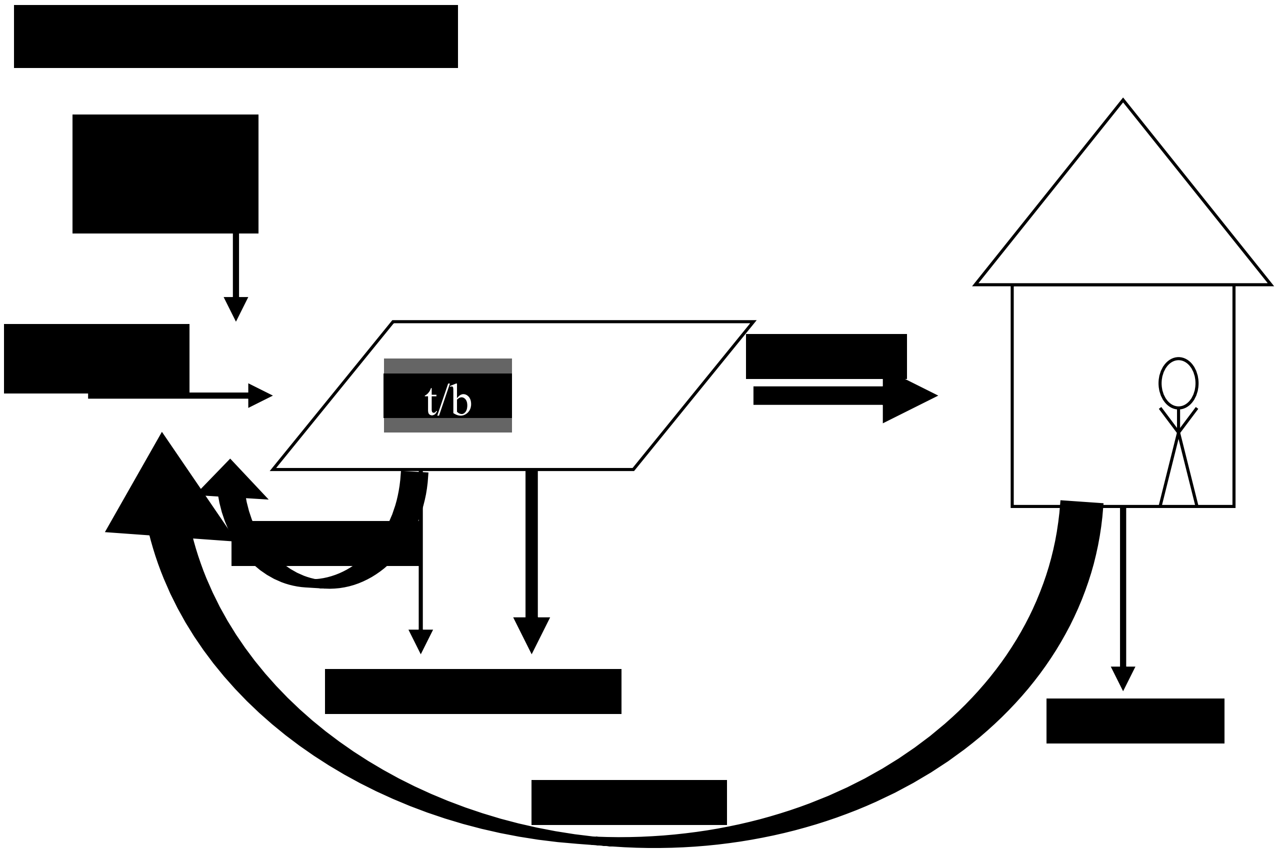
Urban Harvest Approach



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