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More meat, milk and fish by and for the poor
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A life cycle assessment of the environmental impacts in the Egyptian aquaculture value chain

Malcolm Dickson (WorldFish) and Patrik J.G. Henriksson (WorldFish)

Key messages

- Life cycle assessment (LCA) was used to benchmark global warming, acidification, eutrophication, water consumption and land occupation for improved aquaculture practices in Egypt.
- Assessments were made of four intervention farm scenarios: control; those using best management practices (BMP) alone; those using an improved strain of fish; and those using BMP and the improved fish.
- Feed stood out as a critical issue in terms of emissions, acidification and land occupation.
- Long grow-out times and an arid climate were the major causes of freshwater consumption, while pond run-off water was the main cause for eutrophication.
- The LCA results covered a more diverse range of processes than the related CLEANED[1] approach, including feed production, fuel use, electricity and hatchery production. The time needed to model, propagate and interpret the data was substantial.

The challenge

Egyptian aquaculture has expanded rapidly since the early 1980s when the government made major commitments, allocating over 100,000 ha of land for aquaculture ponds, establishing a legal and management framework, providing training for technical specialists and building catalytic infrastructure, including a research centre, feed mills and hatcheries. The profitability of aquaculture has driven private sector investment, particularly in tilapia monoculture and tilapia/mullet polyculture systems, feed mills, hatcheries and market chains. The current Egyptian aquaculture industry is estimated to produce around 1.2 million tonnes per year, representing around 75% of total fish production in the country and 65% of fish availability. The growth of aquaculture has resulted in per capita availability of fish rising from around 15 to 20 kg over the last 10 years.

The predominant aquaculture system in Egypt is un-lined, earth pond culture of tilapia using complete, formulated feeds. After the winter in late March or April, tilapia seed from local hatcheries are stocked into the ponds of around 0.5 ha and 1.5 m deep. Many farms also add around 10% mullet seed, sourced from traders who sell wild-caught fry and fingerlings from collection centres on the Mediterranean coast. The ponds are usually fertilized with organic manure when or before they are filled with water. By law, the water has to come from irrigation drainage canals or lakes, not directly from irrigation canals. This affects the quality of water entering the ponds and with increasing re-use of water in irrigation systems it generally carries high nutrient loads and is partly saline. After a short period when the fish depend on natural food, farmers apply formulated feeds, starting with finely ground, high protein powders, then crumbles and pellets as the fish grow towards market size. Grow-out feeds for tilapia contain around 25% crude protein with most of the protein coming from soya and very little or no fish meal. Most farms plan to harvest their fish before winter when tilapia have reached average weights of around 250–300 g, while others over-winter their fish in expectation of higher market prices in the following year.

Under the Livestock and Fish CGIAR Research Program, WorldFish carried out a rapid value chain assessment that indicated that the profitability of fish farms was threatened by increasing feed costs and static or declining selling prices. In response, WorldFish provided best management practice training to 2500 fish farmers and released the faster-growing Abbassa improved strain (known as 'G9') of Nile tilapia to the industry under the Improving employment and incomes through development of Egypt's aquaculture sector project. An impact assessment study was carried out in 2015 to examine changes in productivity, feed efficiency and profitability of farms using the Abbassa improved strain and/or applying improved management practices compared to control fish farms. This indicated that farms applying best management practices concentrated on improving the efficiency of feeding, thereby

[1] CLEANED was a pilot project supported by the Bill & Melinda Gates Foundation to produce a Comprehensive Livestock Environmental Assessment for Improved Nutrition, a Secured Environment and Sustainable Development along Value Chains.

saving on operating costs rather than increasing their production. Similar results were also achieved by farms growing the improved strain of Nile tilapia.

The environment agenda

Until now, aquaculture has not been recognized as an important driver of global environmental change. Fish, as monogastrics do not produce high levels of methane or other by-products of enteric fermentation. However, fish farming has been responsible for other locally important impacts, including displacement and genetic contamination of wild fish populations due to escapes, transfer of disease from farmed to wild stocks, release of eutrophying nutrients to aquatic ecosystems, water use and destruction of wetlands and mangroves.

Looked at the sector from a LCA perspective, where all impacts are assessed from resource and land use for pond inputs through to consumption or sale, aquaculture results in significant global impacts, including greenhouse gas emissions. Growing market demand for fish and limited opportunities to increase wild fish harvesting means that aquaculture is growing rapidly and will continue to grow to fill the gap. This makes it important to estimate impacts and to understand how to mitigate or reduce impacts.

In Egypt, despite the large scale of the industry, little concern has been expressed about negative environmental impacts from aquaculture. Most of the pond-based fish farms are in designated zones and it is illegal to farm fish outside of the zones and illegal to do anything except fish farming within the zones. Most fish farms use indigenous species. Salinized land outside the zones has been used for fish farming with the concept that fish farming will remediate the soils and the land will revert to agriculture. In some cases, the land has not been returned to agriculture and fish farming has been allowed to continue.

