# Developing capacity in the Ecosystem Approach to Aquaculture Management (EAAM)

***CAPACITY PLUS***

***Inland aquaculture***

# Definition EAA

- “An Ecosystem Approach for Aquaculture is a strategy for the integration of the activity within the wider ecosystem such that it promotes sustainable development and resilience of interlinked social-ecological systems”.

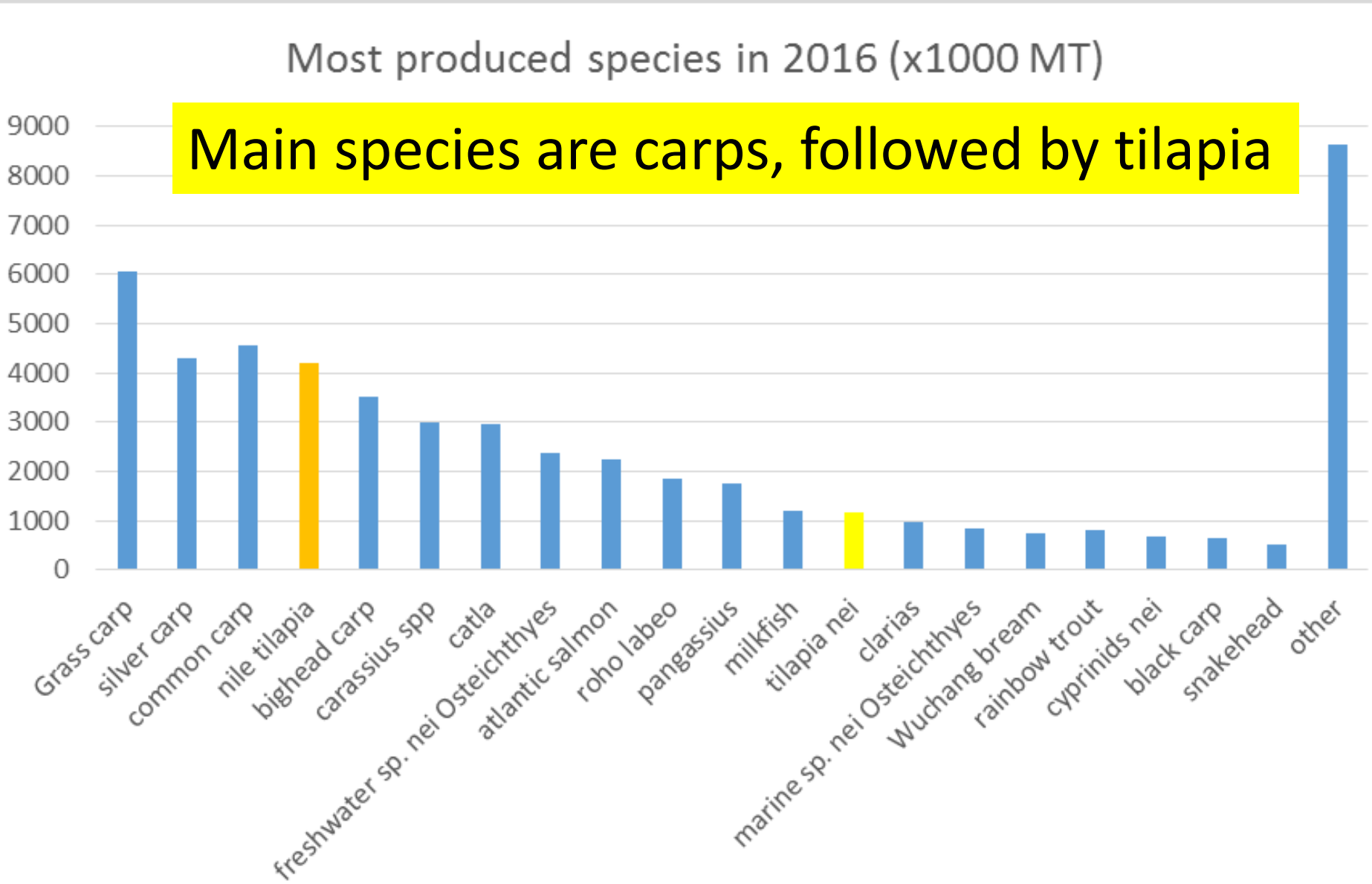
# Principles of EAA

1. Aquaculture development and management should take account of the full range of **ecosystem functions and services**, and should **not threaten** the sustained delivery of these to society.
2. Aquaculture should improve **human well-being and equity** for all relevant stakeholders.
3. Aquaculture should be developed in the context of **other sectors, policies and goals.**

# Freshwater aquaculture

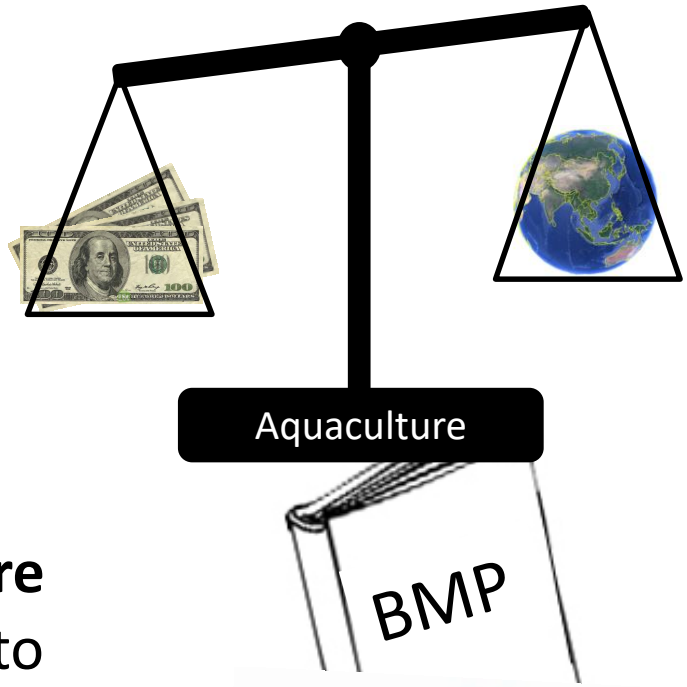
Inland finfish aquaculture is the main type of aquaculture globally

| Category | Africa | Americas | Asia | Europe | Oceania | World |
|---|---|---|---|---|---|---|
| Inland aquaculture | | | | | | |
| Finfish | 1 954 | 1 072 | 43 983 | 502 | 88% | 47 516 |
| Crustacea | 0 | 68 | 2 965 | 0 | 39% | 3 033 |
| Molluscs | | | 286 | | 2% | 286 |
| Other aquatic animals | | 1 | 531 | | 57% | 531 |
| **Subtotal** | 1 954 | 1 140 | 47 765 | 502 | 5 | 51 367 |
| **All aquaculture** | | | | | | |
| Finfish | 1 972 | 1 978 | 47 722 | 2 332 | 87 | 54 091 |
| Crustacea | 5 | 795 | 7 055 | 0 | 7 | 7 862 |
| Molluscs | 6 | 574 | 15 835 | 613 | 112 | 17 139 |
| Other aquatic animals | 0 | 1 | 933 | 0 | 5 | 939 |
| **Total** | **1 982** | **3 348** | **71 546** | **2 945** | **210** | **80 031** |

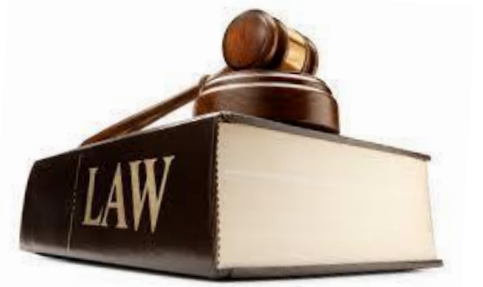

Most produced species in 2016 (x1000 MT)
Main species are carps, followed by tilapia
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Grass carp
silver carp
common carp
nile tilapia
bighead carp
carassius spp
catla
freshwater sp. nei Osteichthyes
atlantic salmon
roho labeo
pangassius
milkfish
tilapia nei
clarias
marine sp. nei Osteichthyes
Wuchang bream
rainbow trout
cyprinids nei
black carp
snakehead
other

# Background

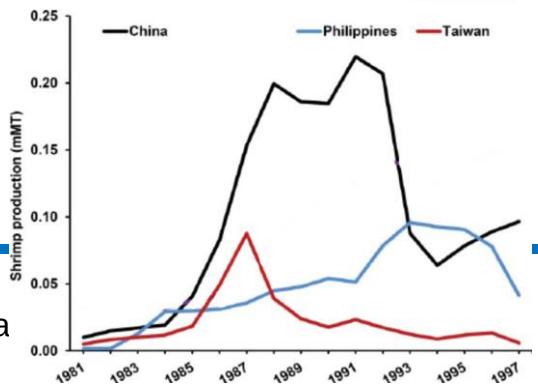
The **technology** and **profit-driven nature** of aquaculture tends give **little consideration to environmental issues**




Governments have introduced **aquaculture legislation** and attempts are being made to promote **best management practices (BMPs)**.




