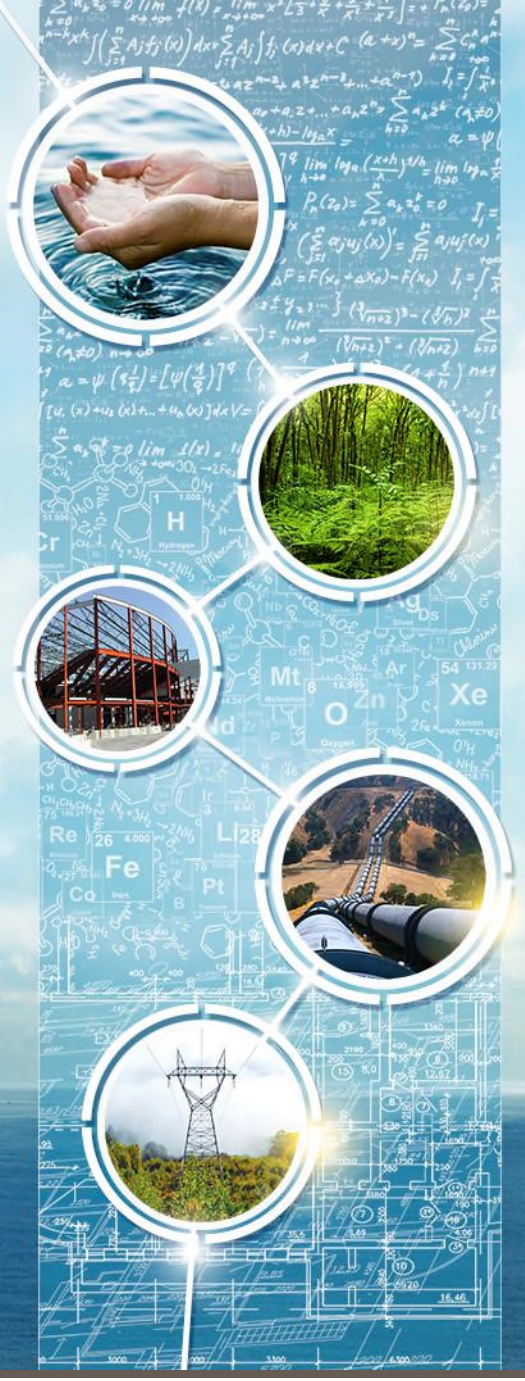

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Putting the Use back in Reuse

January 16, 2016

Bobby Tucker, PE

Management of Complexity

"Among the illusions which have invested our civilization is an absolute belief that the solutions to our problems must be a more determined application of rationally organized expertise.

The division of knowledge into "feudal fiefdoms of expertise" has meant that general understanding and coordinated action are increasingly difficult and often looked upon with suspicion, as evidenced by our systems of education which reward the specialist and disdain the generalist.

It has also resulted in a fracturing of society into smaller and smaller and increasingly insulated professional groups."

Human Endeavors vs. Challenges

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Mechanical/Technological

Development of:

- Transportation
- Computers
- Communication
- Weaponry
- Medical tech
- Genetic engineering
- Chemistry

Nonmechanical/Complex

Management of:

- Agriculture
- Water/air quality
- Land/soil management
- Economies
- Wildlife (including insects)
- Human relationships
- Government
- Human health

Facing Reality: "The Giant Elephant"

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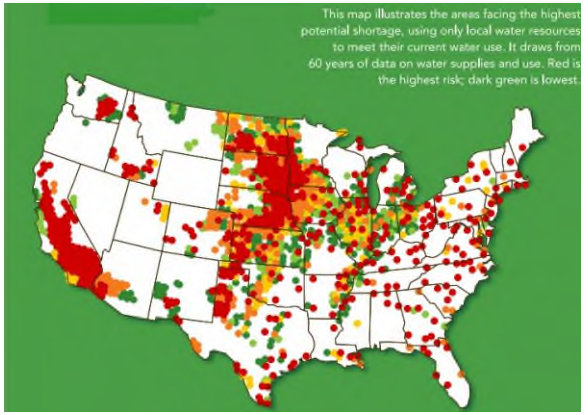
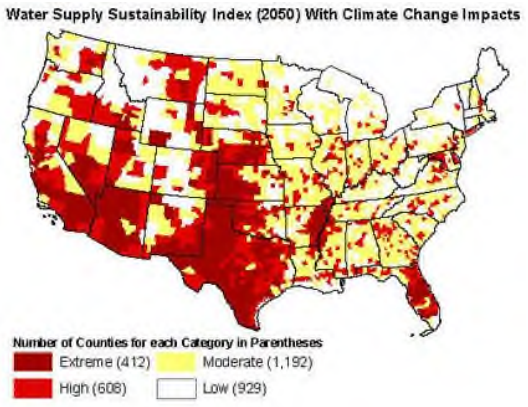
U.S. Agriculture Policy

- Thermodynamically imbalanced
  - 10:1 caloric food-input ratio
- Future Resource Deficit
  - Soil bank (10x more erosion than food)
  - Water supply
  - Fossil fuels
  - Mined nutrients (e.g., phosphorus)
- Ecologically Degrading
- Elitist