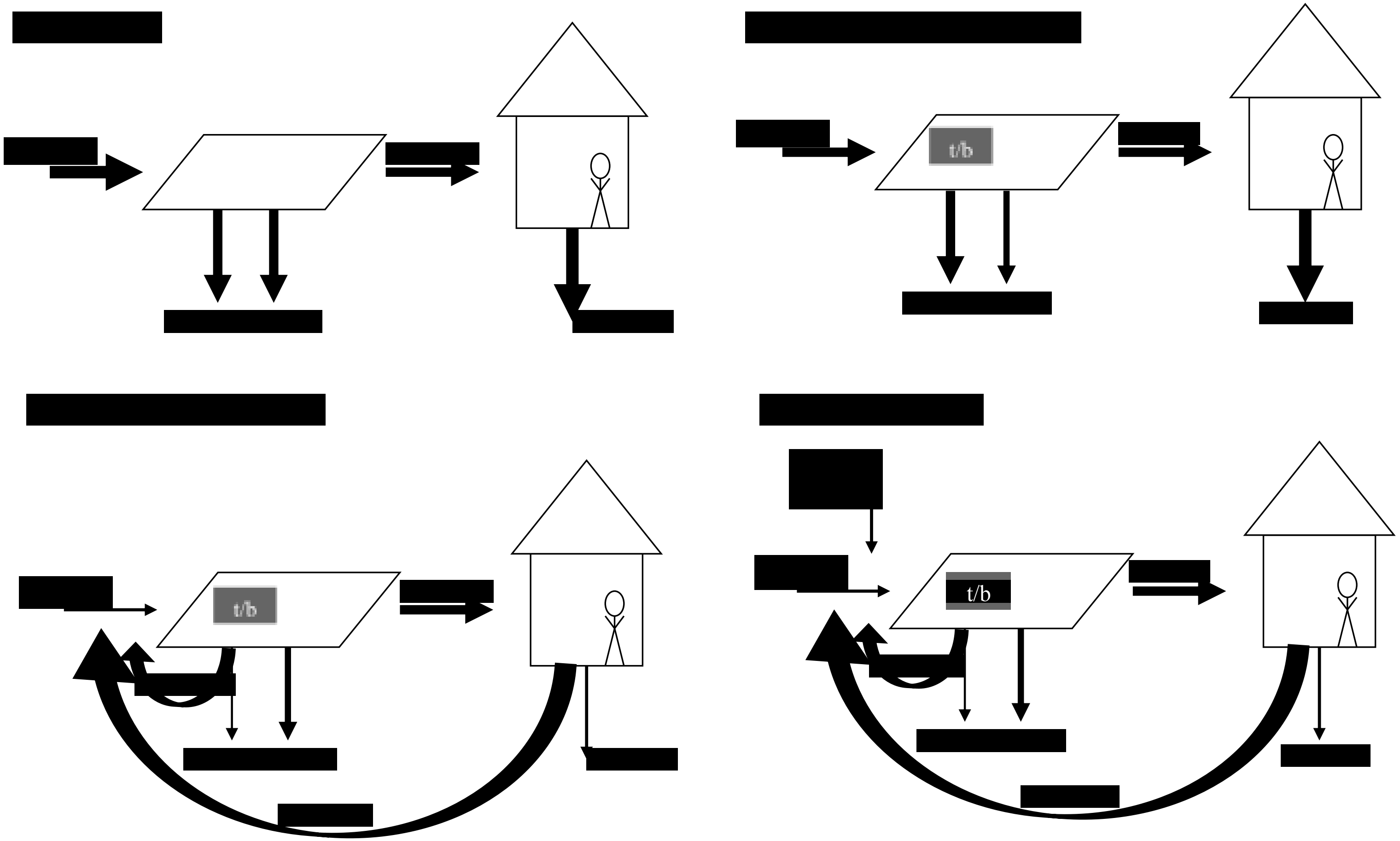
Urban Harvest Approach



