





A new concept for aquaponic systems to improve sustainability, increase productivity, and reduce environmental impacts

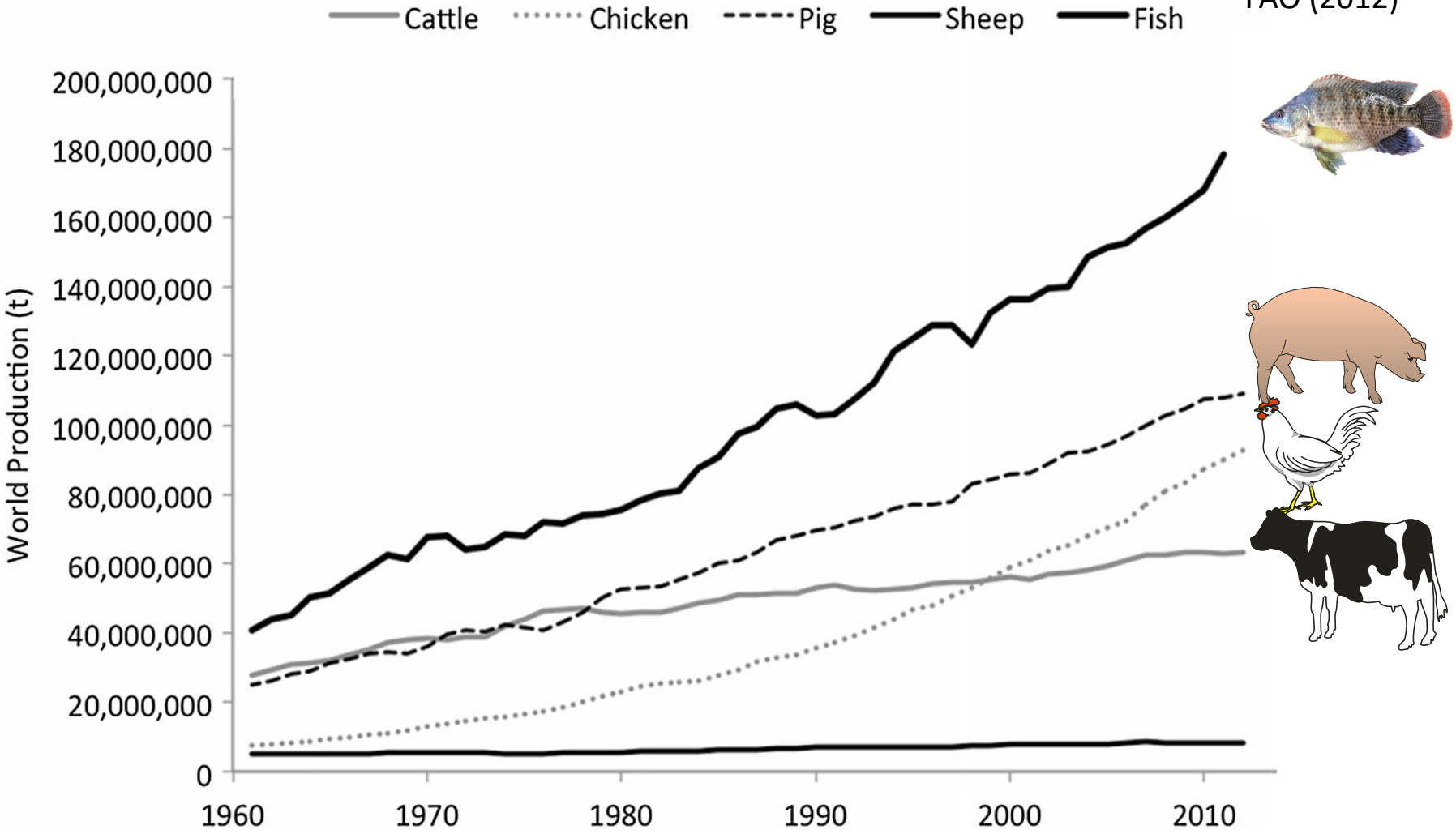
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Aquaculture & Fisheries July 20-22, 2015, Brisbane, Australia

Global meat production

FAO (2012)



Fish is globally the largest animal protein source for humans!
FAO forecasts an increase of more than 25 mill. t fish/a until 2030, that can only be produced by aquaculture!

Aquaculture

- fastest growing sector of agriculture
- mostly freshwater fish
- fish as high value protein for human nutrition
- limitations for space, freshwater, feed resources (fishmeal!)
- needs to be sustainable by saving resources - **“blue aquaculture“**

“Blue aquaculture“ - requests

- no contamination or use of landscape of natural ecosystems
- sustainable fish feed – alternatives for fish meal!
- minimizing/avoiding emissions (CO_2, N, P,…)
- integration into agricultural production, bioeconomy
- organic pond/creek/lake culture of carp, trout,…sustainable but…

  …limited space & freshwater resources, productivity too low for feeding the world – **sustainable alternatives?**

How can blue aquaculture add resilience to the global food system?

Aquaculture - saving water resources

Closed recirculation aquaculture systems (RAS)

Advantages

- indoor facilities independent of location rural/urban
- intense production of fishes according to animal welfare
- protection against environmental impacts, no emissions into ecosystems
- most efficient use of freshwater (only 5-10% freshwater/d)

Disadvantages

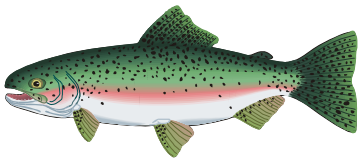
- high tech, high investment technology
- fish “wastewater“ with high load of nutrients (N, P), sewage treatment

Aquaculture – reducing water foot print by RAS

Water footprint

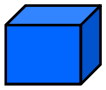
[water L/kg biomass]

based on fish meal diet!



