Integrating water and waste management to support sustainable inland aquaculture

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Introduction

- aquaculture, as any type of economic development is shaped by demand, technical advances and resource constraints
- integrated aquaculture, in which water and nutrients are used for production of aquatic products, is part of larger food production, and livelihood systems

Introduction(contd)

- aquacultural development cannot be de-linked from broader development
- in particular urbanization and industrialization have large impacts
- defined at the boundary of a farm, watershed, region or national boundary
- convergent evolution e.g. ditch-dike,overhung latrine

Concepts

- aquaculture is dependent on the availability of both water and nutrients
- where one or both of these resources is most limiting, the fish culture system can become critical as a temporary or main source

Concepts

- modern forms of stand-alone specialised aquaculture require optimal conditions for success, both technical and economic.
- scarcity or surplus water, nutrients or both can stimulate aquaculture to develop as a component of broader, integrated food production.
- can aquaculture be defined by the level of ‘leakiness’ or consumption of nutrients and water?

Concepts

- Quantity, quality and time of inputs, transformation and outputs
  - the quantity of water and nutrients used by aquaculture
  - the quality of water and nutrients used by aquaculture
  - the quantity and quality of water and nutrients after use

Concepts

- Quantity, quality and time of inputs, transformation and outputs
  - the quality and value of the aquatic product (size, species, off-flavours, human health risks, proximate composition)
  - time over which water and nutrients are used (opportunity costs; seasonality)

Concepts

- By improving the efficiency of water and nutrient use, fish culture can become
  - a cornerstone of ‘sustainable intensification’ (Pretty,1996)
  - key to avoidance of hydrocide (Lundqvist, 1998)

Stand-alone aqua-production

- Requires
  - water-rich conditions (quality, quantity)
  - feed and seed resources
  - market access
- But,
  - high input costs, especially feeds, mean that unit profit margins are low.

How flood and drought promote integration

- flood and/or drought stimulates change in land use to reduce risk to livelihoods, through damage to health, housing, food production and employment
- development of pond aquaculture in sites with poor agricultural potential e.g common carp in Hungary, *Trichogaster* systems in Thailand

How flood and drought promote integration

- Flood
  - ponds for flood control (Dhaka, Ha Noi), linked to urbanization of flood plains,
  - borrow pits are the most common form of culture unit-near to human and livestock housing
  - significant crop diversification of floodplains requires ditch-dike
  - Unproductive waterlogged areas within irrigated areas

How flood and drought promote integration (contd)

- Drought
  - wet-dry tropics-long periods without predictable rain-need on-farm storage to hold water for domestic and agricultural purposes
  - supplementary irrigation can extend periods of crop production,e specially for high value crops

How flood and drought promote integration (contd)

- But
  - engineer-managed irrigation systems are generally unreceptive to fish production or multipurpose use generally
  - farmer-managed systems are constrained by a host of factors including lack of available knowledge and the complexity of social management of water and aquatic resources

Why integration has occurred where it has

- flooded agro-ecosystems, including river deltas with high population densities, were dependent on aquatic foods
- dominance of aquatic foods, especially fish, in diets compared to meat/dairy products
- nutrient reuse was a necessity in pre-industrial agriculture

Why integration has occurred where it has

- population pressure stimulating movement away from water-rich environments; taste and demand for fish has also traveled, with a need to use water more efficiently
- integrated water management has occurred in Israel because of extreme shortages of water for all purposes; required adaptation of technologies used where water is more abundant

Water availability and fish production

- the water level in most water bodies fluctuates seasonally
- depth of water in most water bodies varies with topography, construction method etc
- water inputs from rain, runoff, off-farm irrigation
- off-takes -for agriculture, non-productive losses (seepage, evaparation, overflow)

Water availability and fish production

- characteristics of water use
  - dike-side cropping perennial, deep rooted;
  - pumped removal for field-dike crops; crop demand
- soil types

Water availability and fish production

- timing of seed availability and stocking,
- size of seed at stocking and predator level
- staggered harvest, marketable size of fish