An Unsustainable Model

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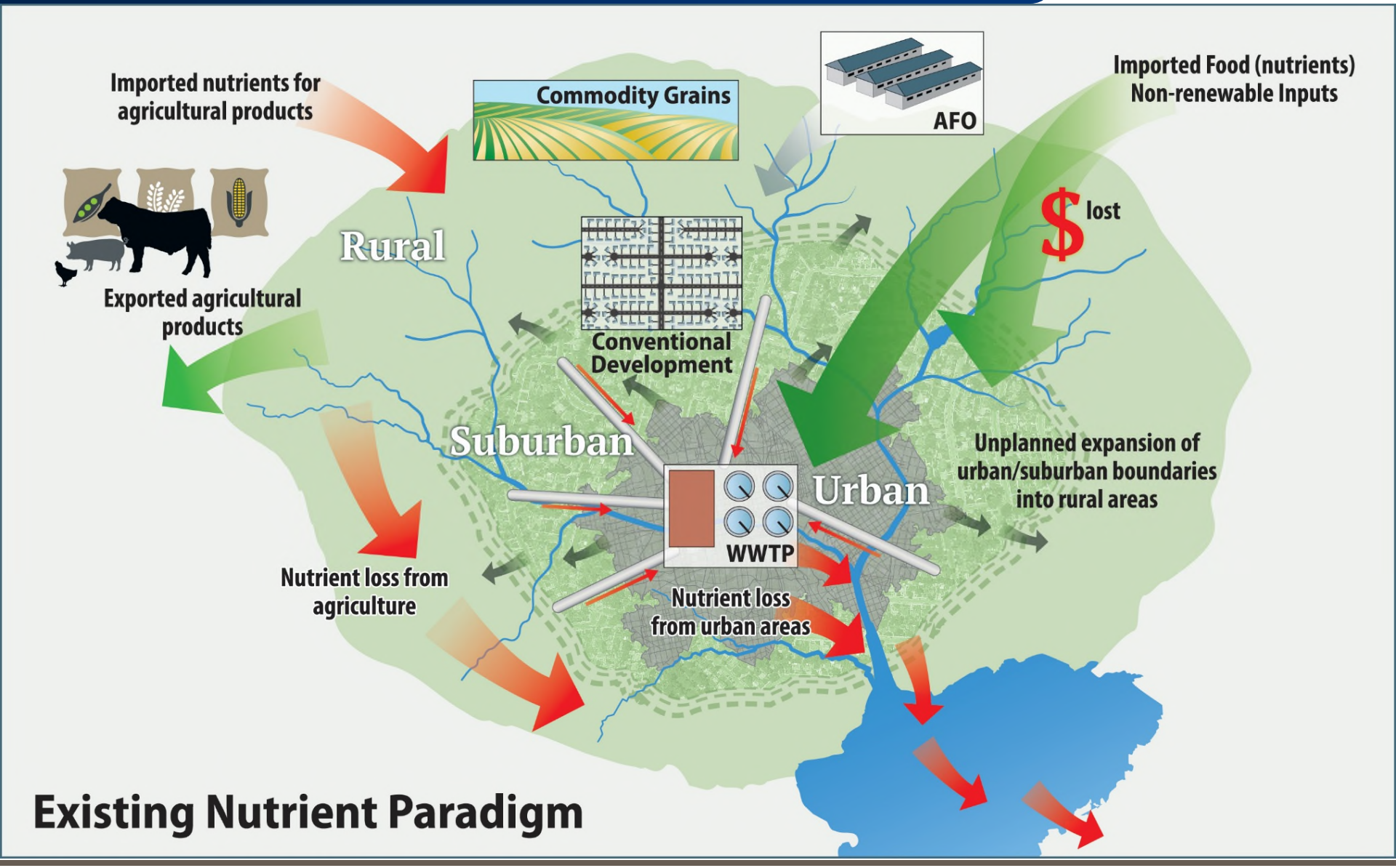

Existing Nutrient Paradigm

What are we <u>really</u> talking about today?

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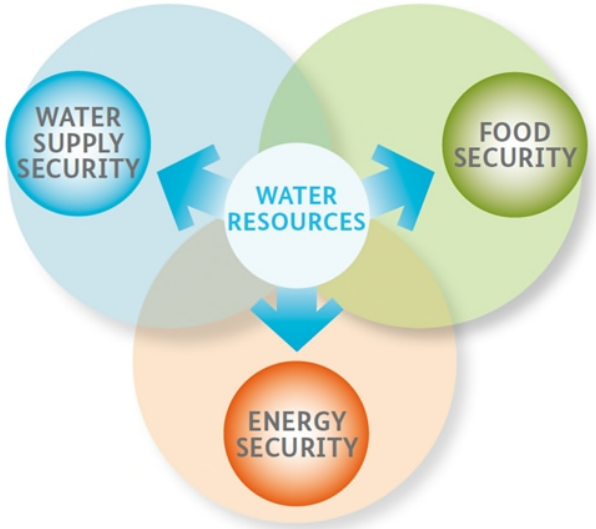
1. Developing <u>Complex</u> Solutions

- Holistic goal-setting
- Multi-disciplinary
- Full-capital valuation



2. Preserving Our Future Resource Base

- Sustainable regional agriculture
  - Productive rural lands and economies
  - Maximized solar wealth
  - Effective water cycling
  - Optimized mineral cycling (e.g., soil, fossil fuels, nutrients)
  - Improved community dynamics