$$SSI = \frac{Resources\ reused\ (Rr)}{Minimized\ demand\ (D)} * 100$$

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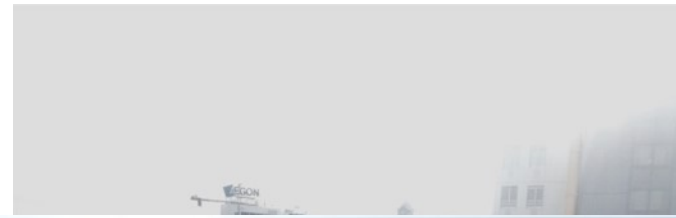
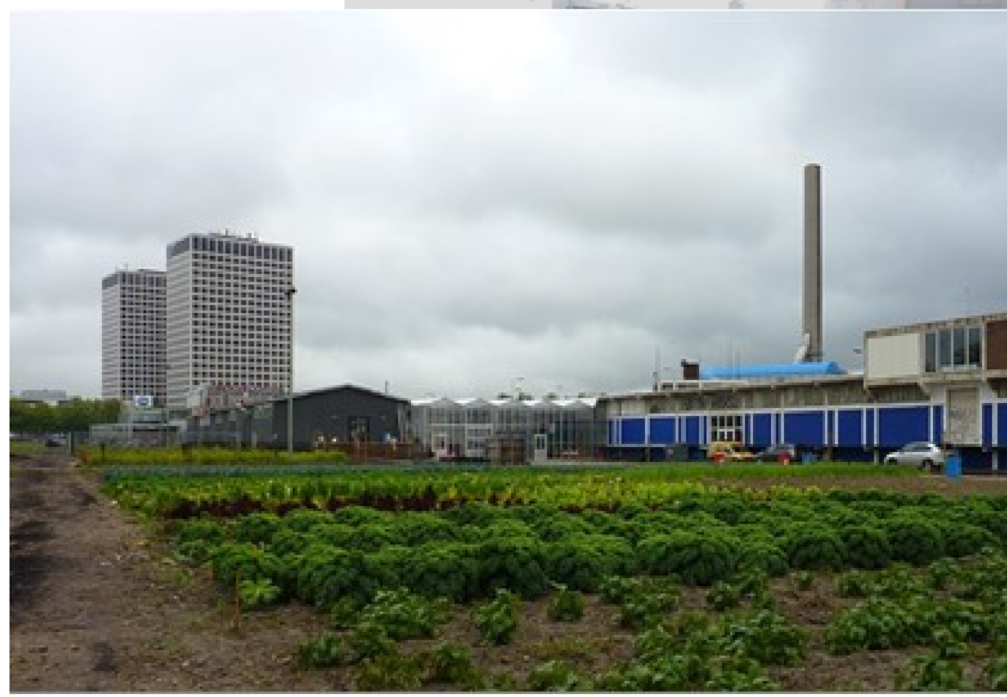
Urban Agriculture Typologies

- Ground-based
    - Uit Je Eigen Stad
- Rooftop
    - De DakAkker





Minimized Demand Ground-based UA

	Nutrient and Organic Matter Demand				
	kg/ha/yr				
	N total	N available	P_2O_5 total	P_2O_5 available	Organic Matter[3]
UIT JE EIGEN STAD					
TOTAL DEMAND UJES	**330.6**	**110.8**	**253.3**	**221.1**	**7861**
CONVENTIONAL NORMS AND REGULATIONS	-	178.3	-	65	-
EQUILIBRIUM FERTILIZATION	-	202.7	-	32.2	-