Freshwater aquaculture has been **less prone to the boom and bust cycles** typical of much coastal and marine aquaculture



# Some key points

- *"Aquaculture should be developed in the context of **ecosystem functions and services** (including biodiversity) with **no degradation of these beyond their resilience**"* In many cases however, the relationships are poorly specified and the thresholds unclear
- **Biodiversity** is often **associated with "resilience"**. A reduction in biodiversity necessarily "reduces the options", and by implication resilience

# Some key points

- Many of the **key ecosystem services** (flood prevention and mitigation, fisheries production, water purification etc) are under direct and **immediate threat**, and are **closely linked to particular habitats/species**.
- The EAA should **involve management** to **increase ecosystem productivity**, in particular through **integrated aquaculture**

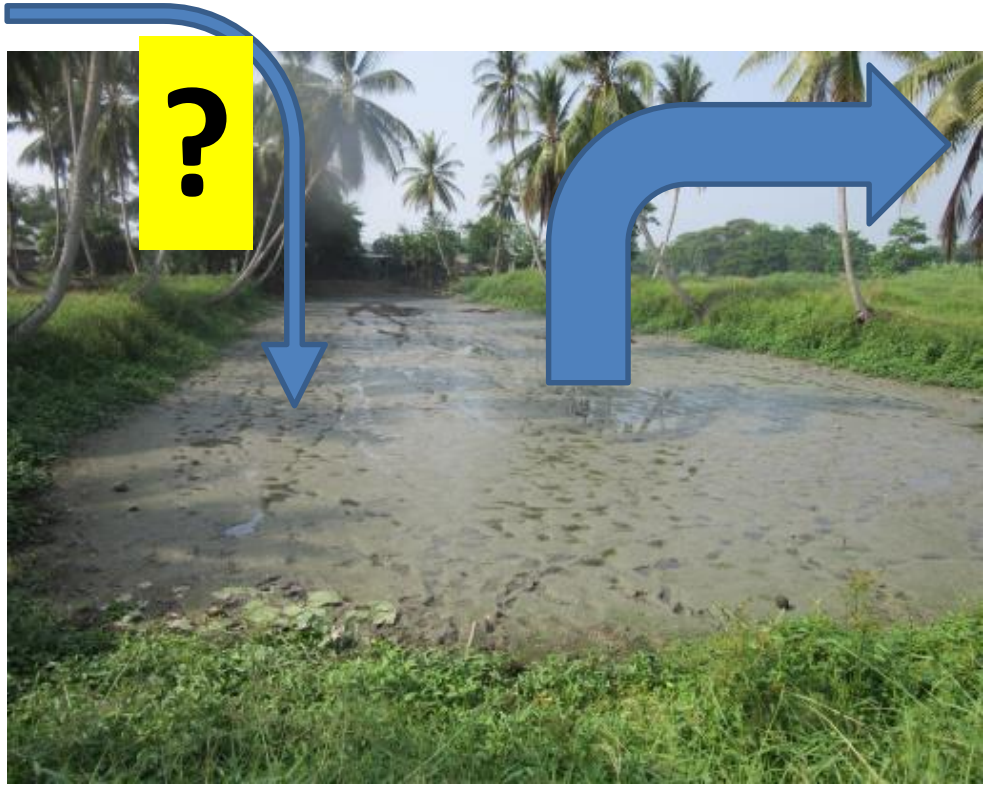
# Some key points

- EA should seek *to "enhance benefit sharing"*

- Aquaculture should improve human well-being and equity **for all stakeholders**

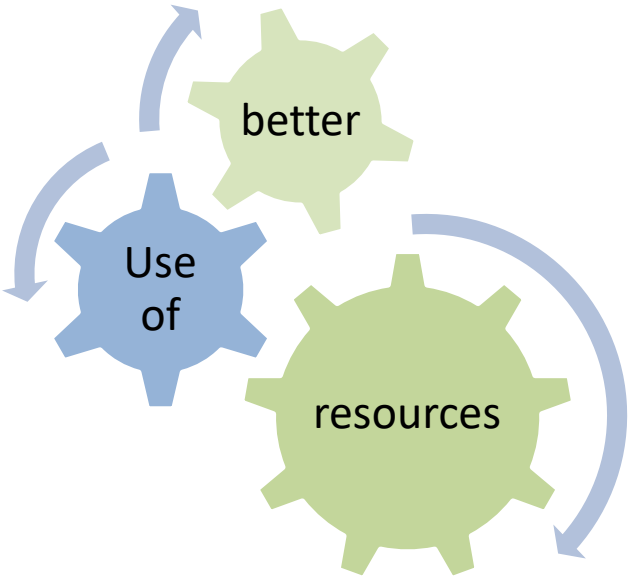
# Building nutrient-neutral systems

Nutrient build-up (or extraction) at any one place should not be such as to threaten the delivery of ecosystem services. This may be achieved through one or more of the following options:



# Building nutrient-neutral systems

Local recycling and integration




More efficient use of input resources

Limits based on estimated environmental capacity

Empowering natural treatment through green infrastructures

# Building nutrient-neutral systems

**Some drawbacks**

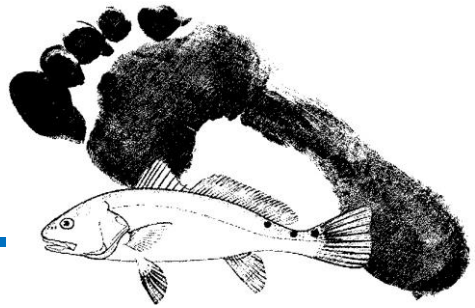
- local **recycling and integration** may be efficient but has **lower production** than intensive aquaculture and has often **higher labour** and **management costs**.
- the "**solution to pollution**" should be considered with very **careful economic analysis**.
- **Recycling** is also likely to be increasingly influenced by **carbon footprint**

Integration

=

- Productivity

+ costs



# Traditional versus industrial aqua-ecosystems

**Traditional aquaculture**

farmers or local communities

on-farm or locally available resources

integrated with other huma activity systems to get input

**industrial aquaculture**

science/industrial-based

use of agro-industrially manufactured feed


inorganic fertilizers

# Impacts of aquaculture on ecosystem functions and services

- **Loss of biodiversity** through **habitat conversion** and intensification
- **Organic sediment discharge** leading to benthic change
- **Eutrophication** of waterbodies
- Impact of released **chemicals and drugs**
- **Genetic, ecological and disease impacts** on wild stocks
- **Indirect impacts on supply fisheries** and other **sources of fish feed**;
- Impact of **wild seed collection** on wild stocks
- Introduction of **invasive species/alien species**

# Habitat conversion

- All forms of agriculture and aquaculture have a major impact on biodiversity.
- These systems are als characterized by huge changes in terms of topography, soils and hydrodynamics

# Habitat conversion

Despite impacts, some systems are widely regarded as sustainable, because:

1. They are *stable*, since operating for centuries
2. No significant impact
3. Moderate to high biodiversity

# Habitat conversion

- In many cases ponds are the result of other human activities (e.g. road construction, highlands for houses, etc) and make productive an area otherwise useless.
- fish ponds in natural wetlands also make use of marginal lands.

# Loss of biodiversity

- **Extensive systems** are relatively rich in biodiversity, but over a too much big area, which does not meet present food needs.

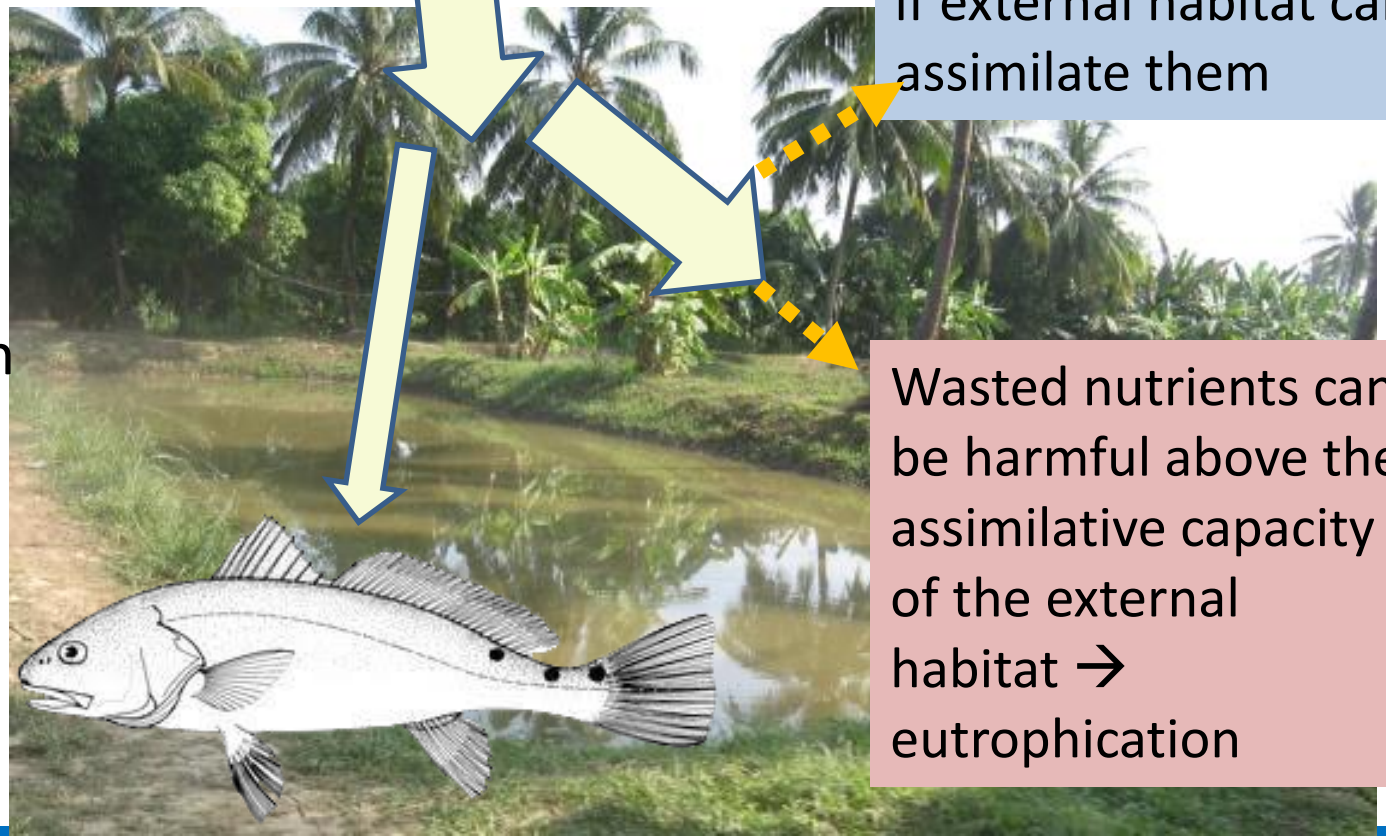
- More **intensive systems** are characterized by lesser biodiversity, but at least offer the opportunity of leaving more land aside as natural habitat and “green infrastructure”.