A Resilient Model

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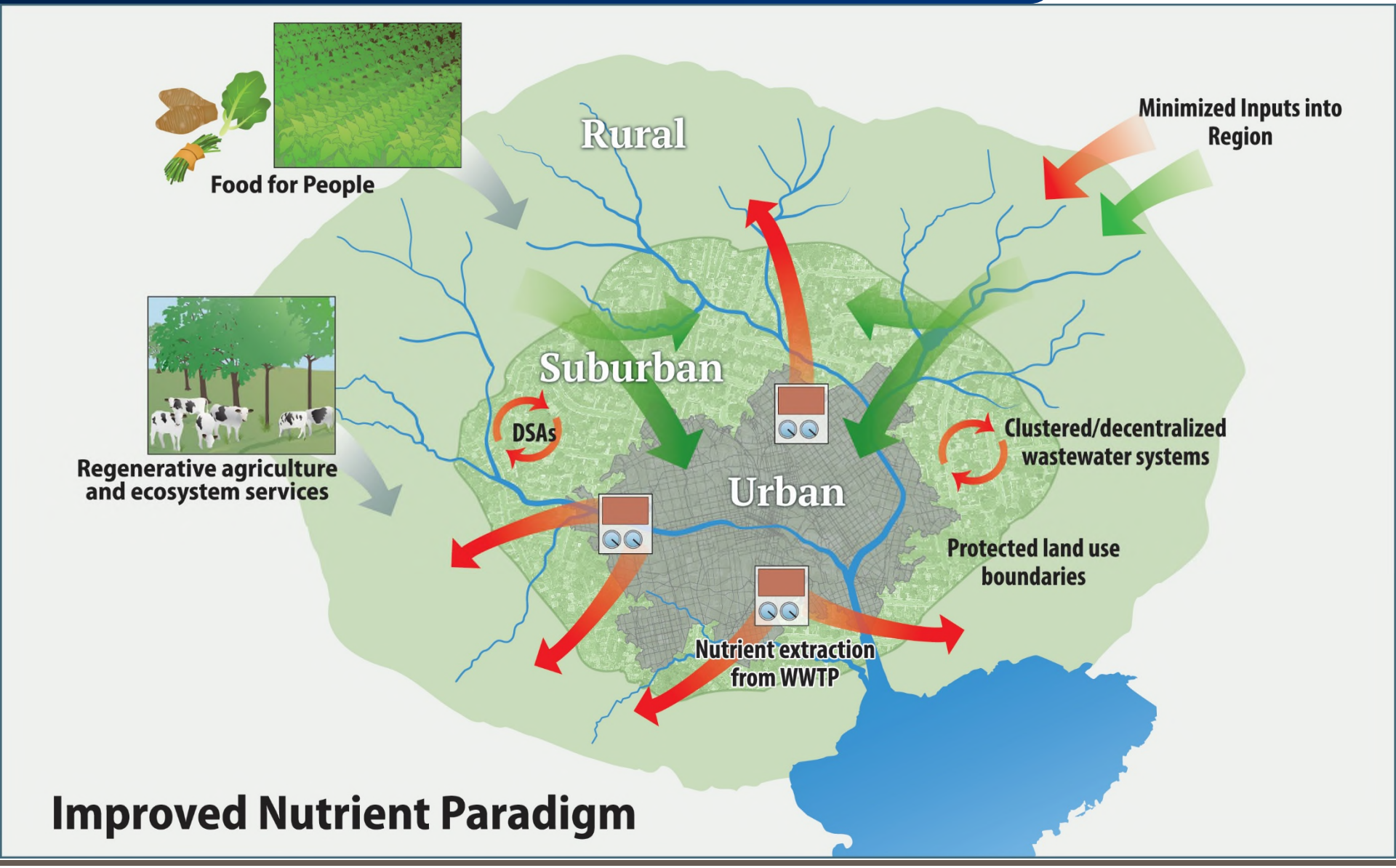

Improved Nutrient Paradigm

Resilient Food Regions

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- *Urban* Agriculture = Green Infrastructure
  - Local Inputs (labor, organic waste, stormwater, microclimate)
  - Nutrition + socio-economic benefits

- *Rural* Restoration
  - Solar-driven
  - Soil-based

- *Urban-rural* Continuum
  - Waste/resource exchanges
    - Nutrients, biofuels, etc.
  - Local markets and Value-chain connections
  - 'Working-lands' mitigation

Matching Source to Sink to Scale

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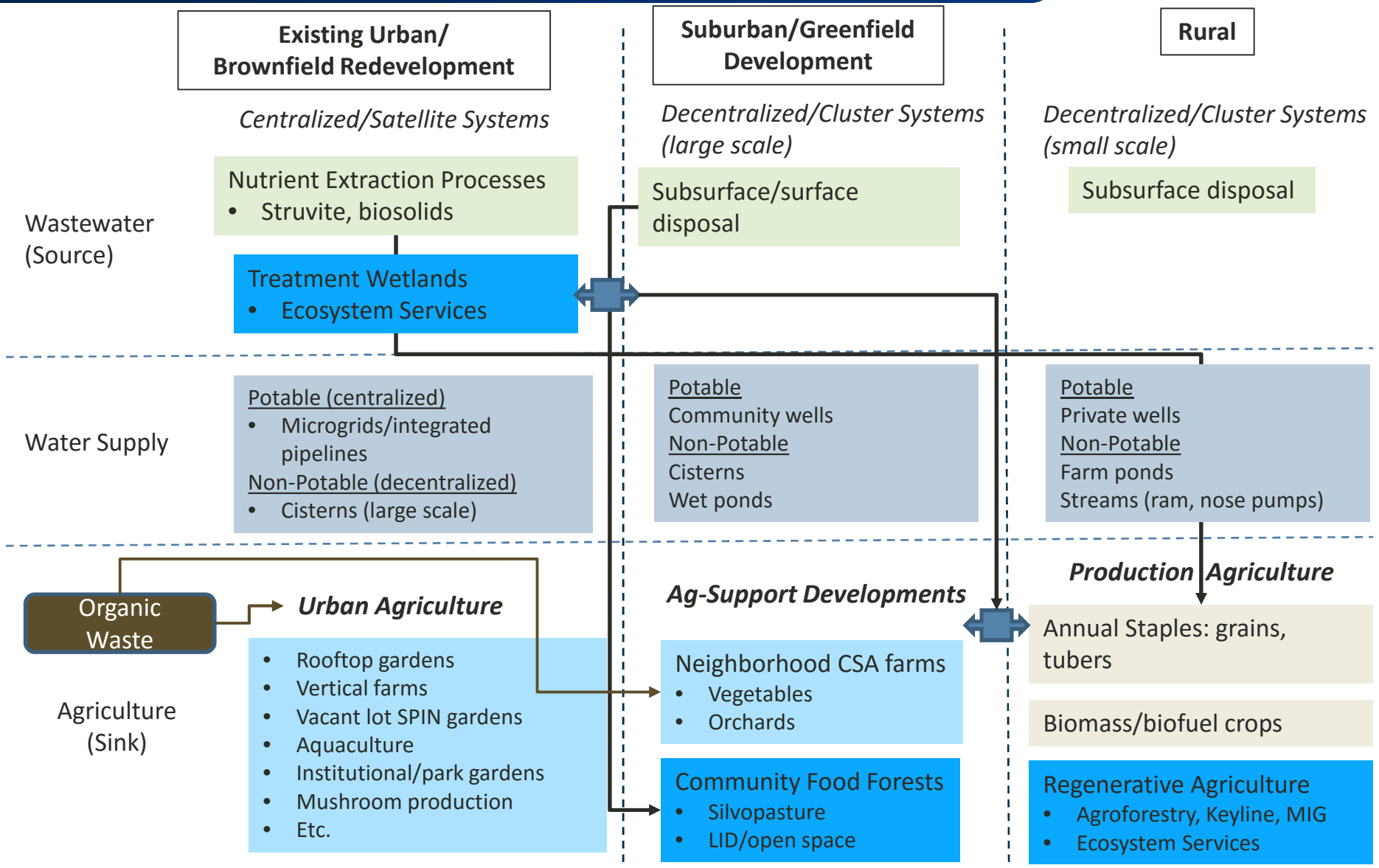