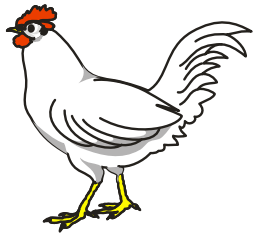
600 – 1,500 L

RAS

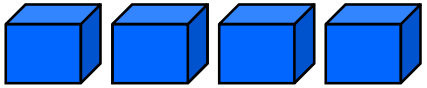


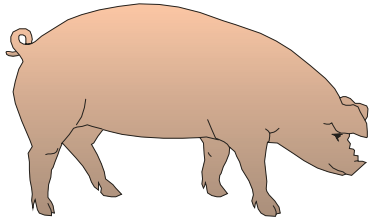
flow-through trout: ~ 220,000 L

carp: ~ 5,000 L

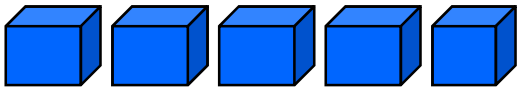


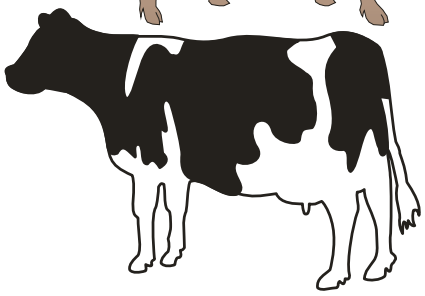
3,900 L



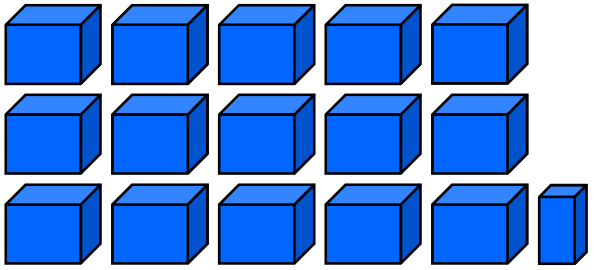


4,800 L





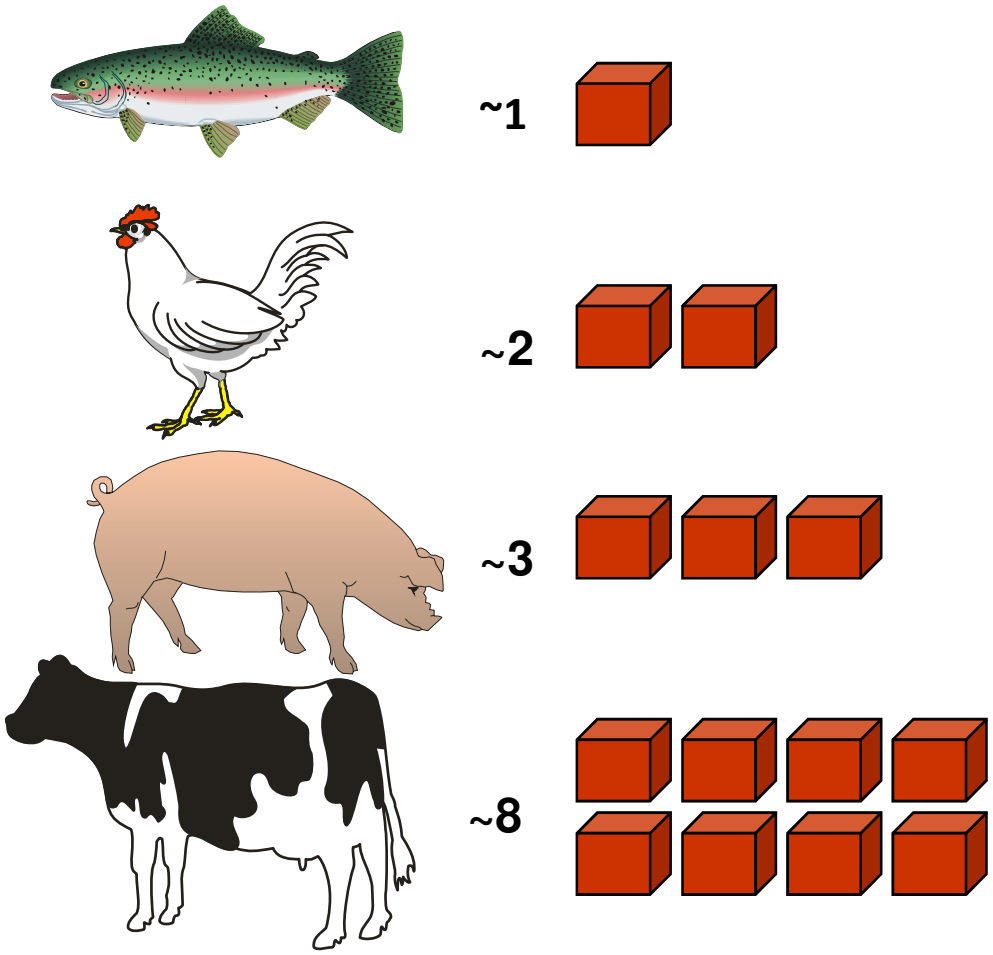
15,500 L



Aquaculture - saving feed resources

Feed consumption

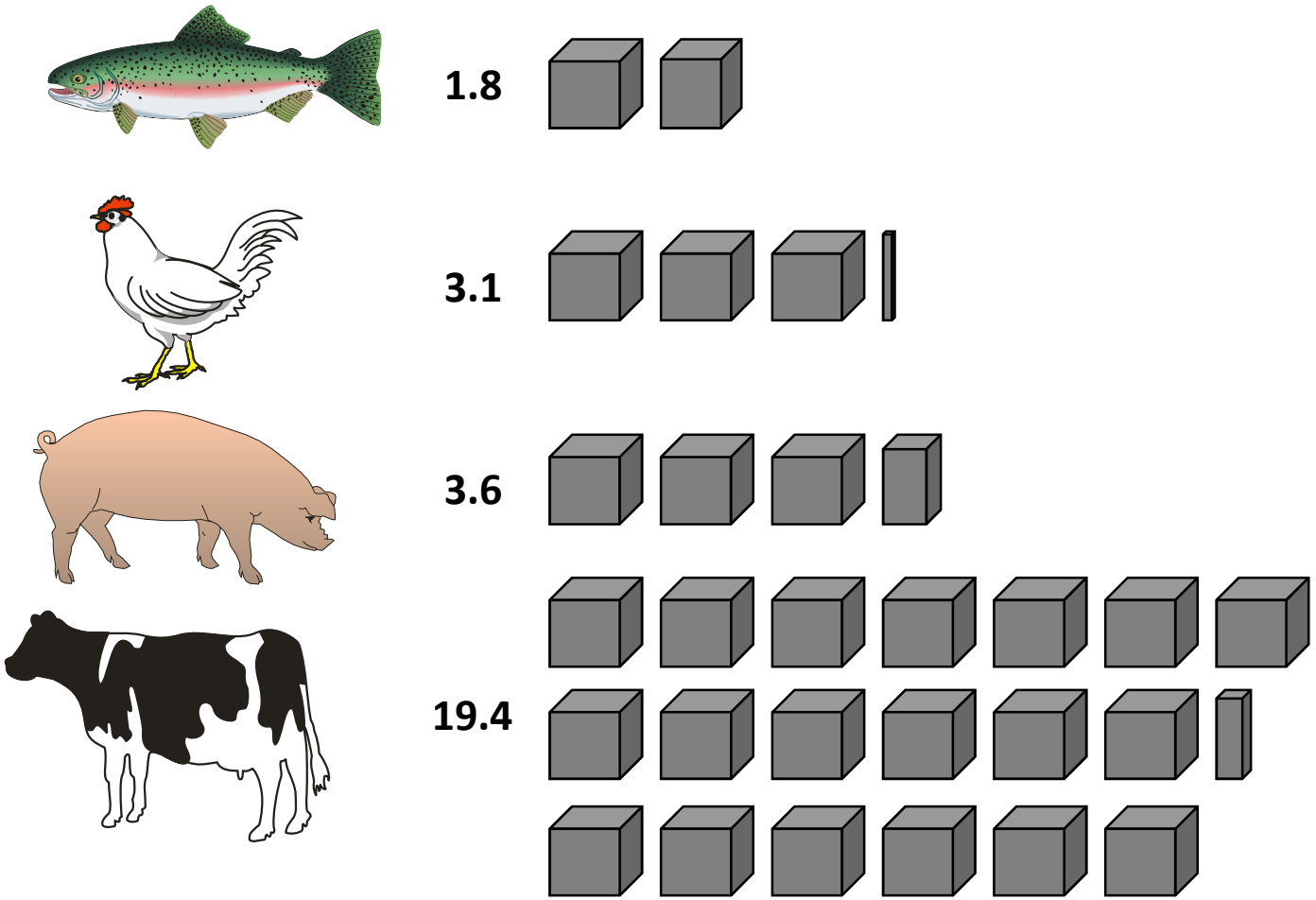
[kg feed/kg biomass] (De Silva & Anderson, 1995)