# Impact from chemicals/drugs

- Pesticides and antibiotics directly **reduce biodiversity** and make the ecosystem **more vulnerable** to pressures and shocks.
- In systems with **poor biosecurity** the impacts of **disease is serious** → more chemicals
- The development of **resistant fish**, **vaccines** and other **preventive measures** allows for a reduction in use of chemicals

# Impact from nutrients

feed
fertilizer



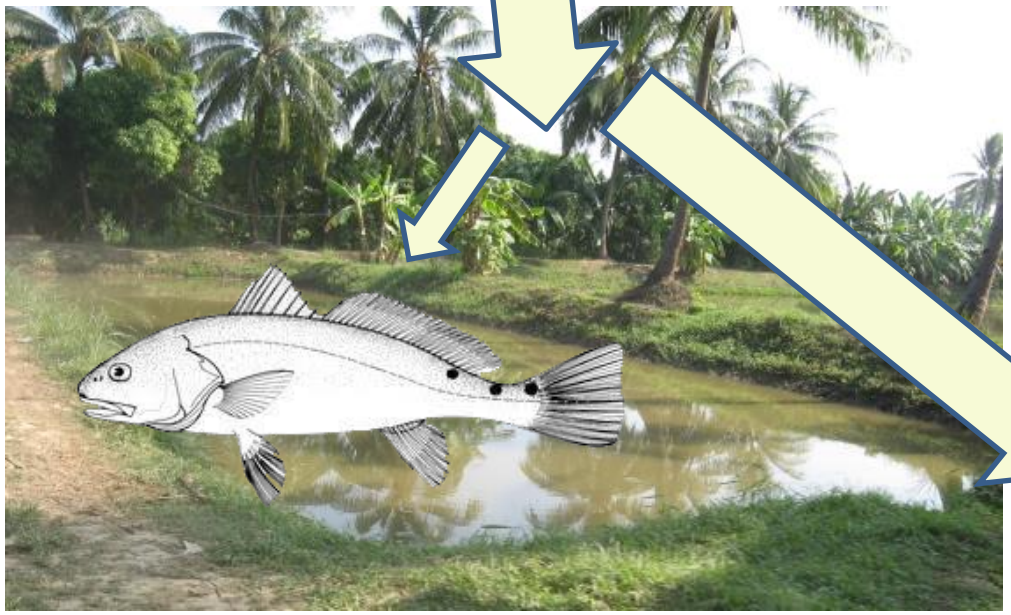
Wasted nutrients can improve biodiversity by boosting food webs if external habitat can assimilate them

Wasted nutrients can be harmful above the assimilative capacity of the external habitat → eutrophication

20-30% Nitrogen and Phosphorus retained in fish

# Impact from nutrients

feed
fertilizer



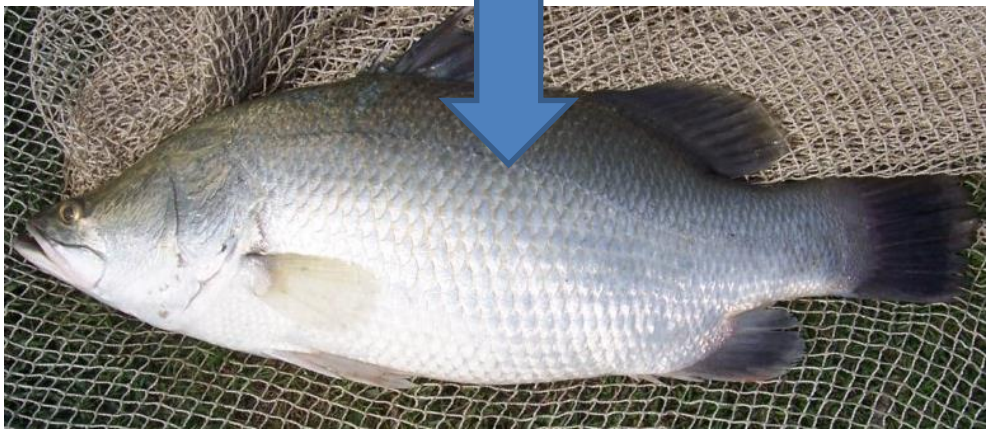
In agricultural systems the impact of nutrients is likely to be positive

# Impacts on fisheries supplies

Several freshwater species are cultured in Asia using mainly **marine trash fish**. But:

1. it is **not sustainable** in the long term
2. **compete with food needs** of poor

Freshwater trash fish is mainly preserved and sold as human food with larger profits than feed for carnivorous fish

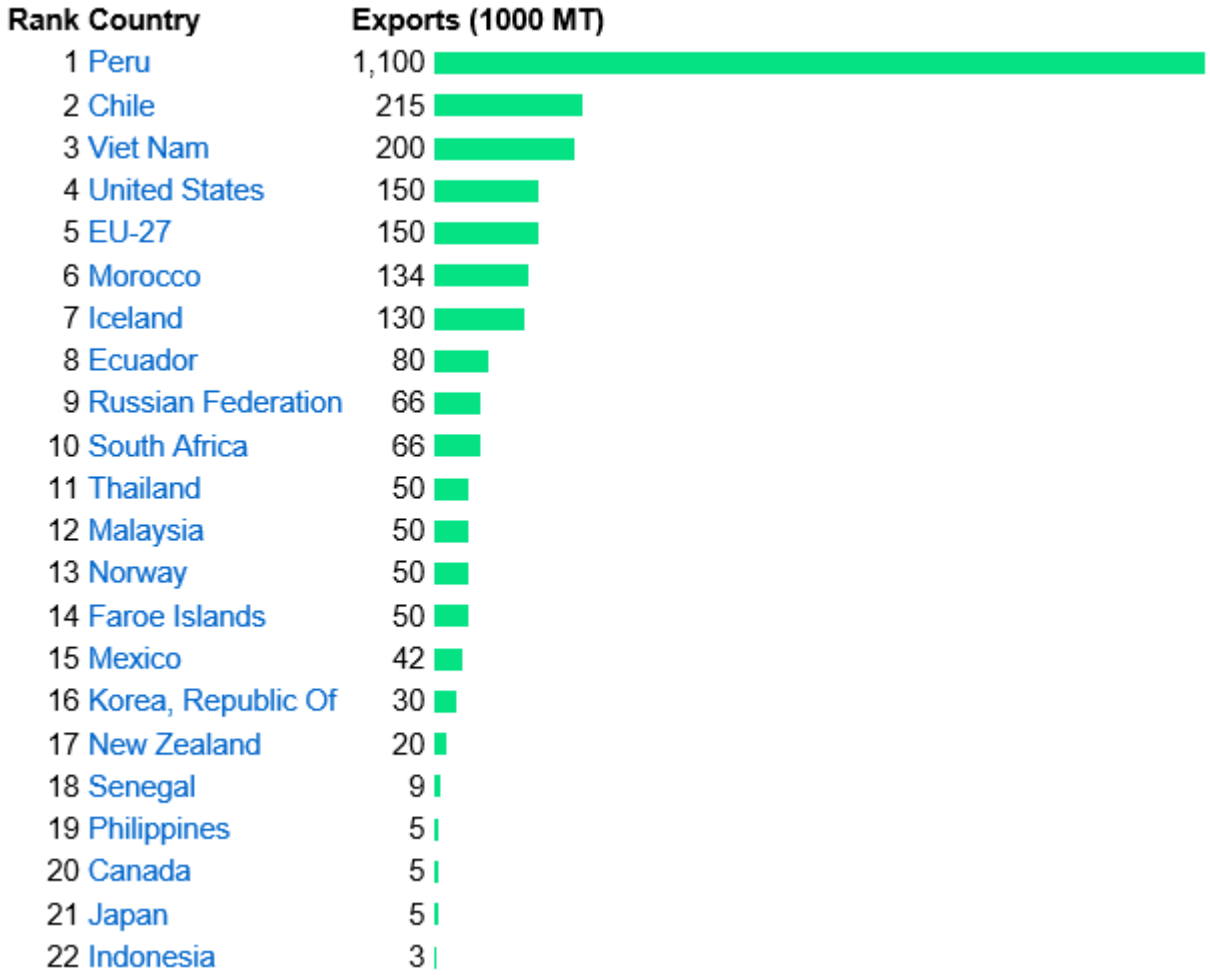


# Impacts on fisheries supplies

- Seek **alternatives** to trash fish in aquaculture
- make **better use** of low value fish and trash fish resources
- There is a need to recognize that change will have **significant implications** for the people involved, especially for the **poor involved in harvest, and use of trash fish**.
- there is a need for **consistent policy** between **aquaculture** development and **fishery** management

# Main exporters of fish meal

- Massive exploitation of marine resources
- Implies the shift towards herbivorous fish



| Rank | Country | Exports (1000 MT) |
|---|---|---|
| 1 | Peru | 1,100 |
| 2 | Chile | 215 |
| 3 | Viet Nam | 200 |
| 4 | United States | 150 |
| 5 | EU-27 | 150 |
| 6 | Morocco | 134 |
| 7 | Iceland | 130 |
| 8 | Ecuador | 80 |
| 9 | Russian Federation | 66 |
| 10 | South Africa | 66 |
| 11 | Thailand | 50 |
| 12 | Malaysia | 50 |
| 13 | Norway | 50 |
| 14 | Faroe Islands | 50 |
| 15 | Mexico | 42 |
| 16 | Korea, Republic Of | 30 |
| 17 | New Zealand | 20 |
| 18 | Senegal | 9 |
| 19 | Philippines | 5 |
| 20 | Canada | 5 |
| 21 | Japan | 5 |
| 22 | Indonesia | 3 |