Rural Restoration

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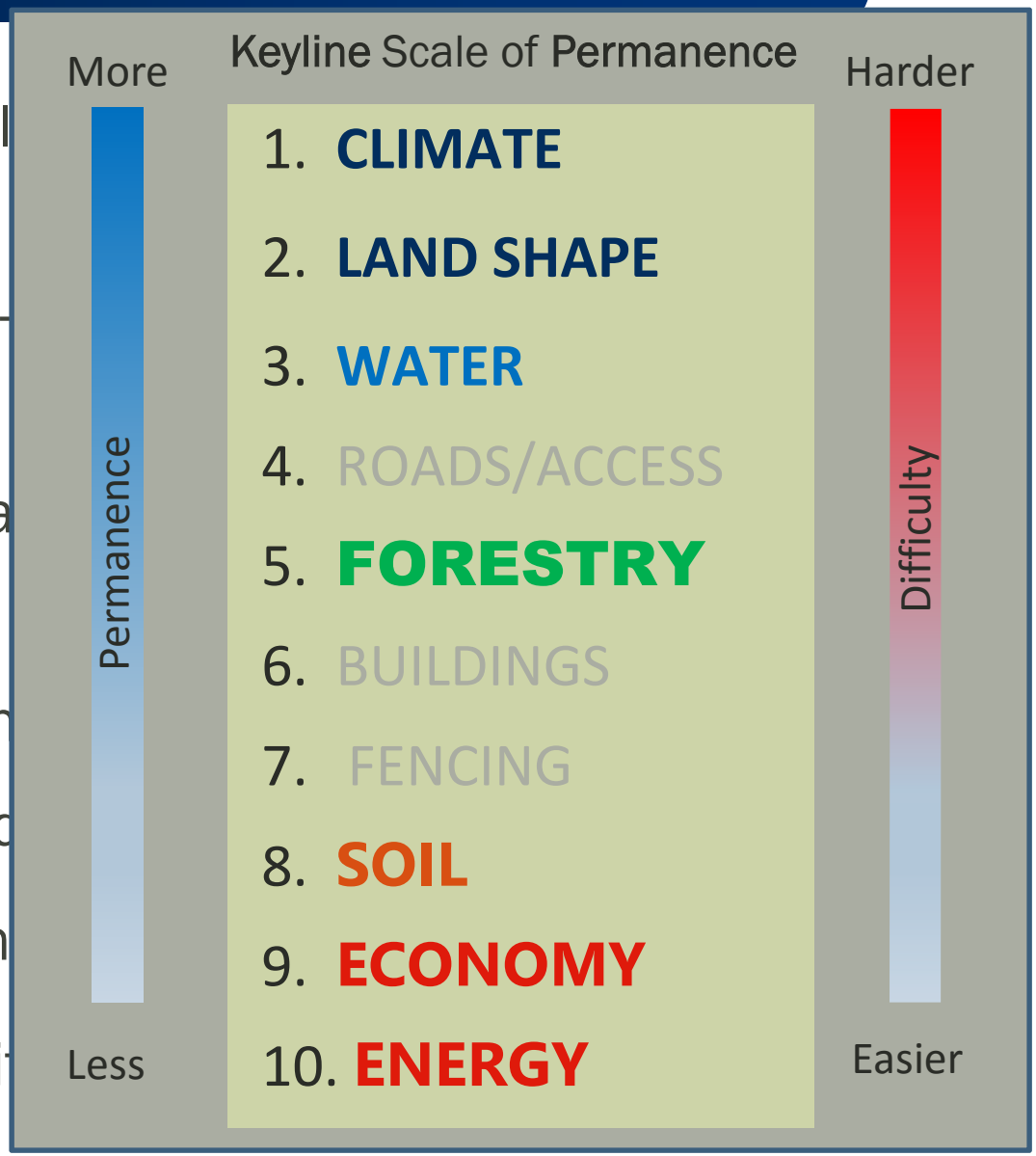
- Perennial Agricul
  permaculture)
  - Soil Building -
    Prosperity
  - Holistic mana
  - Agroforestry
  - No-till croppin
  - Keyline-based
- Design based on
- Planning = Profi