MINIMIZED DEMAND	**172**	**108.7**	**47.4**	**32.2**	**2685**
DMI	N.A.	2%	N.A.	85%	66%

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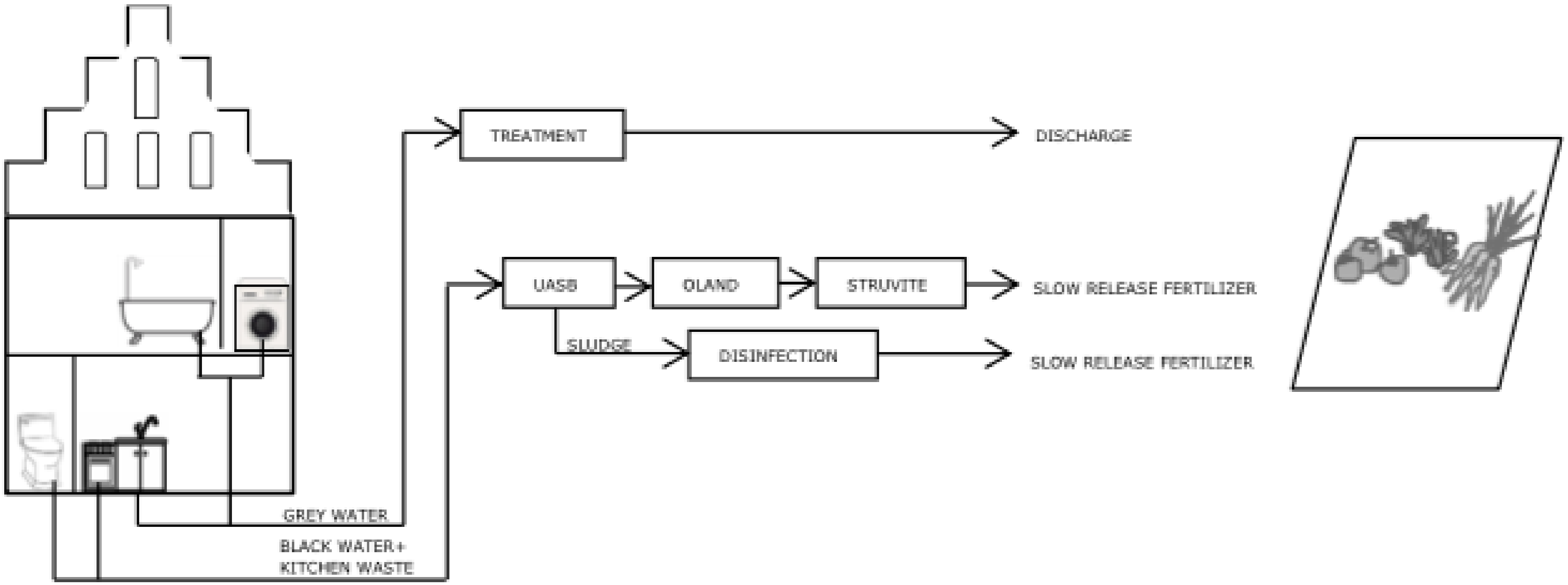
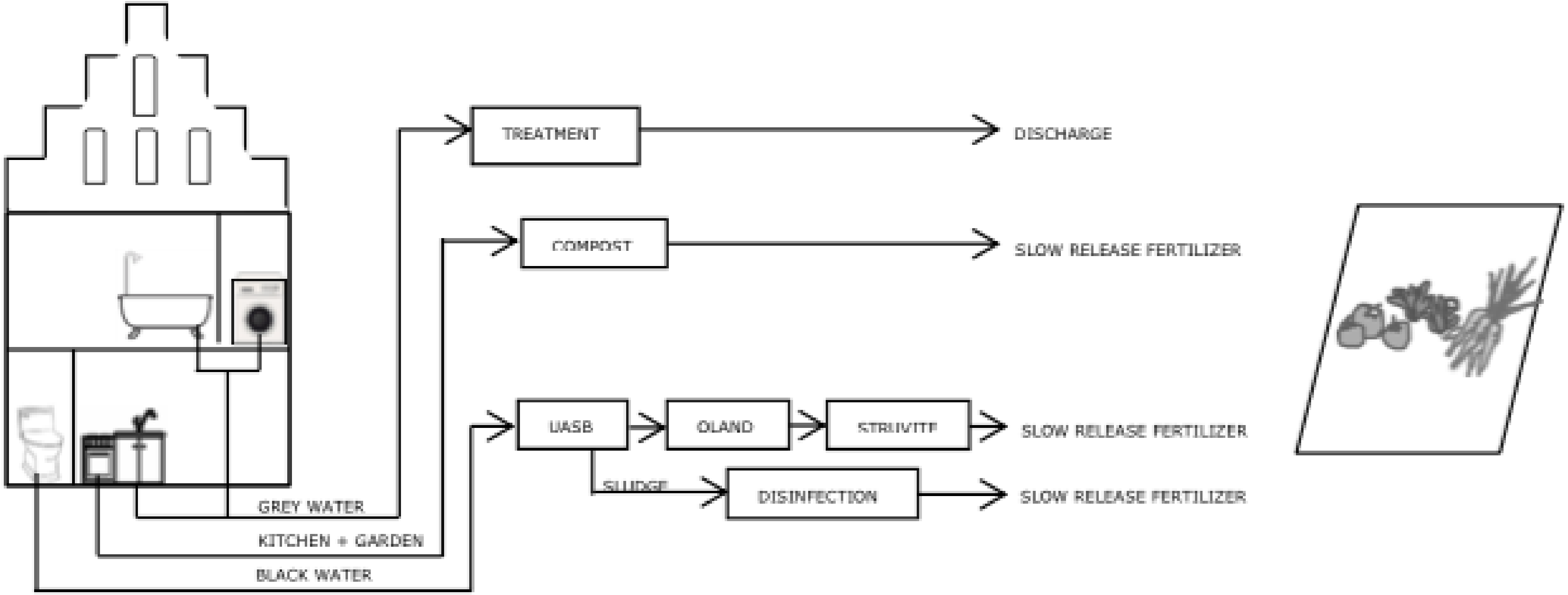
Concept 1