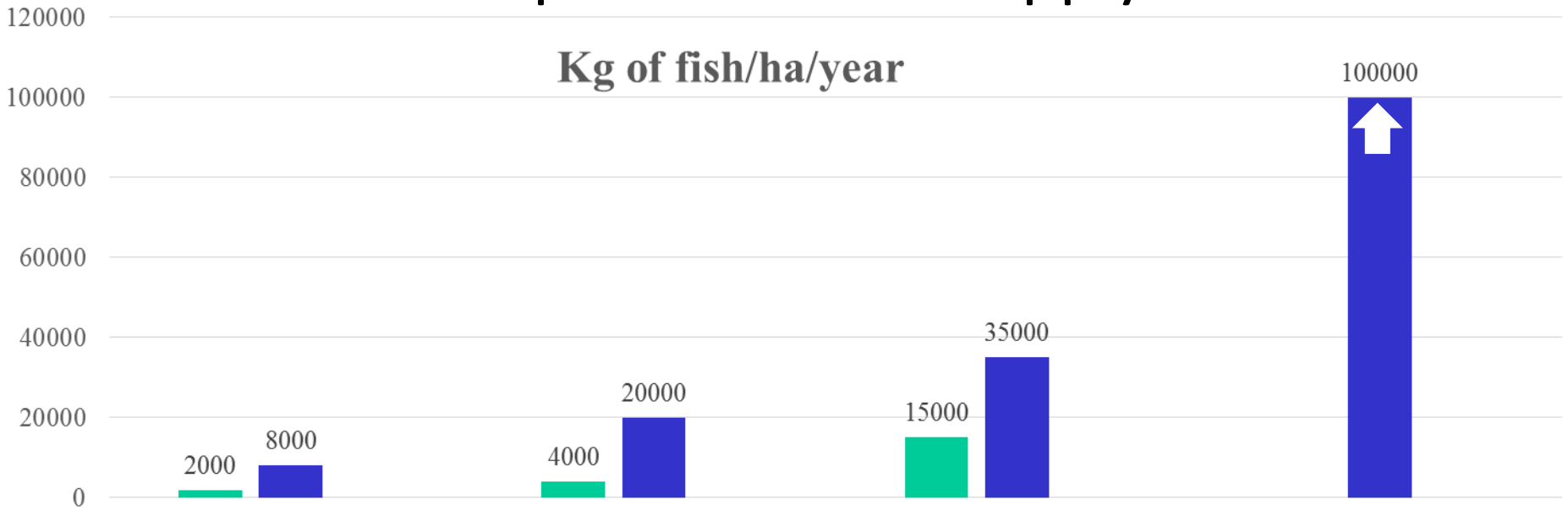
Year of Estimate: 2019
**Source:** United States Department of Agriculture

# Impact on water supply

- **Irrigation** accounts for **70 %**of the water withdrawn from freshwater systems for human use with only **30-60 %** of that amount **returned for downstream use**
- Water-based aquaecosystems such as **cages and pens do not use or consume water** as the culture facility is placed in a natural or artificial aquatic waterbody.

# Productivity

## Impact on water supply




Semi intensive pond

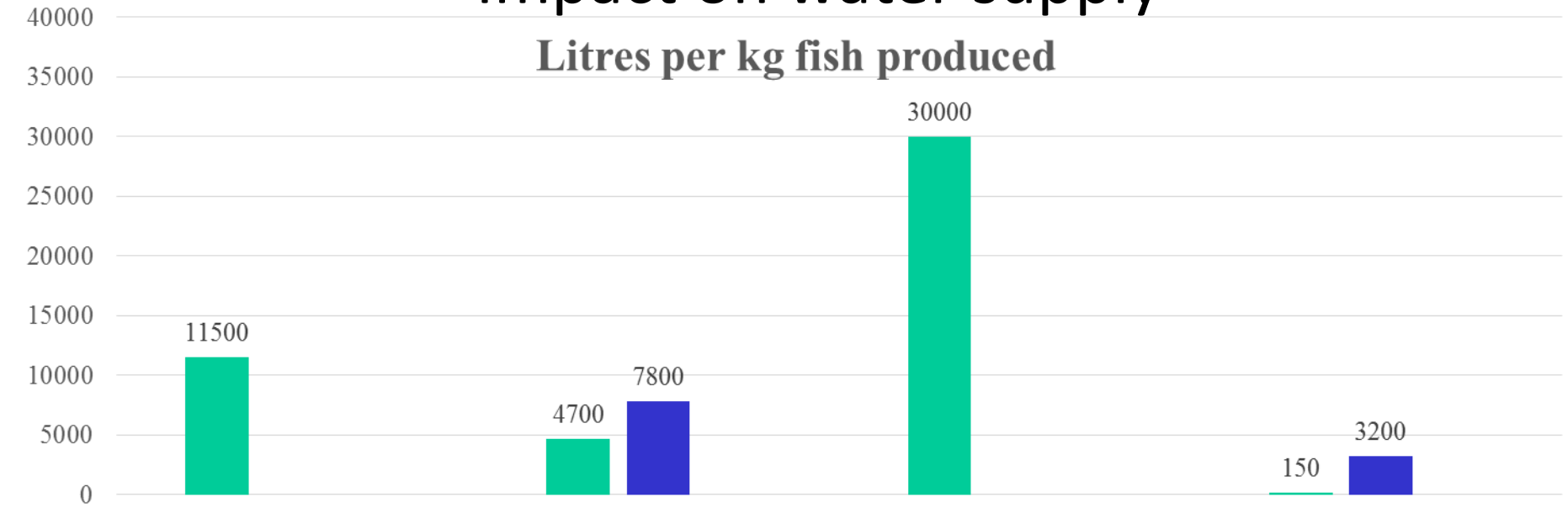
Aerated pond

Aerated pond & Water exchange

Aquaponics RAS

# Water consumption

## Impact on water supply




Semi intensive pond

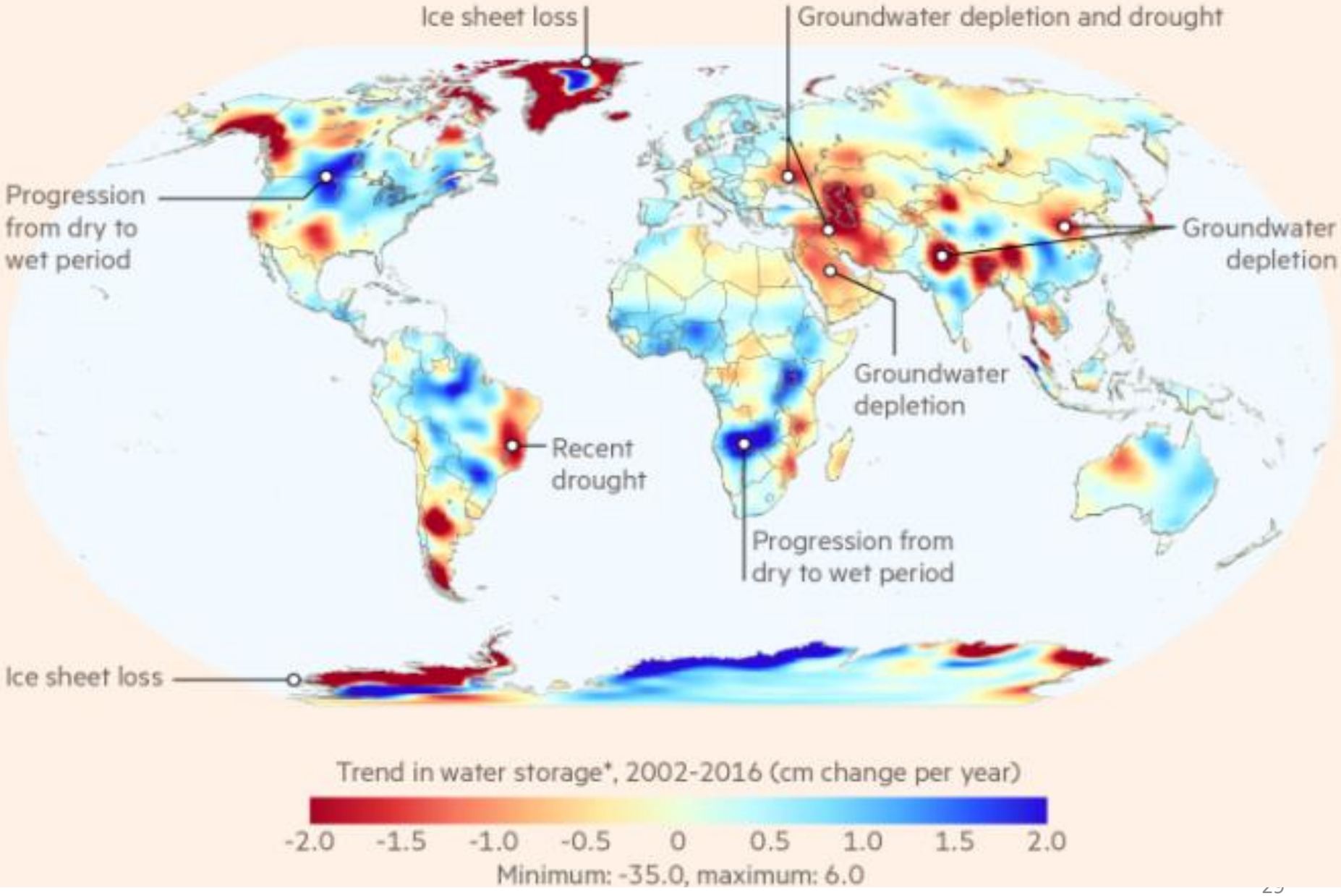
Aerated pond

Aerated pond & Water exchange

Aquaponics RAS

# Impact on water supply

- One predicted effect of climate change associated with **global warming** is on **rainfall**.
- Pumping **ground water** is increasingly common for both agriculture and aquaculture,
- **lowering of water table** has become a significant issue also for the **salinization of ground waters** near the sea
- or the **introduction of seawater** in inland areas to produce shrimps.