How nutrient availability affects the evolution of aquaculture

- integrated aquaculture has become best established in peri-urban areas because
  - high nutrient availability e.g. waste feed, manures (including human)-this results from nutrient import and concentration
  - high demand for cultured fish. People cannot catch fish every day themselves; often reduced stocks of wild fish

How nutrient availability affects the evolution of aquaculture

- feed industry supporting feedlot livestock is well established (linkages to markets and feed resource base)
- traditional competition for nutrients and/or water exists (ami ami, chicken manure, nightsoil in N. Vietnam)
- specialized intensive livestock production tends to develop in areas of relative advantage eg Alabama, Southern USA, Parana State, Southern Brazil; Lopburi, Central Thailand aquaculture development frequently follows.

How nutrient availability affects the evolution of aquaculture(contd)

- where integrated aquaculture is poorly established or absent
  - extensive agricultural practices; little intensification in use of water or nutrients
  - lack of nutrients used in fish culture leading to slow fish growth and poor survival (major hurdle for new adopters)

Options where nutrients are limiting

- in semi-intensive ponds
  - more efficient or /new approaches to the collection of manures
  - increased frequency of use and 'supplementation'(fertilizers/supplementary feeds)
  - reduction in flow-through, flush out of nutrients

Options where nutrients are limiting (contd)

- in larger systems that cannot be fertilized conventionally
  - substrate (periphyton)
  - extensification-use of dispersed nutrients and seasonal water
  - use of polyculture-a variety of fish species that consume a range of feeds (implications for improved space, nutrient and pest management)

Options where nutrients are limiting

- community tanks
  - design, nutrient harvest
  - rehabilitation, drainage and mineralisation
  - livestock and forestry options)
- flooded river basins (controlled flood and harvest; Gregory 1998)

Nutrient concentration

- concentration of nutrients is important to both nutrient limiting and polluting conditions
- most nutrients are concentrated in solids - system designs to encourage sedimentation are important for maximum
  - ‘harvest’ of nutrients in nutrient-poor conditions
  - removal and reuse under nutrient-rich conditions (human, livestock, fish wastes)

Options where nutrients are polluting

- reduce volume of effluents (livestock, fish)
  - better feeding systems
  - more digestible feeds,
  - better husbandry of improved stocks
- waste separation
  - more efficient means to remove solid from soluble nutrients
  - biodegradable and non-biodegradable

Options where nutrients are polluting

- nutrient removal from water
  - sedimentation/filtration
- nutrient reuse
  - use of slurries for agriculture
  - hydroponics
  - aquaculture

Options where nutrients are polluting

- Aquaculture as part of a treatment process. Ideally
  - pretreatment and post treatment
  - tolerant species; high density culture

Wastewater use-nutrients and water

- Wastes from intensive aquaculture and sewage are more dilute and thus problematic to reuse than livestock
  - concentration typically reduces costs of handling and reuse-especially important if waste volumes are high
  - costs of removal and transportation of even ‘thickened sludges’ from intensive aquaculture (>90% water) may prohibit off-site treatment (Summerfelt et al. 1999)

Recycling nutrients and water-land availability

- cost and availability of land constrains peri-urban aquaculture
- conventional semi-intensive fish production relatively inefficient at waste treatment
- waste frequently include *processing* as well as *production* byproducts
  - pre-treat to produce live feed for intensive aquaculture and dry waste
  - livestock mortalities and abattoir wastes

Recycling nutrients and water-land availability

- Nutrient transformation often requires more water and land than fish culture.
  - ‘inputs’ e.g. growing duckweeds on wastewater and feeding to fish in semi-intensive systems
  - outputs e.g.growing lettuce on intensive fish culture effluents.
- Constructed wetlands (vetiver grass) to absorb nutrients from drained catfish ponds require 0.7-2.7 times area of fish culture (hydraulic residence of 1-4 days;Schwartz and Boyd, 1995).