Aquaculture – reducing carbondioxide emissions

Carbondioxide emission

[CO_2-emission kg/kg biomass] (Danish Ministry of Agriculture, 2008)



Improving sustainability of RAS

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RAS produce 5-10%/d nutrients containing waste water!

Development of a sustainable ecotechnology

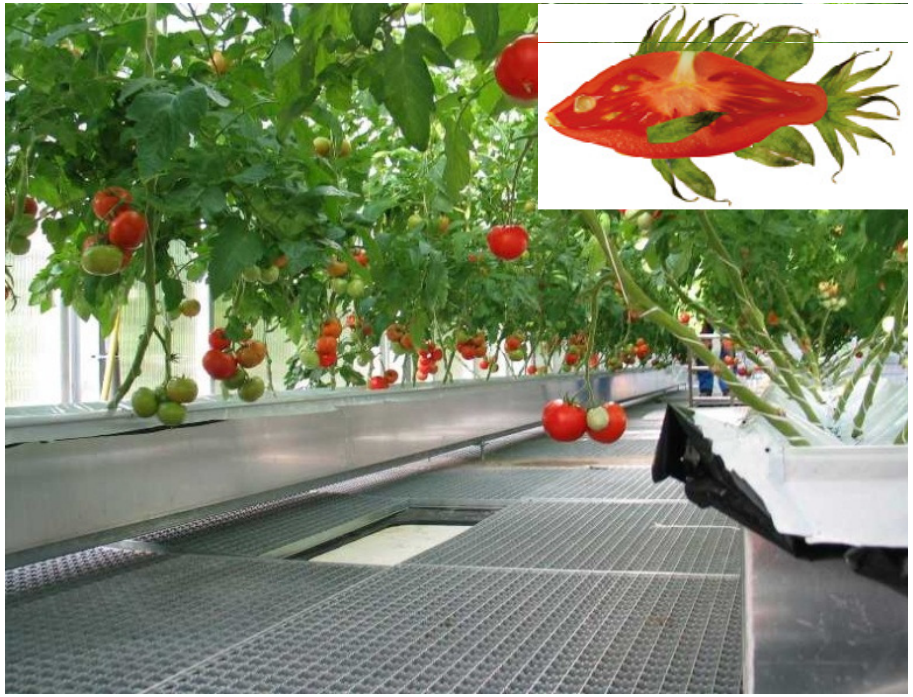
to integrate aquaculture with horticulture by value added chains to save water and to minimize emissions.