Ice sheet loss
Groundwater depletion and drought
Progression from dry to wet period
Groundwater depletion
Groundwater depletion
Recent drought
Progression from dry to wet period
Ice sheet loss
Trend in water storage*, 2002-2016 (cm change per year)
-2.0 -1.5 -1.0 -0.5 0 0.5 1.0 1.5 2.0
Minimum: -35.0, maximum: 6.0

# Introductions, escapes and genetic impacts

- Due to the **ecological risks** most **governments** are understandably **reluctant** to introduction of species tha may enhance or stabilize aquaculture production.
- **Government policies** are typically **weak and inconsistent**. Some countries have sought to exclude tilapia in the past, but now tacitly accept the introductions
- **Movements are difficult to control**, and more widespread release is likely to occur

# Introductions, escapes and genetic impacts

- The motivation to introduce alien species should be reduced as far as possible through development **work with native species**

However, it is **unrealistic** to expect that indigenous species **can replace exotic but globally traded fish** in commercial aquaculture

# Green revolution

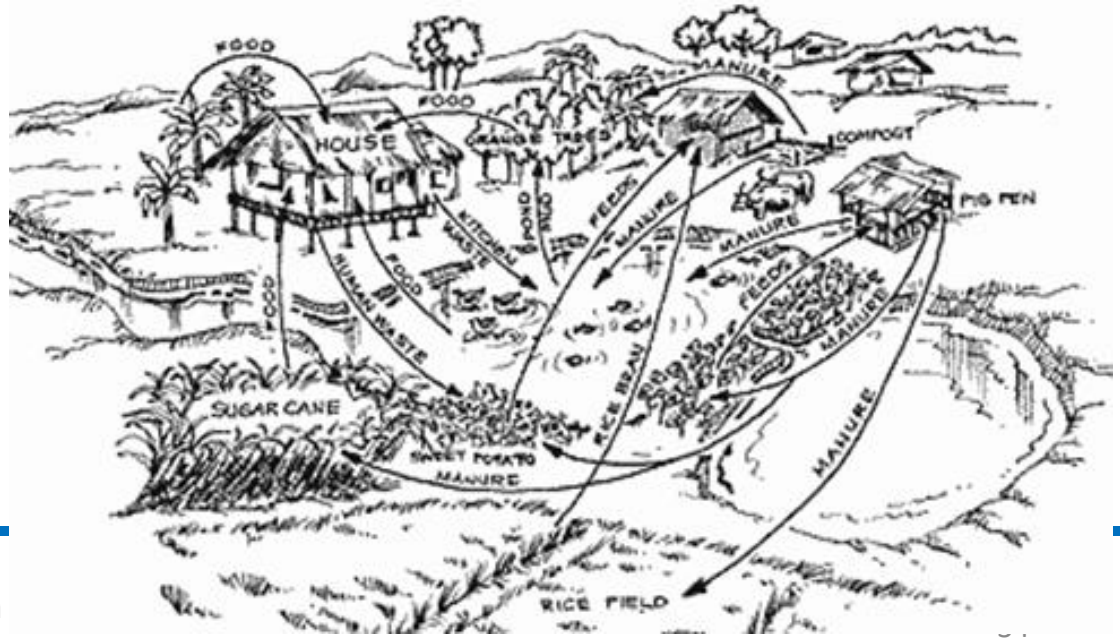
- The major changes in agriculture have been the **shift from family farming**, which causes less diffuse pollution, **to large-scale commercial** and mostly monoculture **agri-businesses**
- A similar change is **occurring in aquaculture**.

# Integrated farming

Integrated aquaculture combines two or more human activity systems which is **directly on-site**, or indirectly **through off-site** needs and opportunities, or both

# Integrated farming

Integrated agriculture – aquaculture systems (IAAS) with usually **limited on-farm or local sources** of **vegetation**, **manures** and agricultural **by-products** as **nutritional inputs** e.g. rice/fish; crop/fish; livestock/fish; sericulture/fish.



# Integrated farming

- **Integrated fisheries-aquaculture systems (IFAS)** use small freshwater or marine trash/low-valued fish as feed.
- **'capture-based aquaculture'** the practice of collecting seed material – from early life stages to adults – from the wild

# Strategies to minimize impact

# Managing sediments

**Pond mud** is a major sink for **nitrogen and phosphorus** in fertilized and supplementary fed semi-intensive systems. It is removed to fertilize, but it is **labour intensive**.

**Rotation** of **fish culture** and **agriculture** by cultivating plant crops in nutrient-rich sediments in drained fish ponds is a traditional practice

Fish (rainy season) → Paddy (dry season) → Dry up pond (endo of dry season)

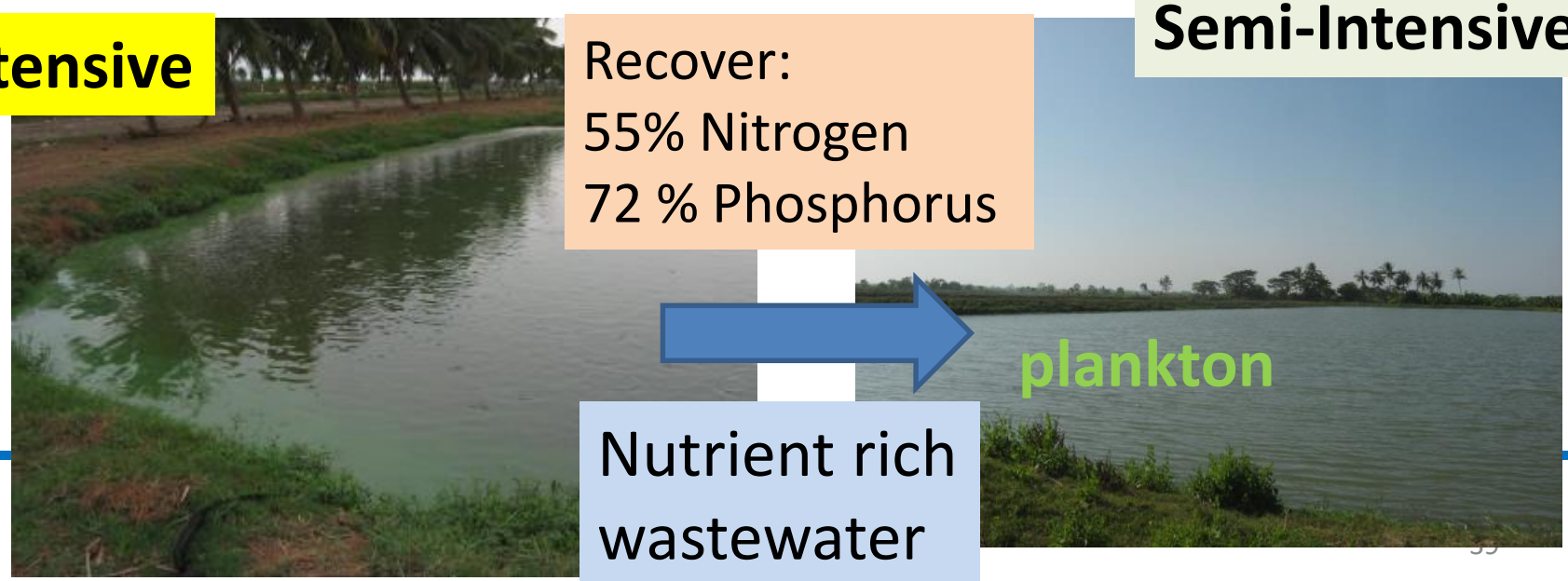
# Managing sediments

- **Shrimp and Macrobrachium** are currently grown in **rotation with rice** in Bangladesh and Viet Nam
- Cultivation of **lotus** (*Nelumbo nucifera*) to **recover nutrients** from pond mud, either cultivated alone in the ponds in rotation or in polyculture with tilapia

# Managing sediments

Successful use of **wetland-type** ecosystems

- high density aquaculture with **pelleted feed in monoculture in 5x1 ha ponds** has effluent water recirculated within a single **20 ha semi-intensive pond** stocked with common carp, bighead carp and silver carp



# Integrated aquaculture systems

**Intensive and semi-intensive aquaculture**

- In **Israel** water from **intensive 1 000 m2** fish ponds on a farm was reported to be **exchanged five times** per day with that in **larger ponds** which function as treatment reservoirs as well as **semi-intensive fish ponds**
- the combined system required a large area of land, **the ratio** of **semi-intensive** to **intensive** ponds was reported to be at least **10:1**.