Recycling nutrients and water-land availability

- Floodplain systems in Asia can utilize herbivorous fish ponds (algal route) for recovery of intensive fish or livestock or human waste.
- Nutrients also recovered directly from wastewater or as overflow from wastewater-fed ponds by aquatic macrophytes eg morning glory (Calcutta), lotus (HCM City)
- A key aspect is that by closing the water cycle, water is preserved and ‘cleaned’ prior to reuse. An important measure in peri-urban where industrial pollution is unpredictable.

Recycling nutrients and water-land availability

- Use of ricefields as wetlands around intensive *Clarias* catfish ponds in central Thailand
- intensive dike horticulture receiving irrigation and nutrients from fish ponds - ‘fertigation’
- Enlarged dikes based on fertigation and mechanized could absorb large amounts of nutrients-overcoming the problem identified by Gunther (1997)for phosphorous disposal of HEAP traps (Hampered effluent accumulation processes).

Constraints and conflicts

- technical
  - mixing of industrial and organic wastes-lack of point source treatment (eg Changzou, China)
  - eutrophication of limited surface water required for many purposes-the cost of providing alternative drinking and domestic water

Constraints and conflicts

- public health and market considerations,
  - food chain effects of agrochemicals and interaction with eutrophication (ecological stability),
  - relationship between application of nitrogen to pond water and ground water nitrate levels hazardous to human health
  - role of water and nutrients in pathogen transfer
  - low acceptability in markets- ‘lengthening the food chain’ to safeguard products from contamination

Constraints and conflicts

- equity-access to nutrients and water and aquaculture products by the poor
  - open access, property rights (private and public water use for individually-owned culture systems.
  - pressure to use land and water more intensively (Bangladesh-growing rice in shallows of water bodies) and
  - small ‘trash’ fish for feeding high value fish or pets or to feed people directly?

Urban planners and engineers threaten future of peri-urban systems

- in LDC's conventional development cannot meet rapidly increasing needs for wastewater disposal and food.
- this increases the likelihood that aquaculture integrated within food production systems have a role in utilizing polluting nutrients, increasingly supplies of low cost food whilst safeguarding human health

- but a reduction in the linking of peri-urban fish production and demand; improved road infrastructure linked to more accessible supplies from rural areas eg Calcutta (Kundu, 1994 in Bunting).
- high tech waste water treatment and drainage systems reduce importance of surface water bodies for waste treatment and drainage
- delinking of urban wastes with periurban aquaculture e.g East Calcutta wetlands (Kundu,1994 in Bunting), also Ho Chi Minh City and Ha Noi.

- expansion of cities and cost of land
- institutional particularly the distance between planning for livestock. Crop and fish production. The lack of irrigation engineers with experience in fish production
- a participatory approach to developing capacity among farmers/communities for innovation;varying levels of knowledge of aquatic production, water and nutrient use

•Future directions

- irrigation systems have fish production components built into them
- need for increased point source treatment of pollutants
- livestock planning includes nutrient analysis for disposal via crops and fish production.
- Guidelines for aquaculture planners

Future directions (cont)

- community development required for equitable development of many water resources-difficult where fractured common property and resource pressures are high.
- development of approaches to overcome lack of seed and appropriate recommendations for managing seasonal water bodies
- tanks within connected watersheds-cascade tanks may face particular problems in terms of externalities- lower tanks suffer if agrochemicals are used further up the watershed

Future directions (cont)

- wastewater reuse e.g. Israel, South Africa and other technically advanced arid countries
- intensification -strategies for producing more fish and other products with less water and integration of all water used for both fish and crop production(Israel). deeper ponds, cages, aeration

Future directions (cont)

- if linked to demand trends - production of predictable supplies of animal protein as white fish to substitute marine stocks currently used for low cost human and pet food.The former already seen in southeast Asia, where waste-fed carps and tilapias are cheaper than marine fish. Stocks used principally for fish meal/oil are also increasingly unstable.
- pressure on prices for consistent quality