aquaculture (fish) + hydroponic (vegetables) = aquaponics

production of tilapia (*Oreochromis niloticus*) and tomatoes - **"tomato fish"**



+



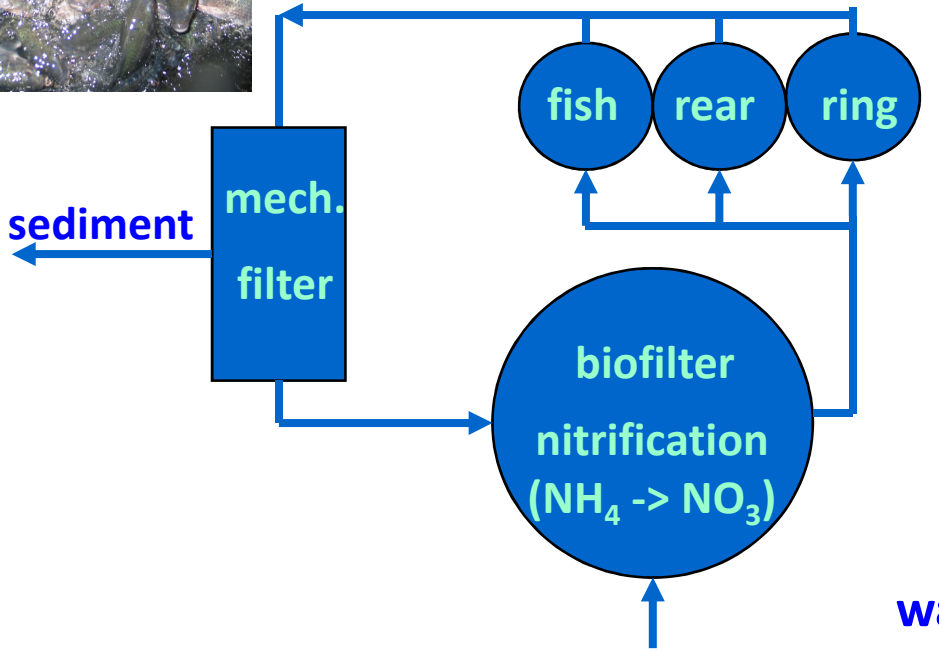
Improving sustainability of RAS



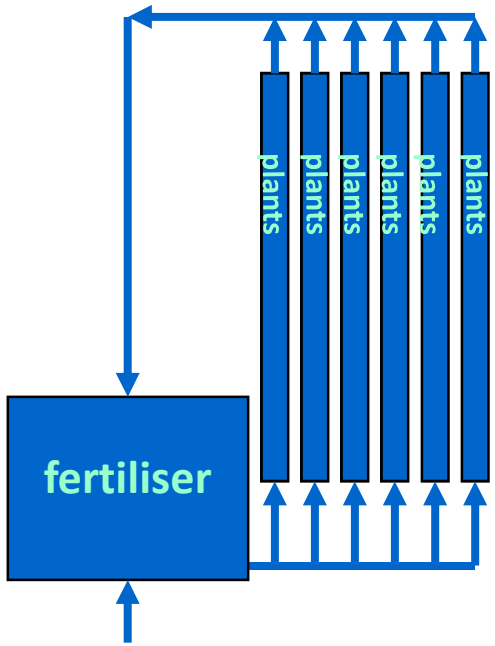
recirculation aquaculture system (RAS)



hydroponic nutrition film technique (NFT)



RAS water contains NO_3 & P!



water/fertiliser (NO_3 & P)/ essential minerals/pH

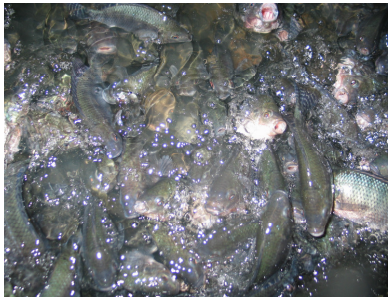
Water use for 1 kg tomatoes?

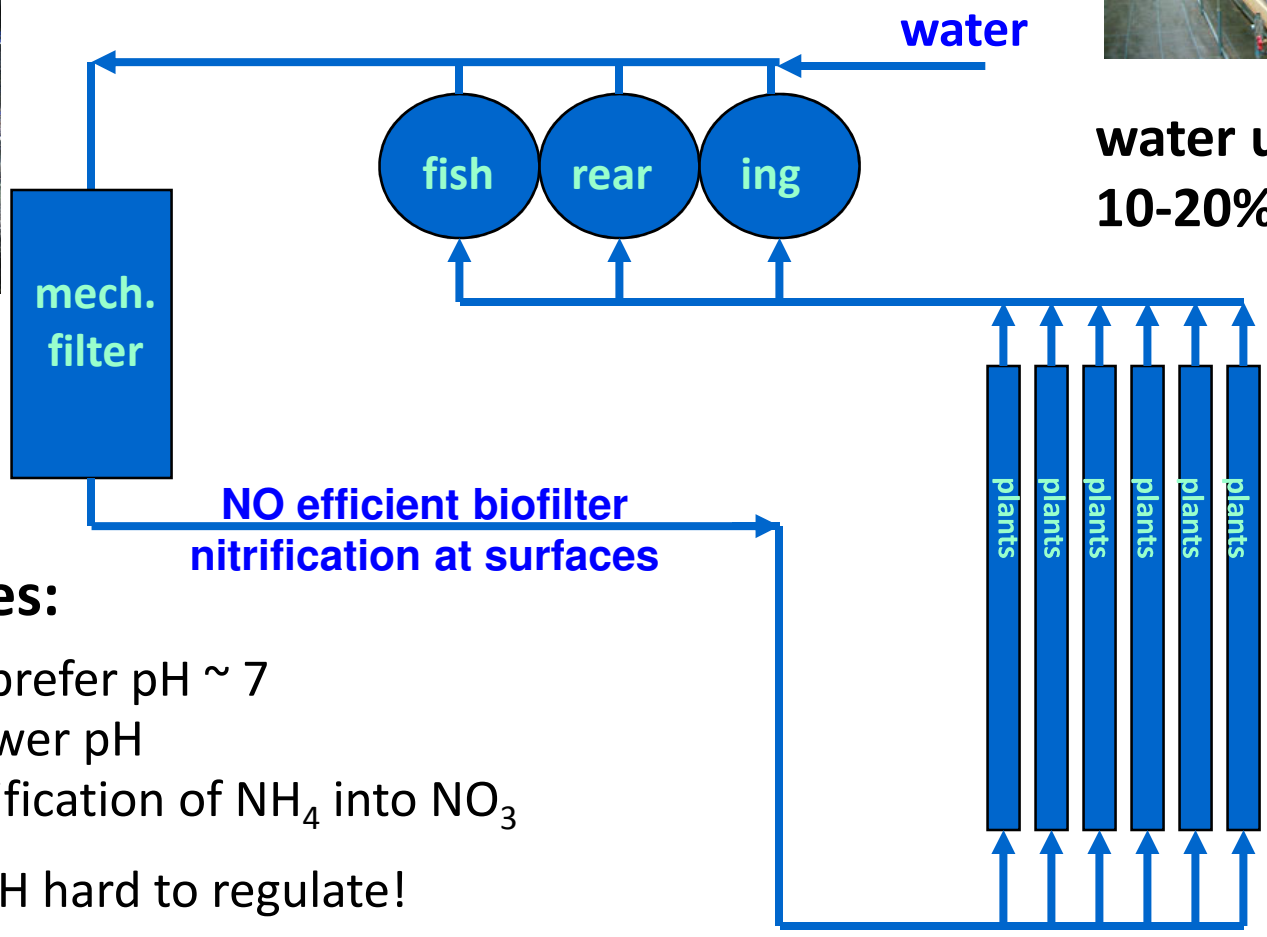
Field-grown: 100-300 L vs NFT: 30-50 L!

Improving sustainability “classic“ aquaponics

single recirculating aquaponic system (SRAPS)







water use
10-20% vol./day!