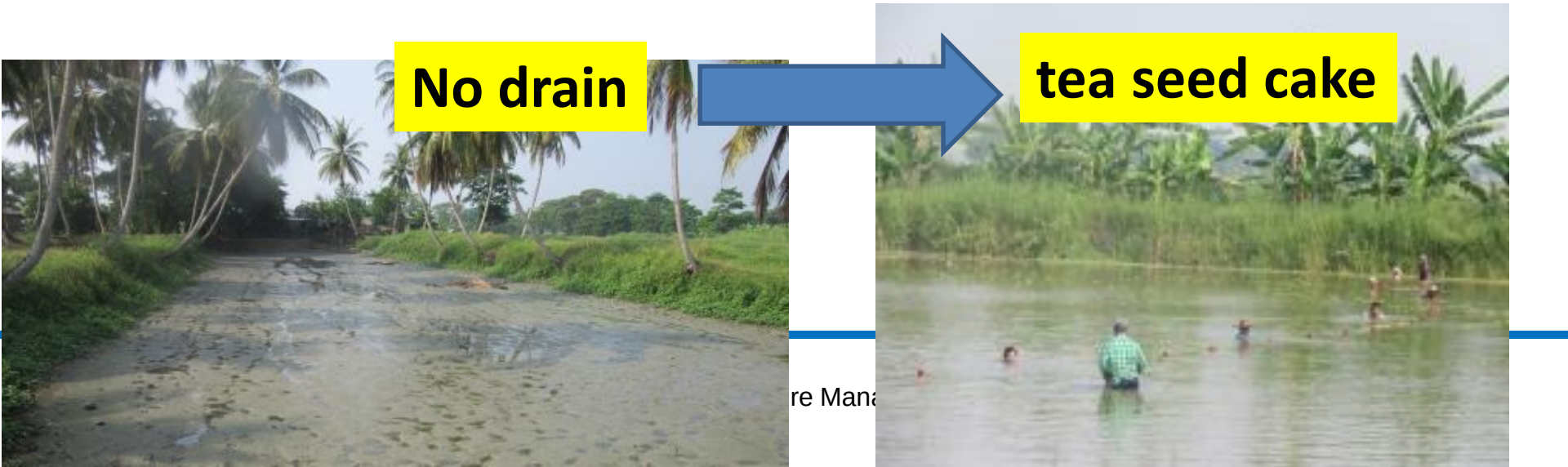
# Managing sediments

- A **pond-wetland system** can treat the effluent of an intensive farm
- Nitrogen and phosphorus removed by filter-feeding fish, suspended solids are retained by the wetlands partially covered by macrophytes such as cattails and reeds.

# Managing sediments

Appropriate management to harvest fish could minimize the environmental impacts of pond effluents:

- in Thailand pond are half drained to harvest fish → large amount of wastes into the environment
- tilapia can be harvested without draining by seining after anaesthetization with **tea seed cake**



# Integrated aquaculture systems

**Biofloc**

- Works with filter feeding animals (tilapia, macrobrachium, shrimps)
- low-value carbohydrate-rich supplementary feed is added to intensive culture of pellet-fed to stimulate nitrogen uptake by heterotrophic bacteria that becomes a source of proteins

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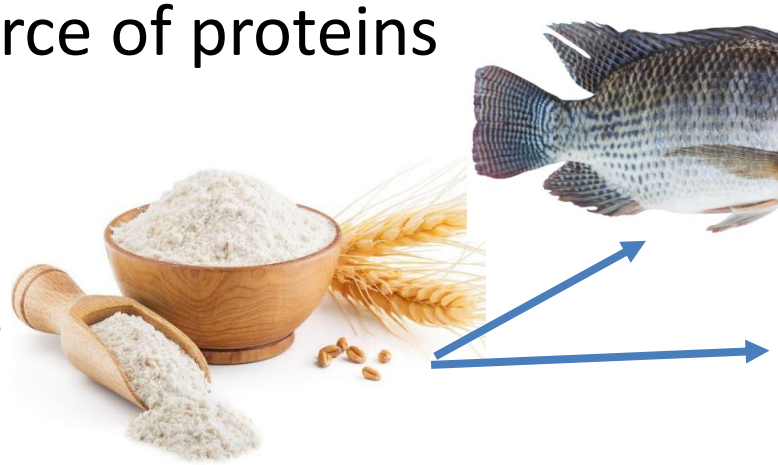
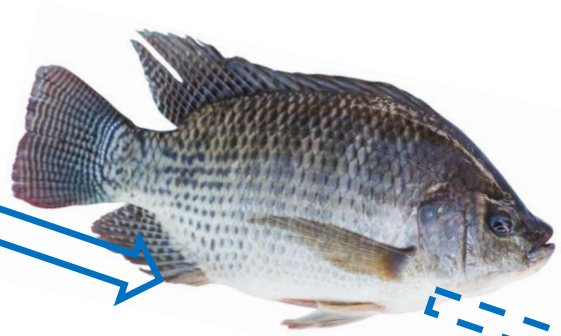


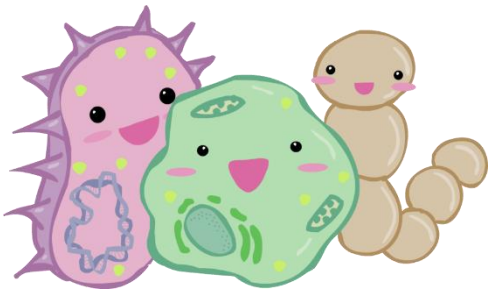
# Biofloc at a glimpse

In biofloc ponds, fish eat the protein twice; 1) as pelleted feed and 2) as microbial protein. **The protein recovery reaches almost 50%.**