- Feces, urine, kitchen: UASB+OLAND+struvite+sludge disinfection



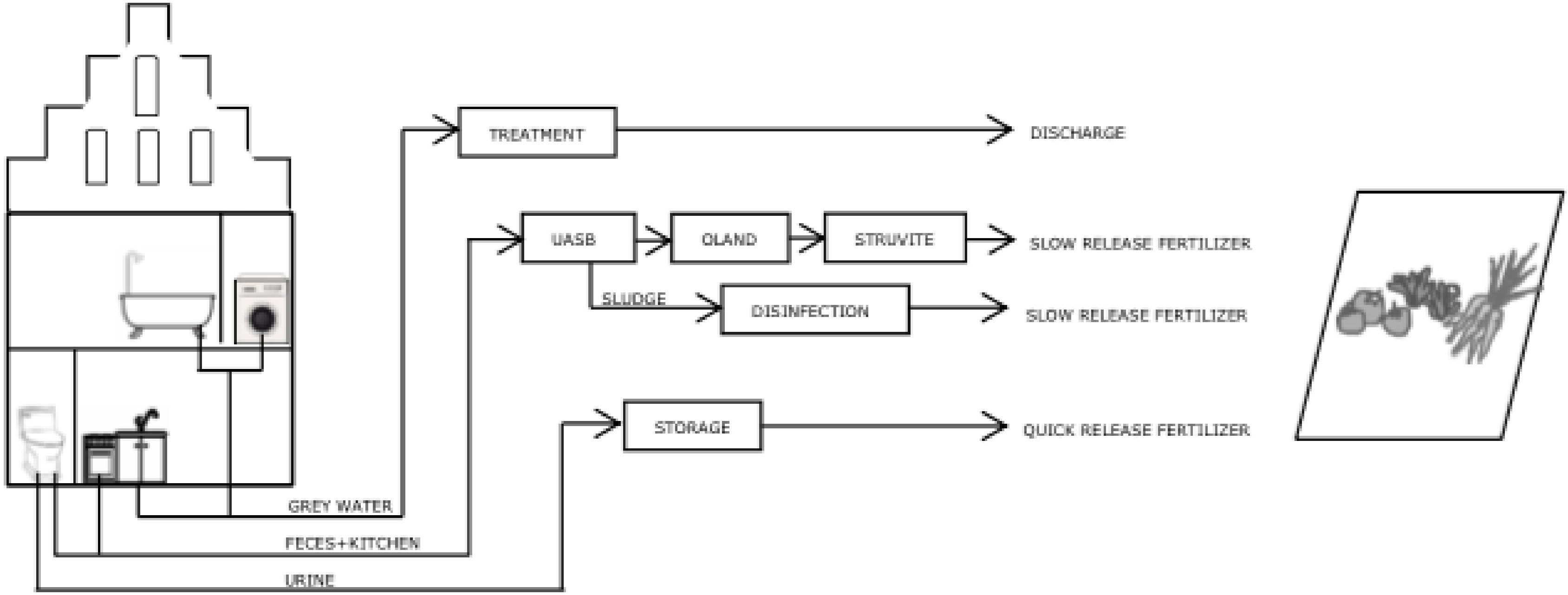
Concept 2

- Feces, urine: UASB+OLAND+struvite+sludge disinfection
- Kitchen, yard waste: composting