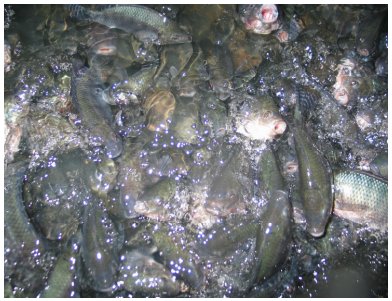
Disadvantages:

fish & bacteria prefer pH ~ 7
plants prefer lower pH
incomplete nitrification of NH_4 into NO_3

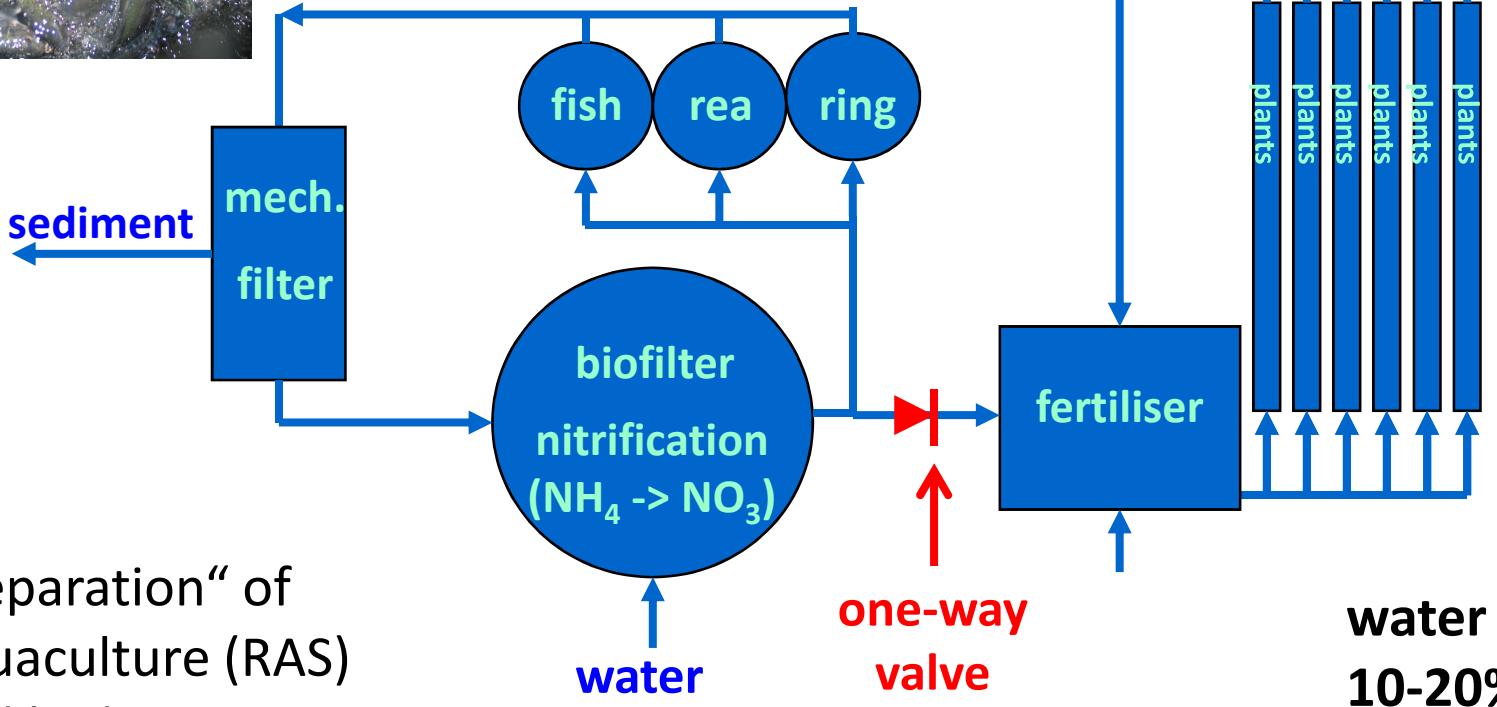
Nutrients and pH hard to regulate!

Suboptimum conditions for fishes and plants, low productivity!

Improving sustainability of RAS - aquaponics







"Separation" of aquaculture (RAS) and hydroponic systems by a **one-way-valve**,

no disadvantages - optimum productivities!

water use
10-20% vol./day!

ASTAF-PRO - aquaponics system for (nearly) emission free tomato and fish production in green houses (170 m²)

double recirculation aquaponic system (DRAPS)

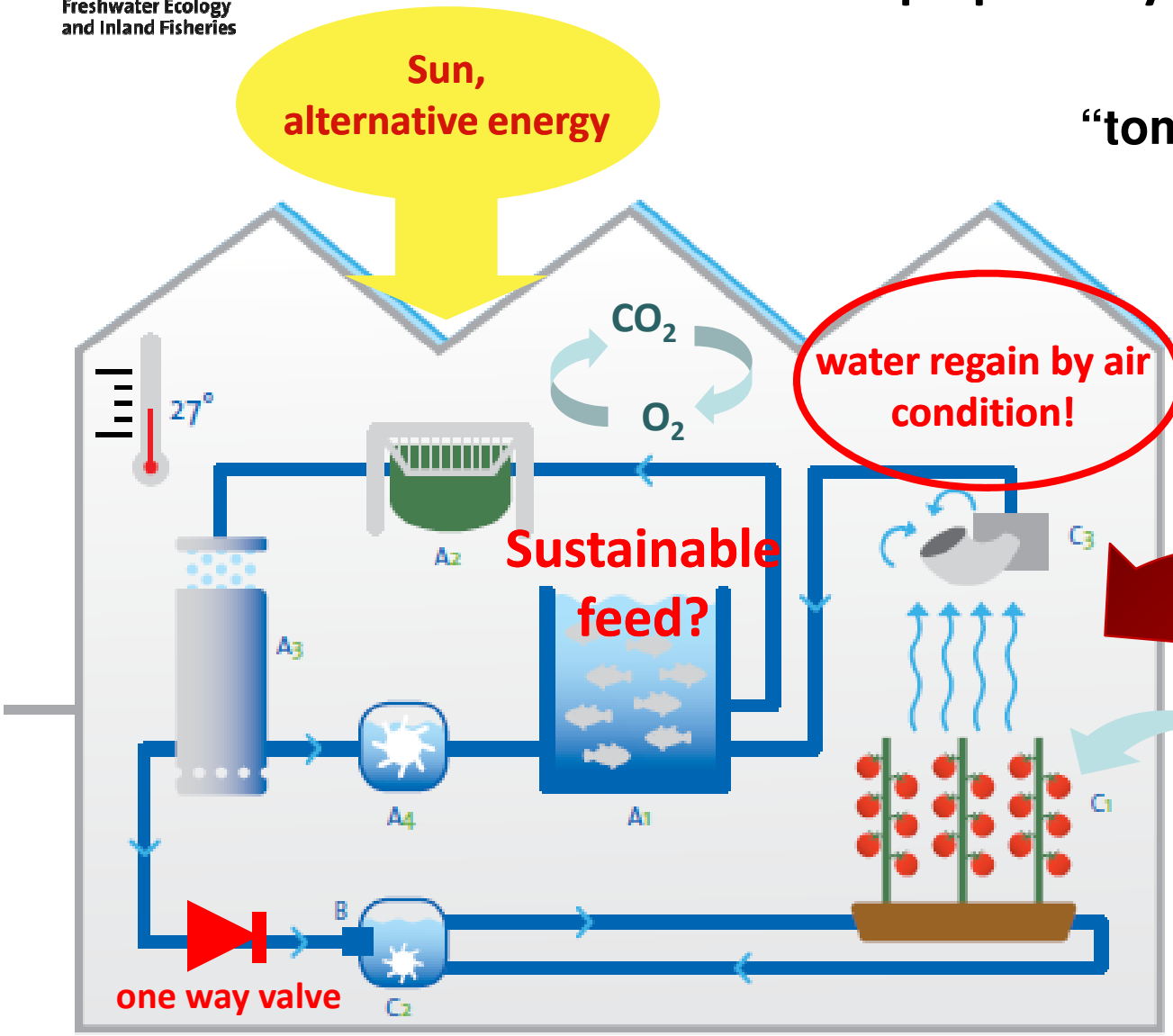
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"tomatofish"