ammonia

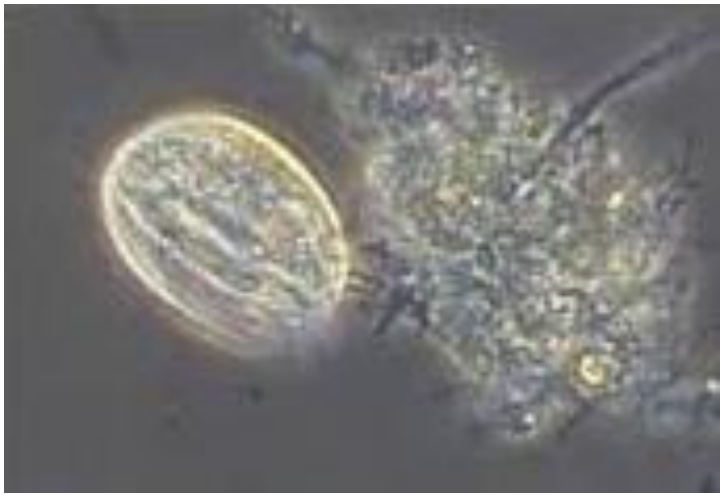
Intense aeration

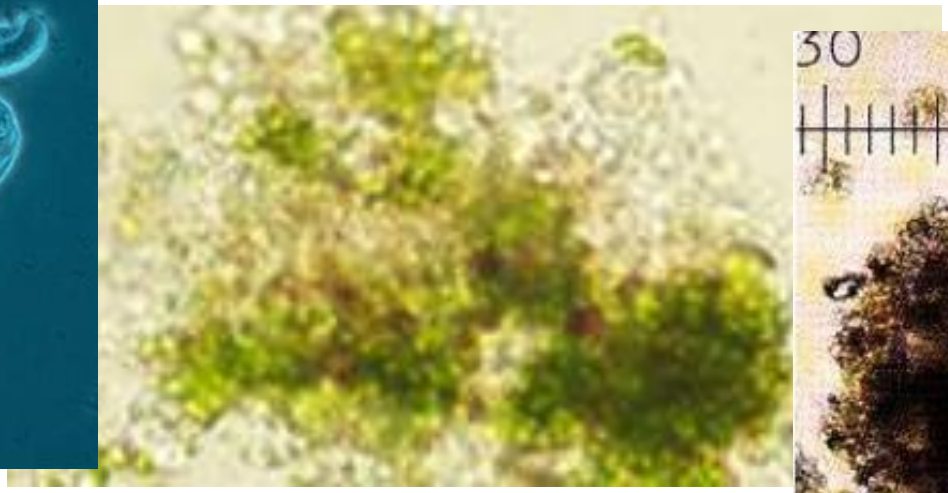


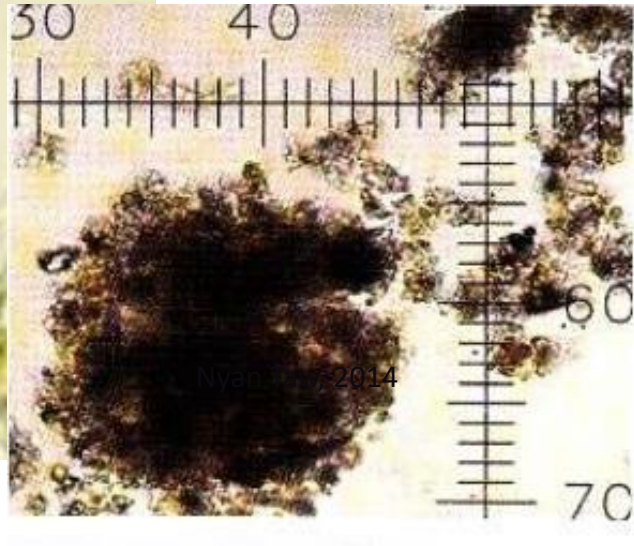
# Biofloc at a glimpse

**Biofloc is made of:**

1. Bacteria
2. Microalgae
3. Suspended wastes
4. Microplantkton/microrganisms







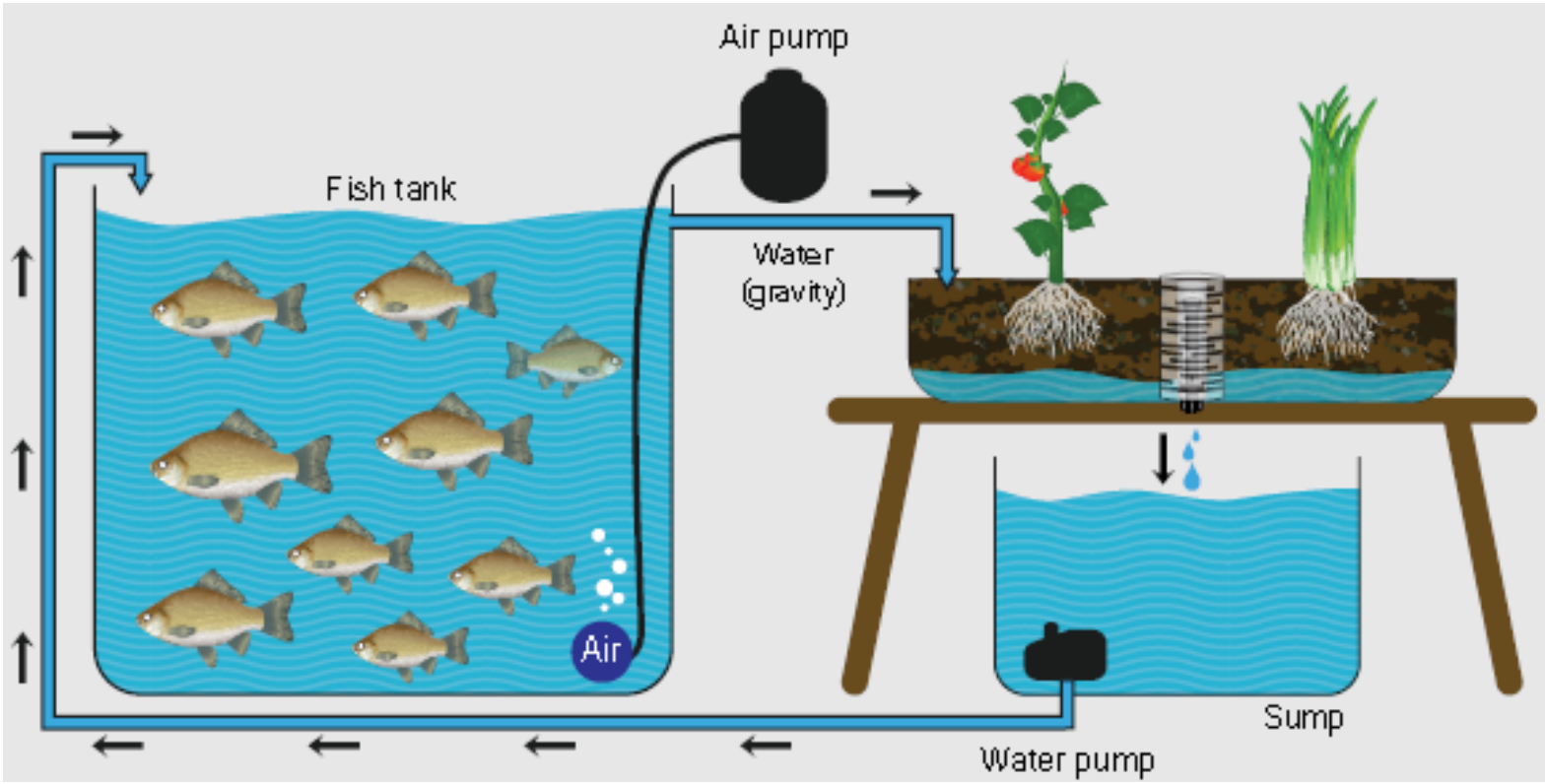
# Integrated aquaculture systems

**Intensive aquaculture and hydroponics**

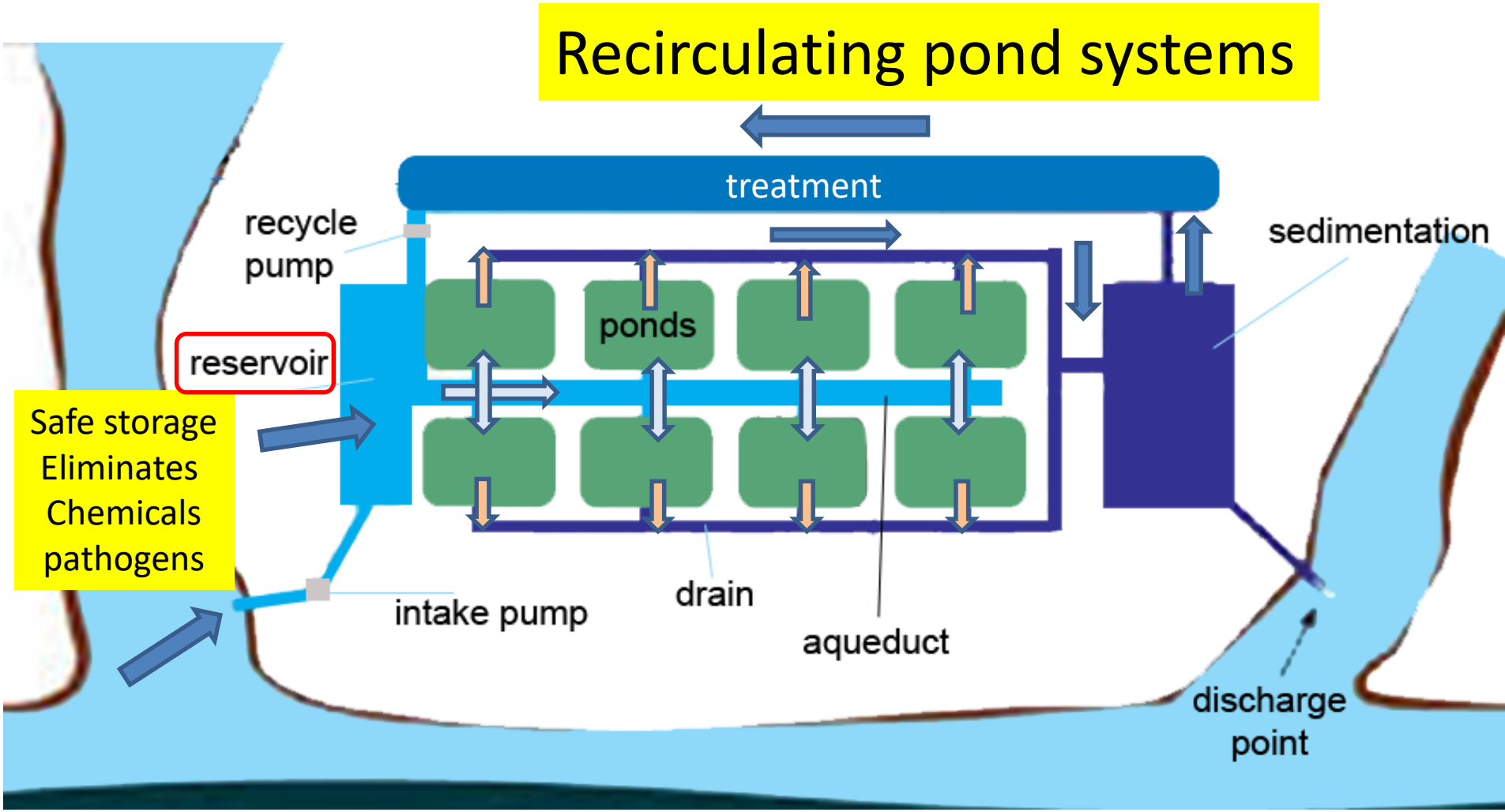
- These are specifically designed to minimise both import and export of nutrients at the farm level, or within a closely associated group of enterprises.
- So far this approach has been driven by environmental concerns rather than profitability. Vegetables eventually are the profitable part rather than fish

# Aquaponics

- Is a *closed* production system that **integrates aqua**culture with hydro**ponics**, the soilless cultivation of plants
- Three main components: **fish**, **plants and bacteria**



# Integrated aquaculture systems



# Fish cages in ponds

**Pellet-fed caged fish fertilizing surrounding fish pond**

Use of feed and microalgae naturally growing in pond wastes from value fish crop eaten by other fish or shrimps

Recovery: 36 % nitrogen and 45 % phosphorus

21% nitrogen and 28% phosphorus in body tissue,

mud acting as a sink for 20-29 % nitrogen and 27-45 % phosphorus

# Integrated aquaculture systems

**80:20 pond fish culture (Chinese system)**

- 80% of the harvest weight comes from one high-value species (grass carp, crucian carp or tilapia) fed with pelleted feed, 20% is a "service species" such as the filter feeding silver carp helping to clean the water and the carnivorous mandarin fish (*Siniperca chuatsi*) to control wild fish and other competitors.
- Pelleted feed further increase feeding efficiency and reduction of wastes.

# Integrated aquaculture systems

**Partitioned aquaculture system**

- A high rate microalgal culture is combined with fish culture.

Intensive catfish culture

Fertilizing wastewater

Microalgae moved by paddlewheel eaten by tilapia

# Integrated aquaculture systems

**Rice fish**

- trenches and ponds associated with rice fields in which a range of fish and shellfish are grown fairly intensively, releasing nutrients into the rice fields.
- In Viet Nam shrimp or *Macrobrachium* may be stocked in alternation or rotation with a rice crop – what might be called “serial integration”. This again allows for recycling excess nutrients and also has the potential to “break” disease cycles.

# Integrated aquaculture systems

**Rice fish**

- The Vietnamese Government's policy encourages conversion of rice fields to aquaculture in flooded areas which are marginal for rice cultivation, this is an example of rational allocation of resources between sectors, by central government.