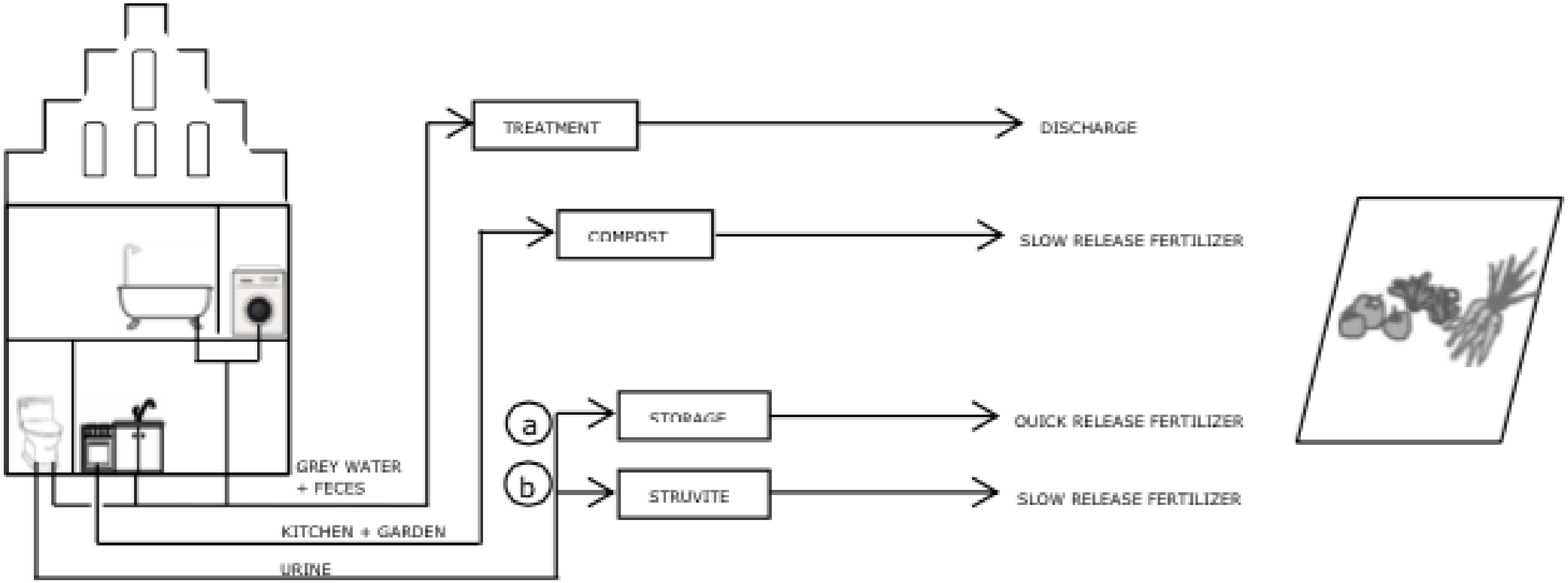
Concept 3

- Feces, kitchen: UASB+OLAND+struvite+sludge disinfection
- Urine: storage



Concept 4a & 4b

- Urine: storage (a) or struvite precipitation (b)
- Kitchen, yard waste:composting