aquaponics

- sink for waste heat
- CO_2-fertilization for hydroponic
- value-added chains for NO_3, P, CO_2 & water (2.7%/d)





Improving sustainability of RAS – aquaponics - first results

Production (2009) in 9 months:

600.1 kg tilapia + 1010 kg tomatoes

Water use 2.7%/day!

Aquaponic system (13 m^3, fish tanks 9 m^3)

theoretically < 1%/day by water regain feasible!

200 L tap water (instead of ~ 1,100 L):

1 kg tilapia + 1.6 kg tomatoes

feasible ~ 5 kg tomatoes!







Improving sustainability of RAS by ASTAF-PRO
(170 m^2) 2009: 601 kg tilapia and 1010 kg tomatoes



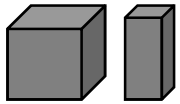
Carbondioxide emission

[CO_2-emission kg/kg biomass] (Danish Ministry of Agriculture, 2008; own results)

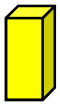
RAS vs ASTAF-PRO aquaponics:



1.3

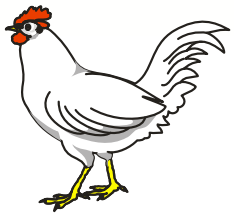


-0.7

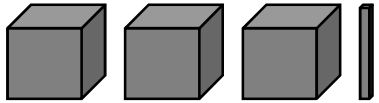


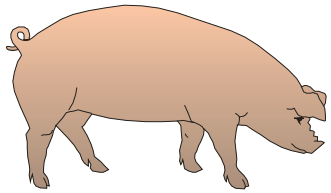
net sink for CO_2 in tomatoes

Kloas et al. (2015) *Aquaculture Environment Interactions*

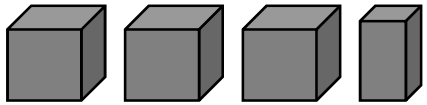


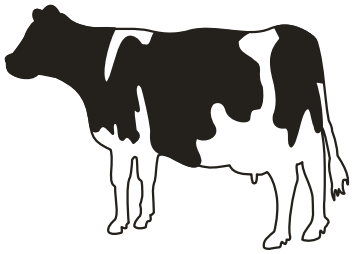
3.1



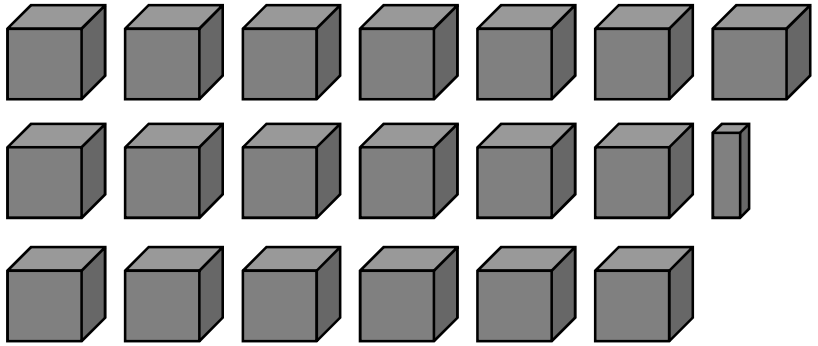


3.6





19.4



Improving sustainability of RAS by ASTAF-PRO



based on fish meal diet!

Water footprint

[water L/kg biomass]

~ 200 L water! Complete use of wastewater would equal + 5 kg tomatoes; reduce < 100 L water!



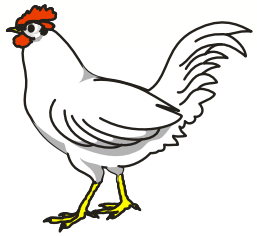
RAS vs ASTAF-PRO:



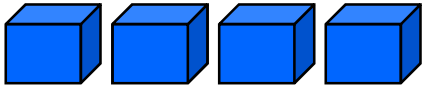
600 – 1500 L

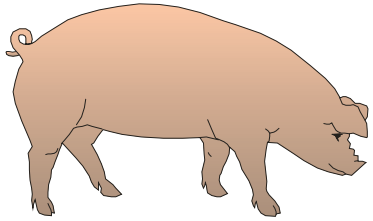


Kloas et al. (2015) *Aquaculture Environment Interactions*

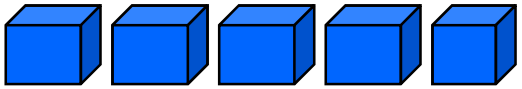


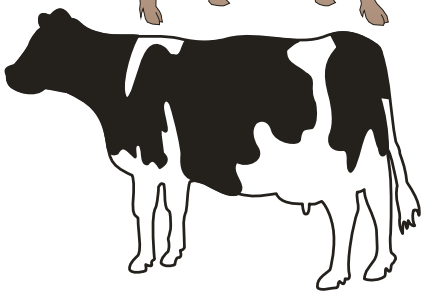
3900 L



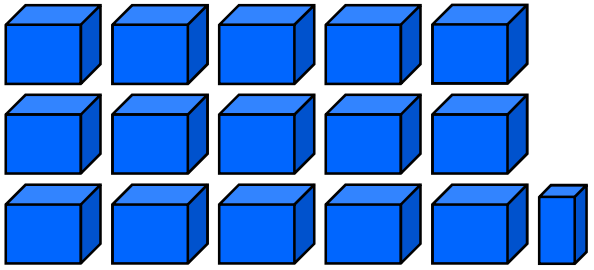


4800 L





15500 L

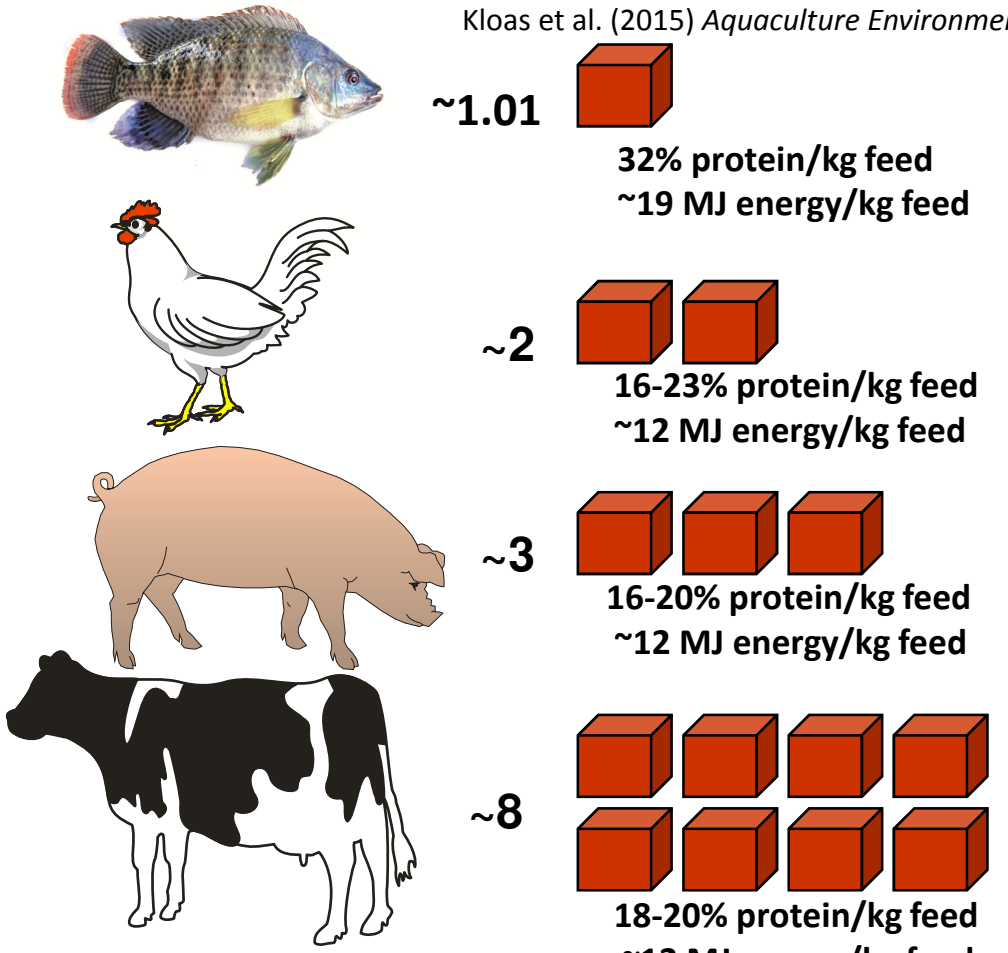


Improving sustainability by alternative fish feed

Feed consumption **protein/energy requests for nutrition!**

[kg feed/kg biomass] (De Silva & Anderson, 1995)

Kloas et al. (2015) *Aquaculture Environment Interactions*



~1.01

32% protein/kg feed
~19 MJ energy/kg feed

~2

16-23% protein/kg feed
~12 MJ energy/kg feed

~3

16-20% protein/kg feed
~12 MJ energy/kg feed

~8

18-20% protein/kg feed
~12 MJ energy/kg feed

Sustainable fish feed?
Fish meal as ingredient is not sufficiently available!
Alternative protein resources?
Plant proteins cause increase of water foot print.
Maggot meal (insects) to regain protein from bio waste is more sustainable!



Improving sustainability of ASTAF-PRO – fish feed





Protein of overdone foodstuffs or spoilt harvest is regained by blacksoldier fly larvae! Only freshwater fishes can grow normally without fish meal in their diets!

ASTAF-PRO as new concept (DRAPS) for aquaponic systems to improve sustainability, increase productivity, and reduce environmental impacts – *Perspectives*

improve sustainability by

- drastic reduction of water use by regain of plant evaporated water, sustainable feed (fish meal replacement by maggot meal), use of alternative energy and waste heat!

increase productivity by

- using DRAPS instead of SRAPS for aquaponics allows fish production as in conventional RAS but also optimum conditions for hydroponics recirculation

reduce environmental impacts by

- lowering drastically emissions of nutrient (N, P) rich fish wastewater that is used for hydroponics and plants are even a net sink for CO_2 released by fish metabolism

Transfer of "tomatofish" into applicability within the EU-project INAPRO "Innovative model & demonstration based water management for resource efficiency in integrated multitrophic agriculture and aquaculture systems"

ASTAF-PRO “Tomatofish“

Leibniz-Institute of Freshwater Ecology and Inland Fisheries

Deutschland Land der Ideen

Ausgezeichneter Ort 2013/14

COOPERATION

INAPRO

Bundesministerium für Bildung und Forschung

FONA Forschung für nachhaltige Entwicklungen

BMBF

Eine Initiative des Bundesministeriums für Bildung und Forschung

Wissenschaftsjahr 2012

Zukunftsprojekt ERDE



Thank you for your attention!

DEUTSCHER NACHHALTIGKEITSPREIS

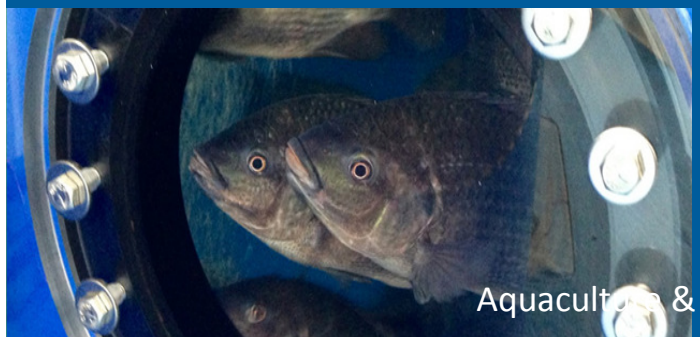
Blue aquaculture can add more resilience to the global food system!

Leibniz-Institute of Freshwater Ecology and Inland Fisheries









Thank you for your attention!