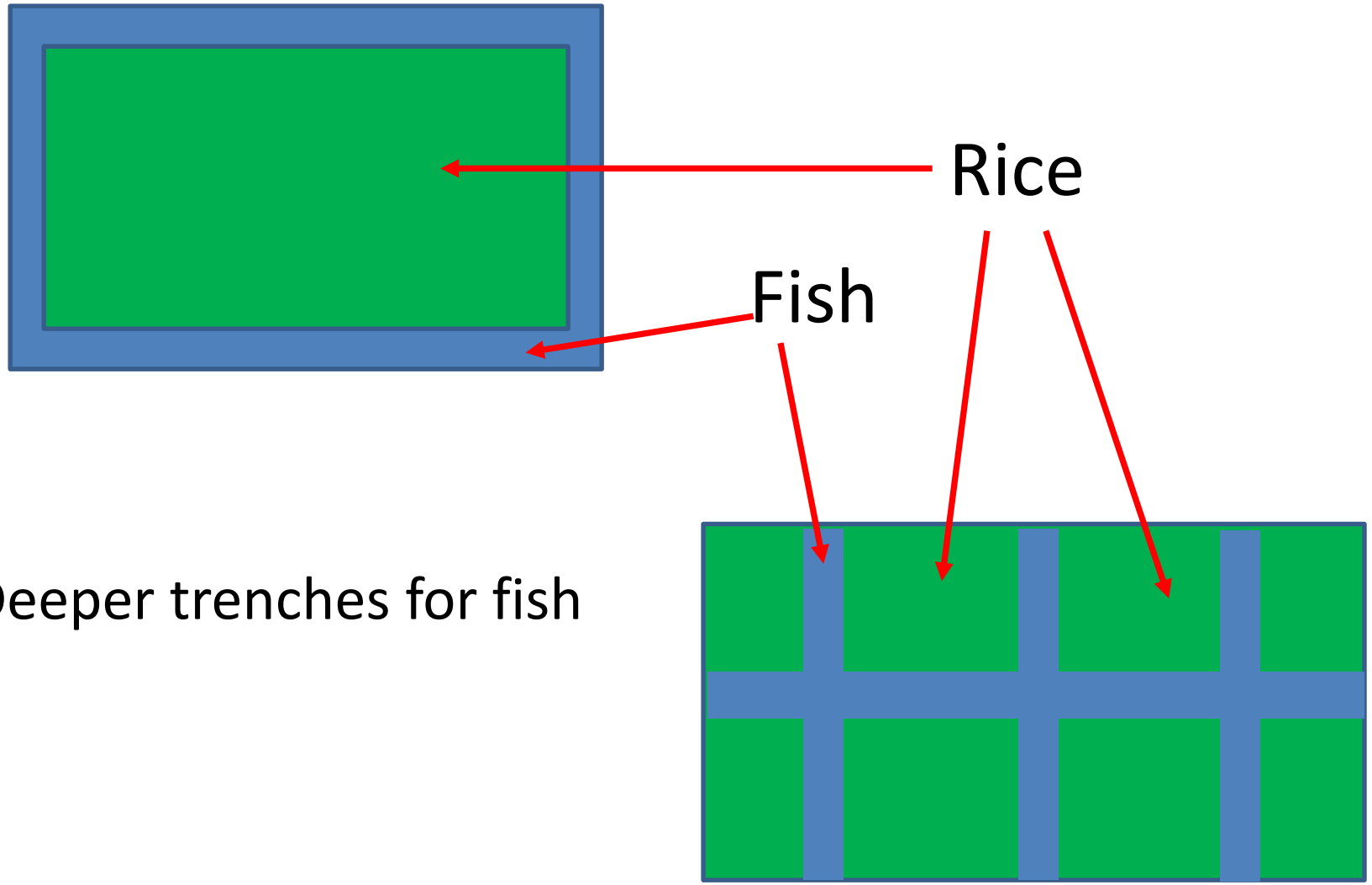
- In Thailand precautionary approaches have banned shrimp farming in rice production areas to avoid salinization and obstruction of irrigation canals

# Case studies

# Rice field-based IAAS in Zhejiang Province, China

- Culture of a red coloured variety of common carp (*Cyprinus carpio*) in terraced rice fields fed by streams has a documented 1 200 year tradition
- Rice cultivated on the small farms averaging only 1 300 – 1 700 m2. Red carp is considered a delicacy earning 4-5 USD/kg.
- fish are bred in a trench with direct release of fry into the paddy

# Rice-fish layout




Deeper trenches for fish

# Integrated Aquaculture-agriculture systems - IAAS

**Vietnamese VAC: garden (vuon), pond (ao) and livestock quarters (chuong)**

- small ponds, 1.0-1.2 m deep, located near the house. Farmers stocked a polyculture of common carp fed rice bran, grass and pig manure.
- Fish yields ranged from <0.1 to 6.7 t ha-1 per season
- Many ponds were dug for soil for use as fill to raise the level of the land for the homestead and surrounding garden
- Ponds are traditionally multipurpose: water supply for domestic purposes; watering vegetables; cultivation of floating aquatic plants for feeding pigs
- harvesting wild fish.
- Pond silt removed annually to fertilize plants
- Livestock housed near pond, wastes used to fertilize pond water

# Integrated Aquaculture-agriculture systems - IAAS

**Chinese IAAS**

- up to 8-9 species and integration with: agriculture, animal husbandry, sanitation and reuse of cottage-level industrial by-products such as from distilleries and soybean processing.
  - herbivorous grass carp (*Ctenopharyngodon idella*)
  - filter feeding bighead carp (*Aristichthys nobills*)
  - silver carp (*Hypophthalmichthys molitrix*),
  - the omnivorous common carp (*Cyprinus carpio*)
  - crucian carp (*Carassius auratus*)
  - snail eating carnivorous black carp (*Mylopharyngodon piceus*)
- Grasses used by 90% of farms due to grass carp, but also grains and oil cakes
- Yields about 4 to 10 tonnes/ha.
- most fish ponds located in low-lying land subjected to flooding and not suitable for agriculture.

# IAAS

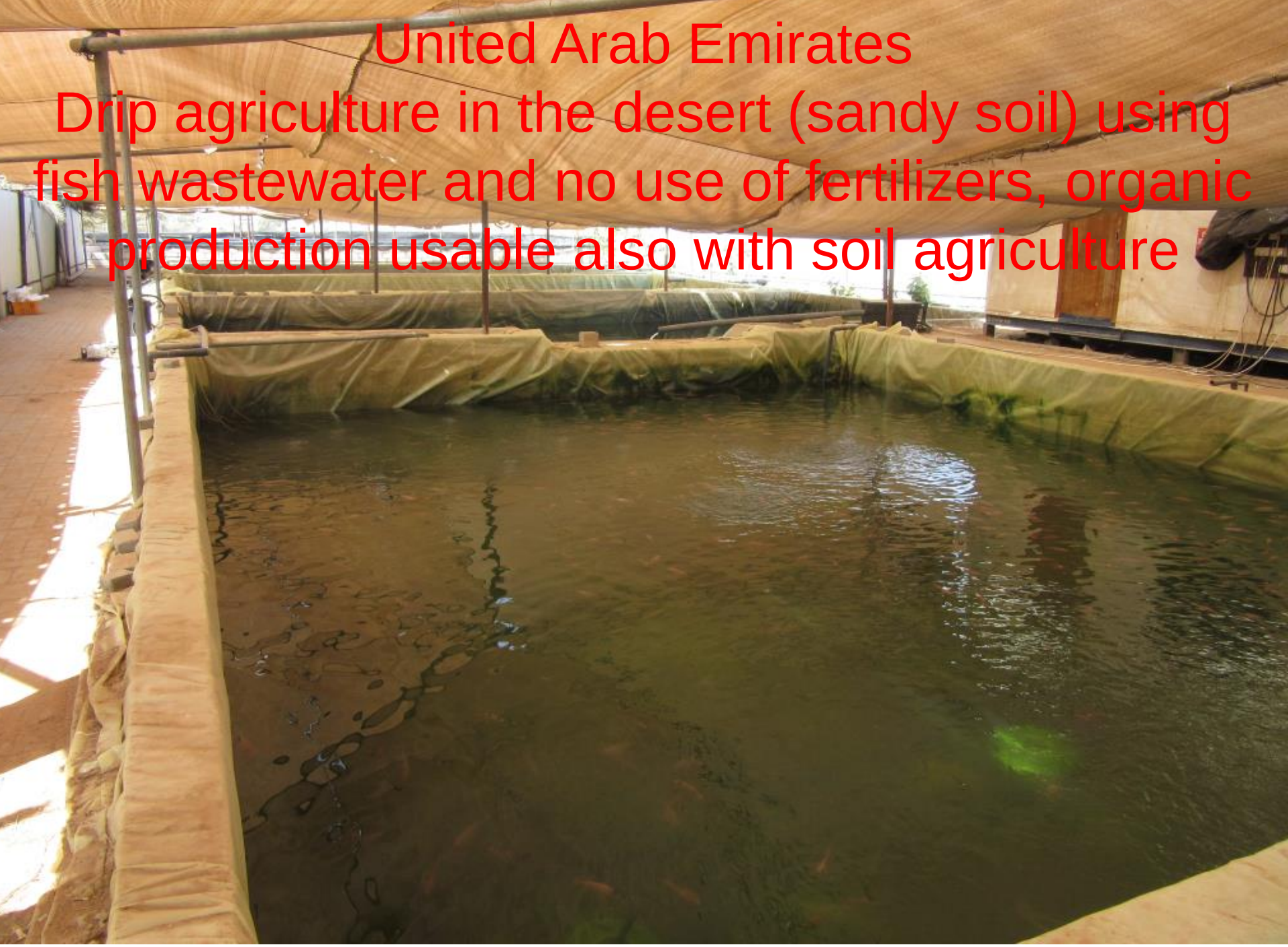
**Advanced Chinese IAAS**

- Traditional IAAS relies on manure and farm by-products and grass to feed the fish, but water quality deteriorates quickly and it affects the health of the fish and the environment.
- high quality agro-industrially manufactured pelleted feeds highly adopted and 2-3 times more nutrient efficient
- As intensive production of common carp in monoculture may yield up to 30-40 tonnes/ha compared to 12-15 tonnes/ha for traditional polyculture
- Some concerns about the sustainability from feed (if fish meal is included)

# Culture based fisheries

- Small reservoirs in Viet Nam are leased to farmers or farmer groups for aquaculture
- Chinese carps (bighead, grass and silver carp), Indian carps (mrigal and rohu), common carp, silver barb and Nile tilapia.
- Fish are harvested from March-May when the water level is the lowest due to irrigating rice
- average yields ranging from 115-429 kg/ha. Stocked fish contribute more than 80% of the total harvest
- Fish yield closely correlated to conductivity and chlorophyll-a.

Fertilization possible?


United Arab Emirates
Drip agriculture in the desert (sandy soil) using fish wastewater and no use of fertilizers, organic production usable also with soil agriculture

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Drip agriculture in the desert (sandy soil) using fish wastewater and no use of fertilizers, organic production usable also with soil agriculture

# *Essential* EAAM

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