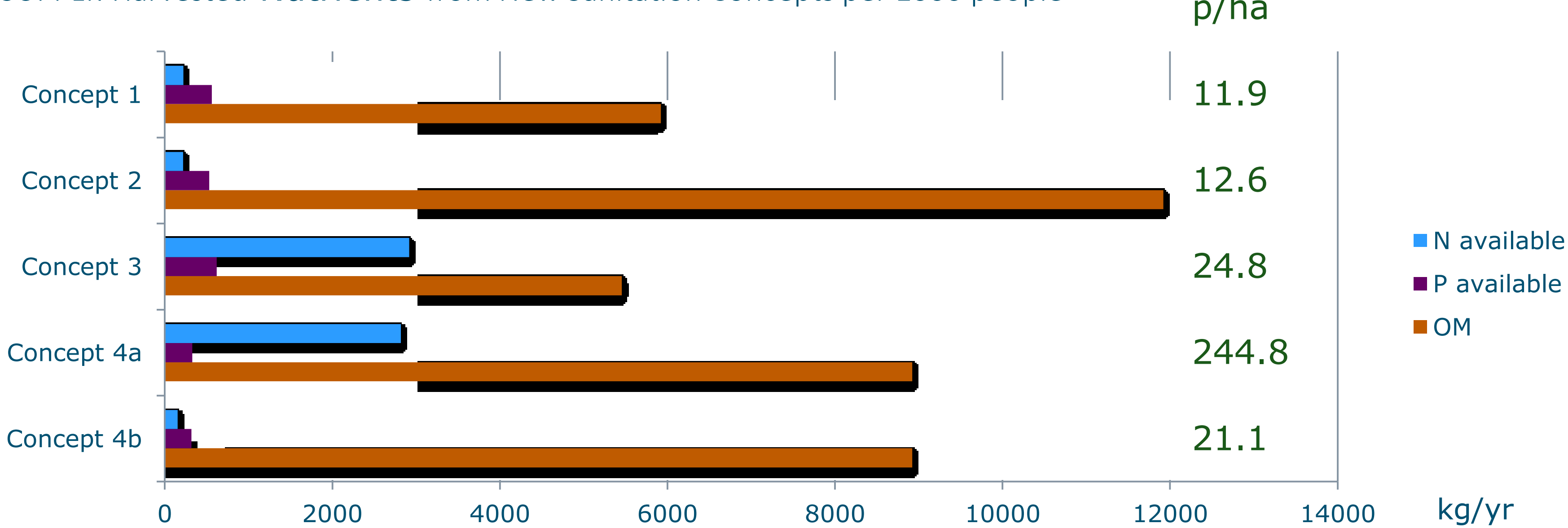


Matching the Demand

DEMAND

N (available): 108.7 kg/yr
P (available): 14.2 kg/yr
OM: 2685.0 kg/yr

SUPPLY: Harvested **Nutrients** from New Sanitation Concepts per 1000 people

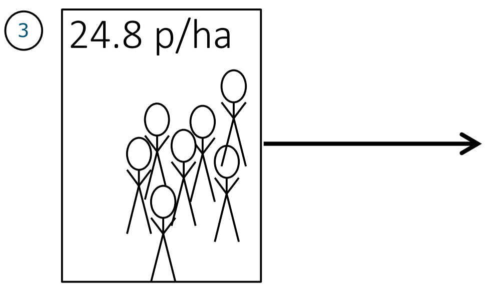


Self-Sufficiency per hectare

DEMAND

N (available): 108.7 kg/yr
P (available): 14.2 kg/yr
OM: 2685.0 kg/yr

SUPPLY



N (available): 72.0 kg/yr
P (available): 14.2 kg/yr
OM: 115.0 kg/yr

Self-Sufficiency Index

N: 52.4%
P: 100%
OM: 4.3%

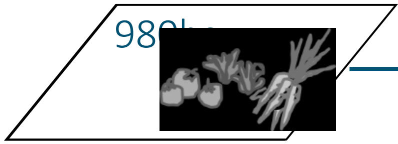
$$SSI = \frac{Resources\ reused\ (Rr)}{Minimized\ demand\ (D)} * 100$$

Case Study: Rotterdam

- Rotterdam population: 616,319
- Recommended daily vegetable intake: 200g/p/d
- Yearly marketable harvest: 46,000kg/ha
- Therefore…
    - 980ha to feed Rotterdam
    - 24,300 people needed (Concept 3) for 980ha