Versaland

Iowa City, Iowa

Investing in Our Rural-shed

TETRA TECH

- Regenerative Production + Holistic Business Models
  - Profitable livestock/agroforestry enterprises
  - Alternative r
    - Co-operativ
    - Regional pr
  - "Working-lan
    - Performan
    - Poor soils
    - Soil C directly related to water and nutrient retention
- Climate Mitigation
  - Grassland/savannah systems = Permanent sequestration
  - Agroforestry

Win^3

ac/-yr over 30 yrs)

Urban Pervious - The Next Frontier

- **Urban Ag.:** "Problem to solution"
  - Waste = Lack of beneficial uses
- Productive landscapes
  - Food, fuel, medicine, habitat, etc.
- Improved stormwater "business model"
- Working with nature
  - Maximize ecosystem services w/ minimized energy inputs

Urban Pervious - The Next Frontier

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Coppice Forestry

Urban Pervious - The Next Frontier

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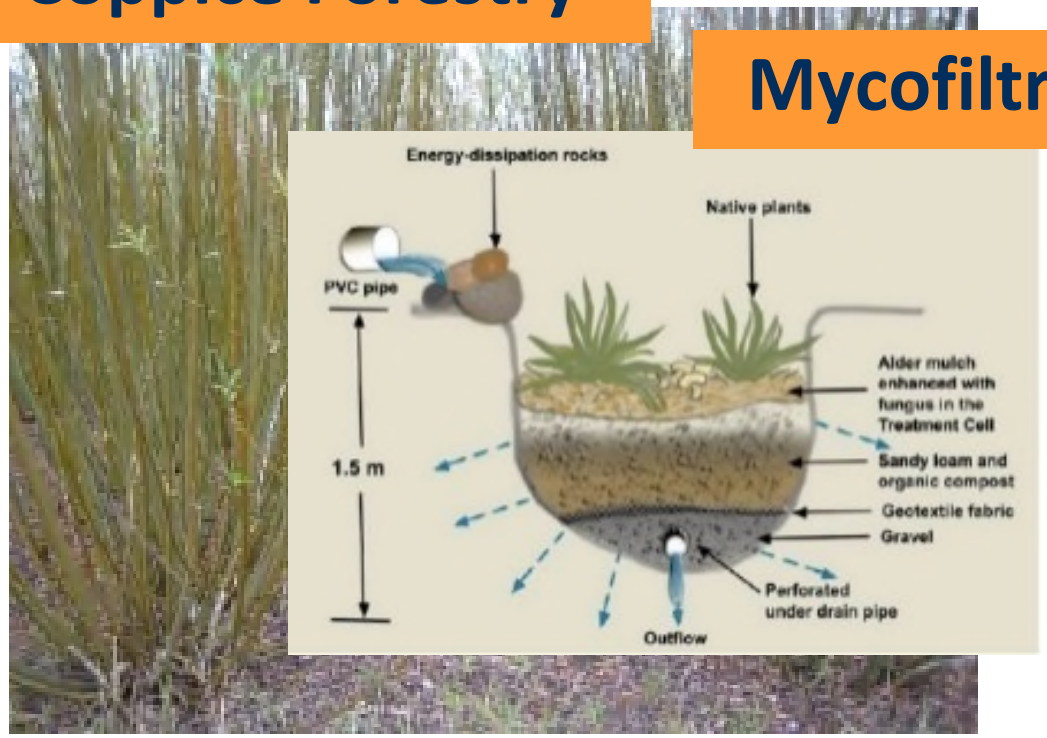
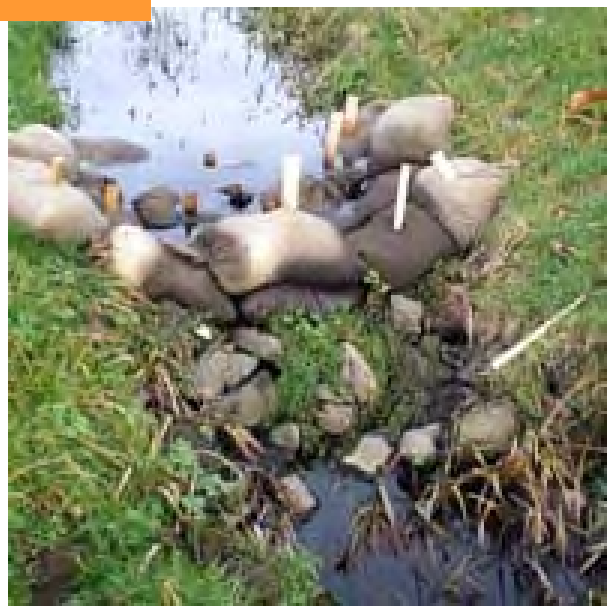
Coppice Forestry