Sustainability of fish species by feed requirements

- nutrition of fishes is mainly based on protein and lipids, not on carbohydrates!
- freshwater fishes need less energy (feed) for metabolism than marine species!
- marine fishes request fish meal as essential part of their diet
- omnivorous freshwater fishes can cope with alternative protein sources!

….THUS fishes differ markedly!

protein/energy requests for nutrition in aquaculture

tilapia



32% protein/kg feed
~19 MJ energy/kg feed

>>

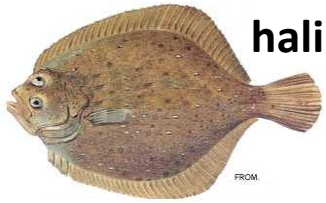
salmon



50-60%
~25 MJ

>

halibut



70-80% protein/kg feed
~25 MJ energy/kg feed

freshwater
NO fish meal needed!

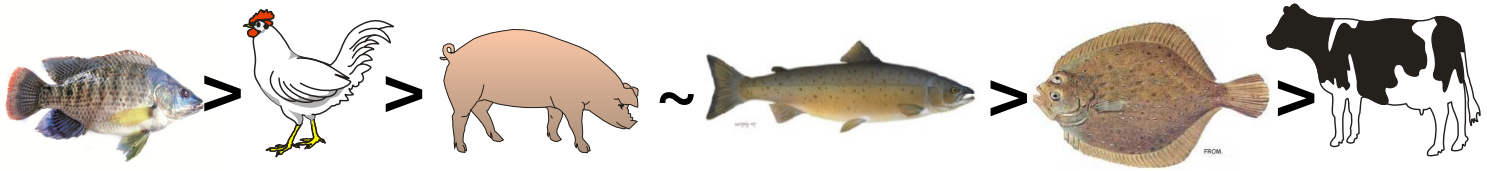
seawater
fish meal at least in part essential!

Comparison of production of fishes in aquaculture

1 kg fish produced	tilapia	salmon	halibut
Protein in diet	32%	60%	80%
Fish [kg] for fish meal diet	1.5-2	3-4	4-5
CO_2 emission [kg]	1.3	2.3	3.0
Fish meal replacement	100%	50%	50%
Water foot print [L] based on diet protein			
Fish meal	negligible	negligible	negligible
Peas dry	3000	3000	4000
Soybean	2100	2100	2800
Rape seed oilcake	1100	1100	1500
Maggot meal (insect)	negligible	negligible	negligible

sustainable?

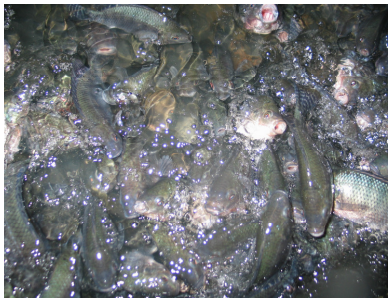
water footprint calculated according to data from Mekonnen & Hoekstra (2013)

Protein efficiency:  > > ~ > >

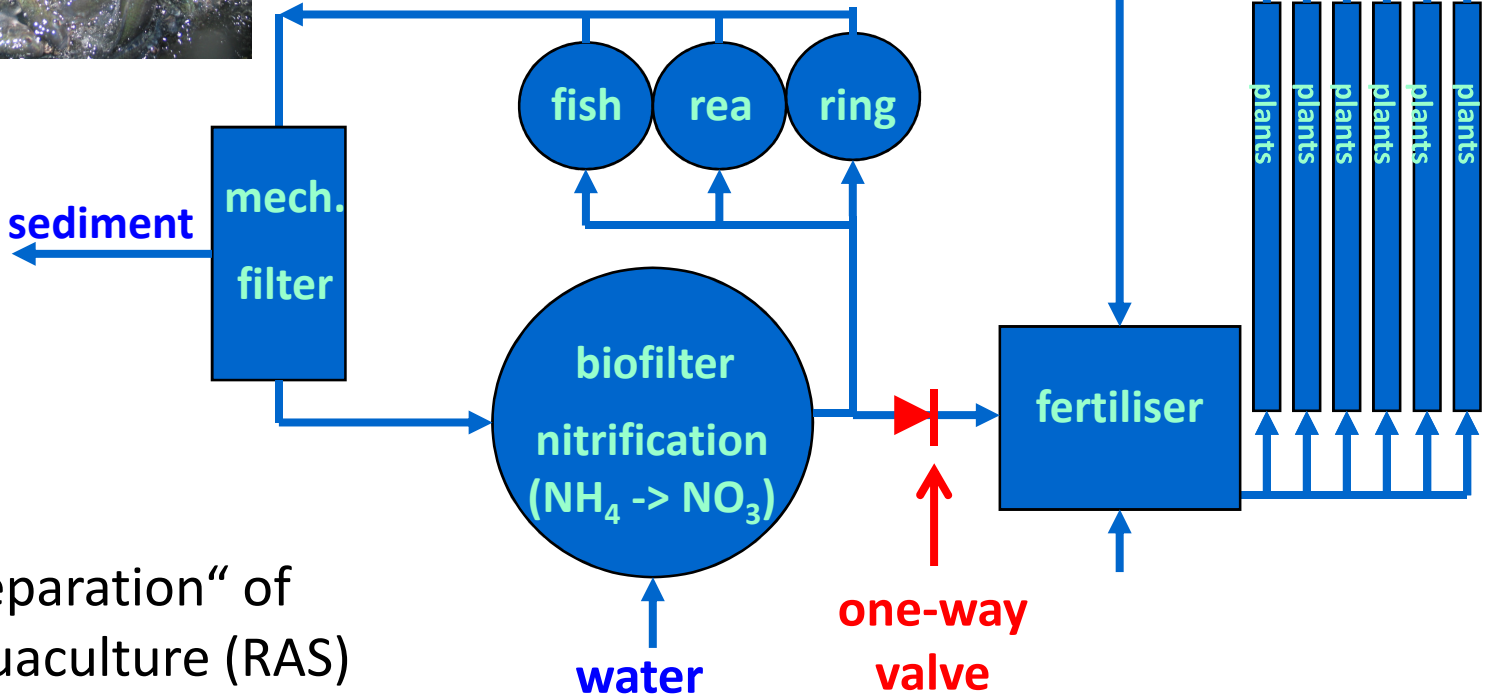
CO_2 emission: Fishes more sustainable than chicken, pig, cattle

Water foot print: depending on feed sources, plant proteins increase water foot print!

Improving sustainability of RAS - aquaponics







"Separation" of aquaculture (RAS) and hydroponic systems by a **one-way-valve**,

no disadvantages - optimum productivities!