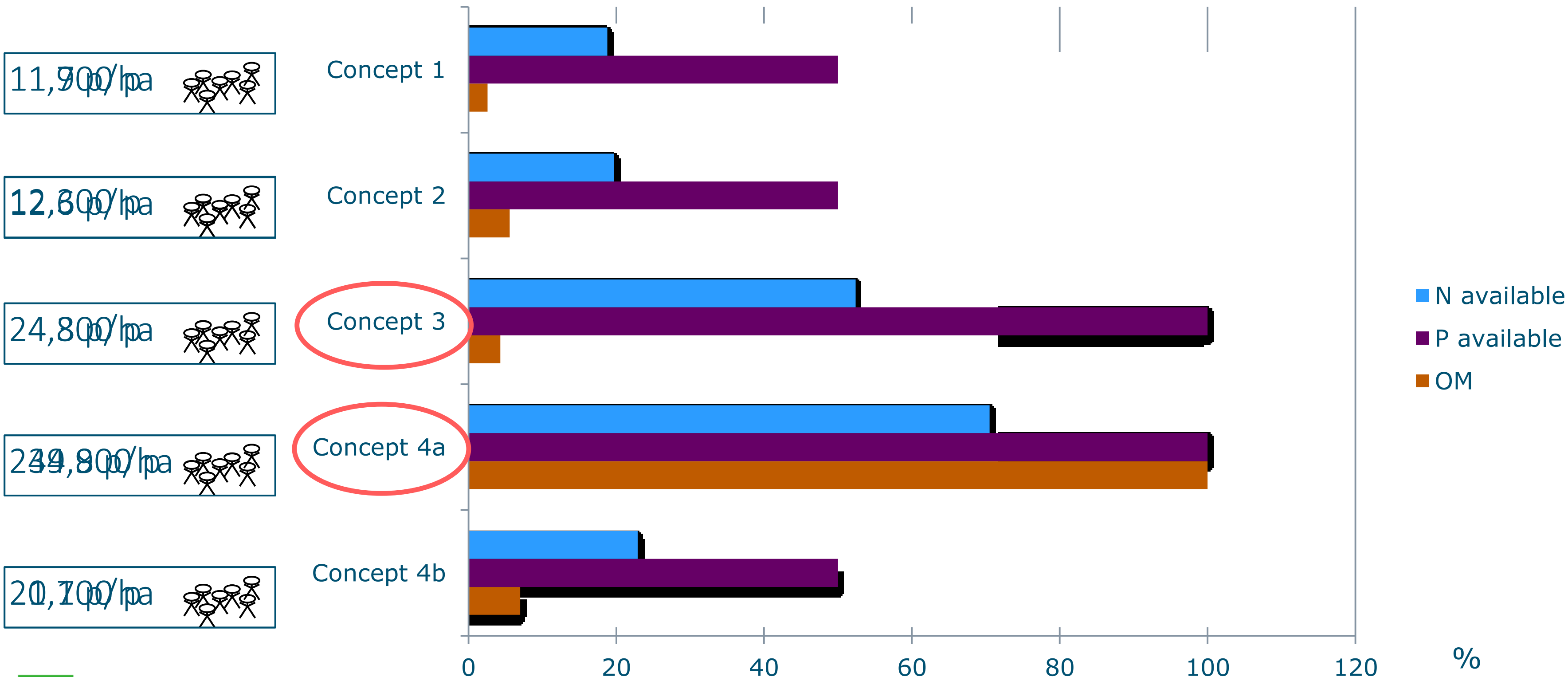
Best Concept for Rotterdam?

DEMAND



N (available): 108.7 kg/yr
P (available): 14.2 kg/yr
OM: 2685.0 kg/yr

SUPPLY: Self-Sufficiency in N, P and OM for New Sanitation Concepts



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Conclusion

- Urban agriculture over fertilizes phosphorus
  - Need regulations? Equilibrium fertilization?
- Urban agriculture + new sanitation = ⇧ Self-sufficiency
- 24.8 people/ha could gain 100% self-sufficiency in P
- Combination promising. Integration possible?

Further Research…Input Welcome!

- Nutrient availability to plants
- The evaluation of NS concepts
  - Criteria and indicators, cost-benefit
- Patterns at spatial and temporal scales
  - Ex. Urine storage
- Interlinked resource flows
  - Water and nutrients? Energy?

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