Mycofiltration



Holistic Approach

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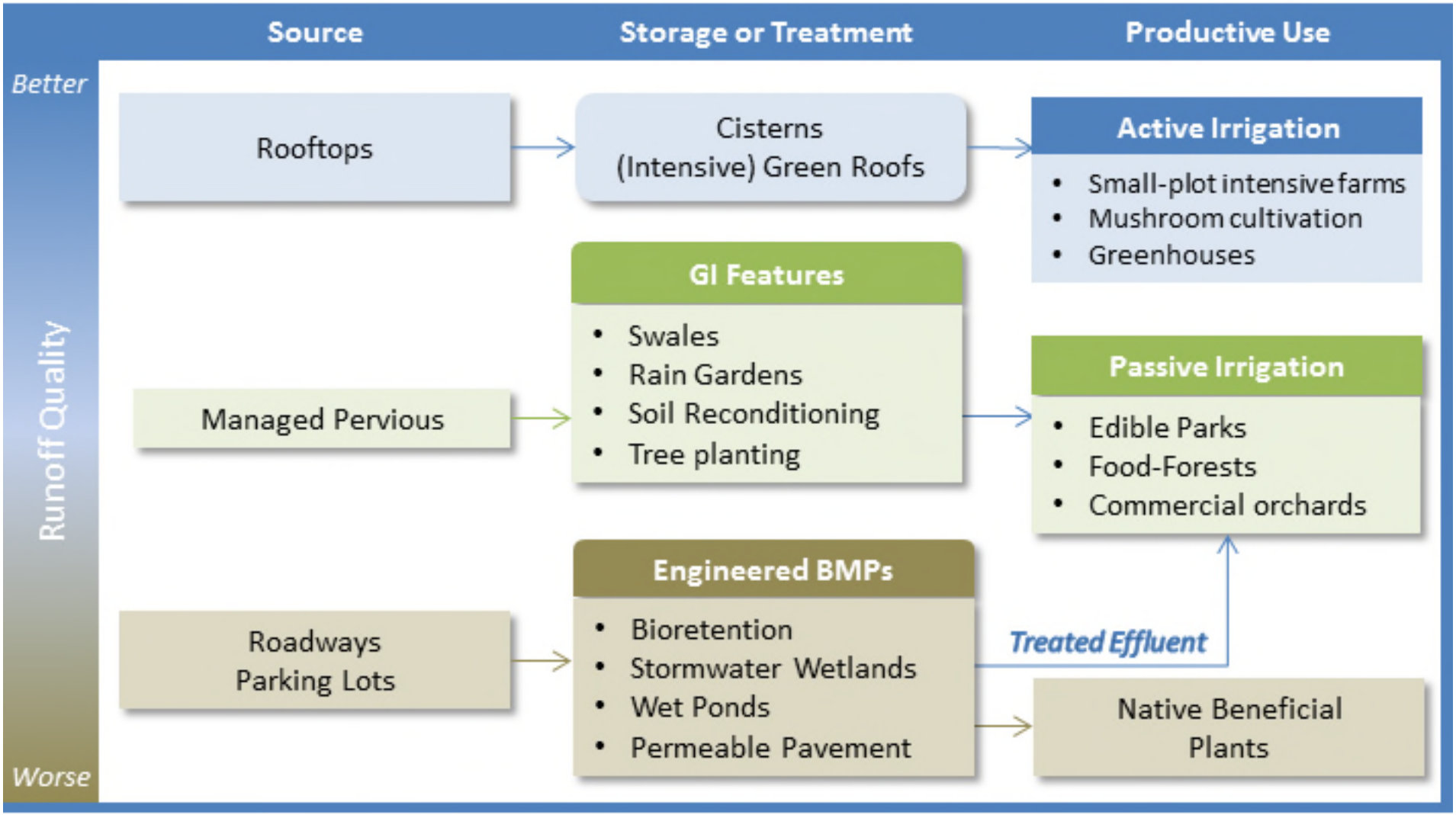
		Stormwater Benefits					Environmental Benefits				Quality of Life Benefits						
BMP	**Offsite Mitigation**	**Median Annual Runoff Reduction (%)**	**Improves Water Quality**	**Water Storage/ Supply**	**Reduces Flooding**	**Reduces Grey Infra-structure Needs**	**Improves Air Quality**	**Mitigates CO2**	**Supports Urban Agriculture**	**Wildlife Habitat**	**Urban Heat Island Reduction**	**Aesthetics**	**Community Cohesion**	**Public Education**	**Recreational Opportunities**	**Increases Property Value**	**Potential Beneficial Use/ Revenue**
Wetlands	Yes	15	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes
Green roofs	No	60	Yes			Yes	Yes		Maybe	Maybe	Yes	Yes					Yes
Dry detention[6]	Yes	10	Maybe		Yes	Yes						Maybe			Maybe		
Cisterns	No	40	Maybe	Yes	Maybe	Yes		Maybe	Yes					Yes			Yes
Bioretention	Maybe	70	Yes		Maybe	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Maybe	Yes	Yes
Rain gardens/swales	Maybe	70	Yes		Maybe	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Maybe	Yes	Yes
Bioswales	Maybe	60	Yes		Maybe	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Maybe	Yes	Yes
Permeable pavement	No	75	Yes		Yes	Yes								Yes			
Green street corridors[5]	Maybe	75	Yes		Yes	Yes					Yes	Yes	Yes	Yes		Yes	
Non-Structural[1]																	
Impervious disconnection[2]	Maybe	80	Yes		Maybe	Yes											
Tree planting	No	20	Yes		Maybe	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Native landscaping	No	20	Yes		Maybe	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Maybe
Soil reconditioning[4]	No	75	Yes		Yes	Yes		Yes	Yes	Maybe	Yes						
Greenway corridors	Maybe	20	Yes		Maybe	Maybe	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Maybe

Linking Stormwater with Urban Agriculture



The Urban-Rural Continuum

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- Interdependent concepts

<u>That consists of:</u>

- Strategic land use planning

  AND/OR

- Agriculture-Supported Development
- Socio-economics
  - Value-chains + food hubs
  - Processing/storage facilities
  - Agri-tourism
  - Jobs/education
- **Waste-to-resource investment**
  - Fertilizer (struvite, biosolids, compost, minerals, feedstock waste, etc.)
  - Bio-energy
  - Irrigation supply

Targeting the Source

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N,P,K Budget of Nutrient Loss in Waste (Source: Jonsson,1994)

Type of waste	Nitrogen	Phosphorous	Potassium
From food production processes in industries and restaurants, etc.	8	10	15
From trade	5	4	6
Domestic (kitchen)	15	26	18
Urine	64	43	52
Faeces	7	22	9

- **Urine:** < 1% of domestic wastewater volume
- **Food waste:** least recycled waste stream nationwide
  - < 5% of generation (US EPA, 2012)

Source Separation

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Parameter	Units	Urine	Feces	Blackwater
Wet mass	kg/person/yr	550	51	610
Dry mass	kg/person/yr	21	11	40.5
Nitrogen	g/person/yr	4000 (88%)	550 (12%)	4550
Phosphorus	g/person/yr	365 (67%)	183 (33%)	548

Source: Rich Earth Institute data from Swedish Study

Urine Diversion

- Easily diverted at the toilet
- Sterile
  - Alkaline treatment through storage
- Fertilizer Value
  - Direct: 18:2:5 (Linden, 1997)
  - Flushed: 15:1:3 (Palmquist et al, 2003)
  - Struvite: 6:29:0 (Mg) 10
  - Micronutrients

Most important nutrients	Urine 500 l	Faeces 50 l	Total	Fertilizer need for 250 kg grain
N	5.6 kg	0.09 kg	5.7 kg	5.6 kg
P	0.4 kg	0.19 kg	0.6 kg	0.7 kg
K	1.0 kg	0.17 kg	1.2 kg	1.2 kg
N + P + K	7.0 kg (94%)	0.45 kg (6%)	7.5 kg (100%)	7.5 kg

(Source: Wolgast, 1993)

Guidelines for Safe Urine Application

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Crop	Example	Inherent risk	People exposed to risk	Application time****	Urine storage***
Slow growing crops	Pineapple	Low	Workers	In early stages	No storage needed
Ornamental flowers, garden plants		Low	Workers	Up until one month before harvest	No storage needed
High growing crops not picked off the ground and with "cover"	Banana.	Low	Workers	Up until one month before harvest	No storage needed
Grain crops processed before eating	Millet, Rice, Sorgum, Maize	Low	Workers	Up until one month before harvest	No storage needed
Hanging plants not in direct contact with the ground and usually not eaten raw	Egg plant	Medium	Consumers and workers	Up until one month before harvest	Storage needed
Fruits likely picked from the ground and eaten directly*	Mango, passion fruit, orange	Low	Workers	Outside the fruiting season**	No storage needed
Hanging plants partly or fully in contact with the soil and eaten raw	Tomatoes	High	Consumers and workers	Up until one month before harvest	Storage needed
Root crops processed/cooked	Cassava, potatoes	Low	Protection of workers	Up until one month before harvest	No storage needed
Root crops eaten raw	Carrots	High	Consumers and workers	Up until one month before harvest	Storage needed
Leafy crops on the ground that *are cooked*	Spinach	Low	Workers	Up until one month *before harvest*	No storage *needed*
Leafy crops eaten raw	Lettuce, cabbage	High	Consumers and workers	Up until one month before harvest	Storage needed
Energy or fibre crops	Cotton, oil crops	Low	Workers	Up until one month before harvest	No storage needed

Dragonfly EcoResort – Moncks Corner, SC

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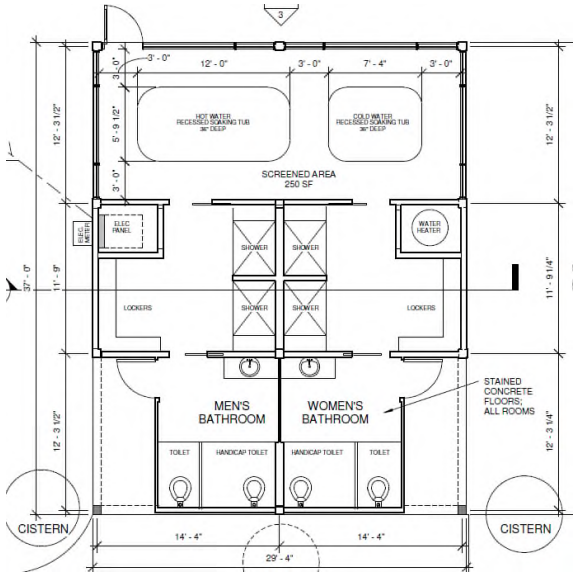
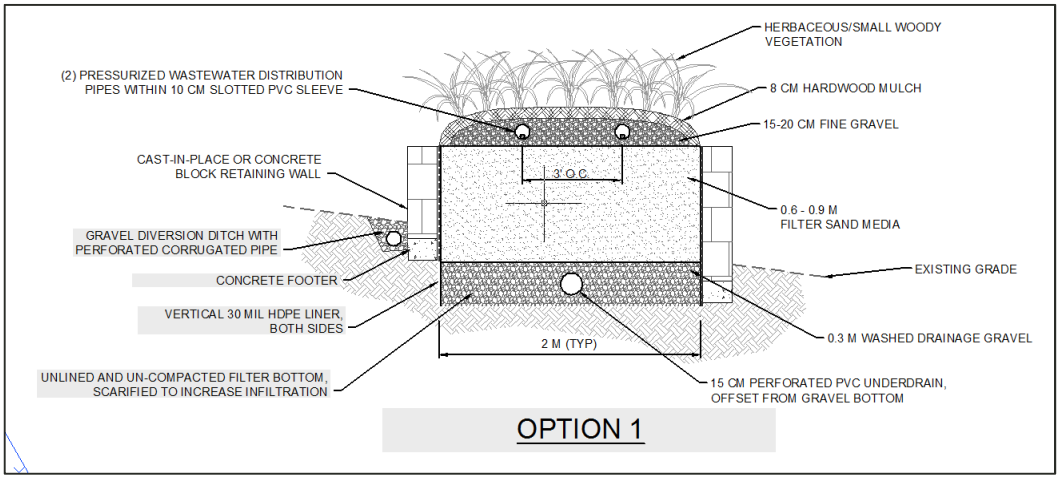
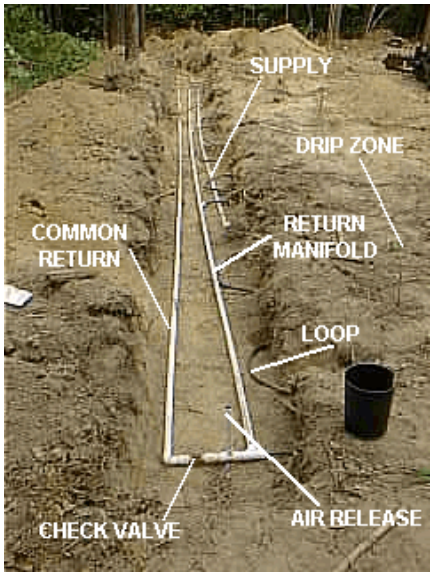
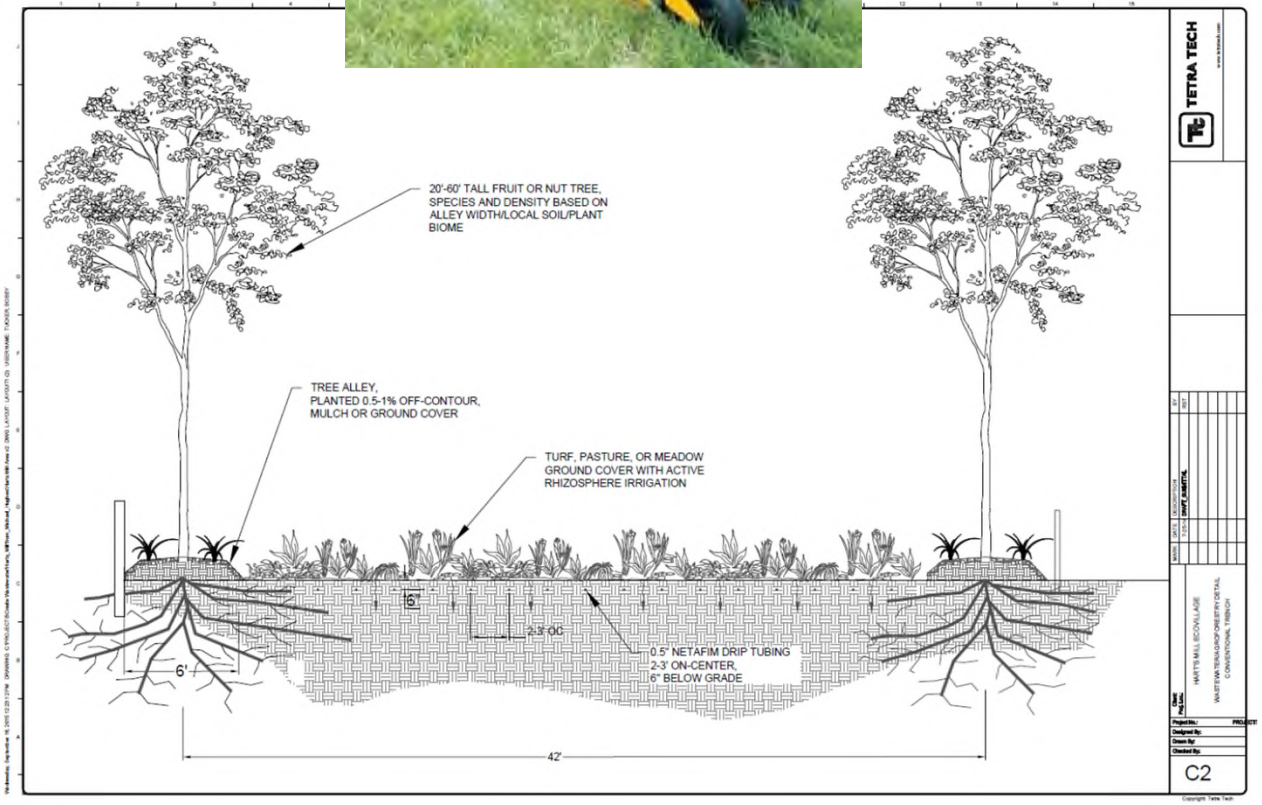
- Urine diverting toilets
  - Storage for ‘fertigation’ of crops
- Reuse quality wastewater
  - Recirculating vegetated sand filters
  - Primary irrigation supply
- Dry toilet composting





Subsurface Drip Systems





Option 2: Dry Toilets

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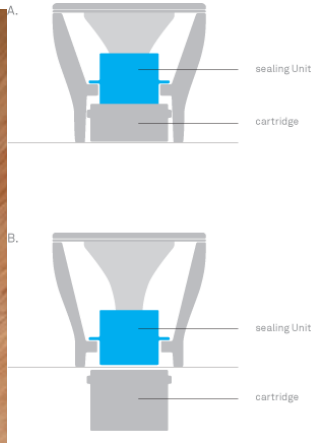
Loowat Self-sealing Toilet



Sawdust Bucket

Summary

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"For in the end, we will conserve only what we love, we will love only what we understand, and we will understand only what we are taught."