Cage-based aquaculture of tilapia developed in the lower reaches of the Nile in the 1980s and 1990s. A lack of planning and regulatory control meant too many cages were installed leading to occasional fish kills and the growing system was banned in 2006. However, a lack of enforcement meant that cage-based farms continued operating until recently when local authorities began taking more definite action to remove cages.

Fish farmers have also been accused of encroachment into coastal lakes adjacent to the designated fish farming zones. The regulatory authority takes action against these farms by breaking down pond banks. Fish farmers are frequently accused of using unsuitable feeds, such as the disposal of chicken carcasses by feeding them to catfish and misunderstandings over the use of chicken manure as pond fertilizer.

Many consumers worry about contamination of aquaculture-produced fish as the agricultural drainage water coming into the ponds is far from clean. Testing by the Ministry of Agriculture reference laboratory (commissioned by WorldFish) consistently shows that contaminants—including heavy metals, polychlorinated biphenyls, pesticides and herbicides in fish flesh—are found at either trace levels or are not detectable. This may be because the fish derive the majority of their nutrition from 'clean' food rather from the water. A full testing program is needed to definitively answer the question over contaminants. However, it appears that consumer concerns over contaminants in farmed fish are unfounded.

Egyptian fish farms tend to pass too much water through their ponds. Ideally they would only add enough water to top up for seepage and evaporation and use aerators to maintain oxygen levels at night. Yet, short lease periods for sites mean farmers cannot invest in electricity grid connections so they leave their diesel powered pumps running overnight to maintain oxygen levels. This means they bring in more water than required but also discharge water back to inlet/outlet canals which feed into other pond systems. This is undesirable as it could result in rapid disease transmission from farm to farm.

The assessment process

LCA was used to benchmark the environmental benefits of introducing BMPs and the improved G9 strain. Primary data was collected on feed, stocking density, productivity for four scenarios: control (n=40); BMP (n=69); G9 (n=13); and BMP+G9 (n=15) grow-out farms in Kafr El Sheikh, Behera and Sharkia provinces in 2014–2015. This data was supplemented with more extensive grow-out farm surveys for more LCA relevant data (fuel use, electricity use and lime). Visits were also made to feed mills and other partners of the value chain. Secondary data was used to model agricultural production in Egypt, as the majority of maize, rice and wheat were sourced domestically. As for fishmeal, a generic global estimate was used as no data existed on fishmeal production in many of the countries of origin, including Morocco and Yemen. Energy mixes and import data were adjusted to an Egyptian scenario based on trade data end government statistics. Other agricultural crops (soy, rape seed and Guar meal), industrial and other process data were sourced from Henriksson et al. (2015) or the ecoinvent v2.2 database (http://ecoinvent.org).

The data was then modelled in the CMLCA (v5.2) software (www.cmlca.eu), using the protocol by Henriksson et al. (2014) to estimate overall dispersions. Overall dispersions are the sum of inherent uncertainty (inaccuracies in measurements and models), spread (variability resulting from averaging), and the unrepresentativeness (mismatch between representativeness and use) of data. The CMLCA baseline impact assessment method (Guinée et al. 2002) was used to classify and characterize the data towards the impact categories global warming, eutrophication and acidification. With regards to freshwater consumption and land occupation, the inventory flows in terms of m^3 freshwater and m^2a (square metres annually) were used as proxies. The final results were then propagated using 1000 Monte Carlo iterations and dependent sampling (Henriksson et al. 2015a). Two allocation factors were explored, mass and economic allocation, to make sure that conclusions remained consistent. Finally the Wilcoxon paired significance test was used to identify significant trends.

Results of the assessment

Comparing the scenarios, the LCA results indicated that the G9 and G9+BMP systems had significantly lower global warming impacts than conventional farming (Figure 1), while with regards to acidification all improved farming methods performed better than conventional farming (Figure 2). The G9 and G9+BMP, moreover, performed significantly better than BMP alone.

Figure 1: Global warming results in relation to conventional farming (control). Letters indicate significant differences.

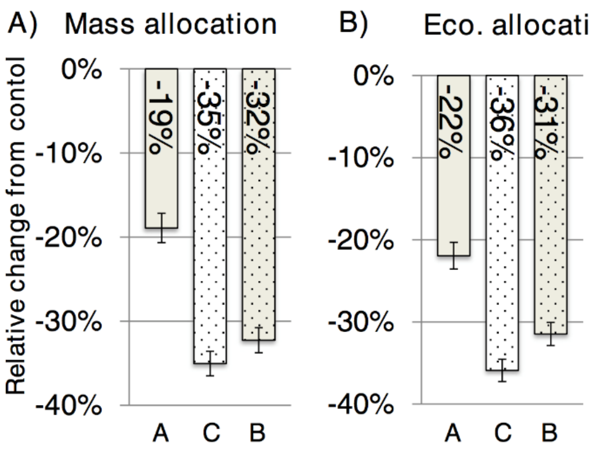
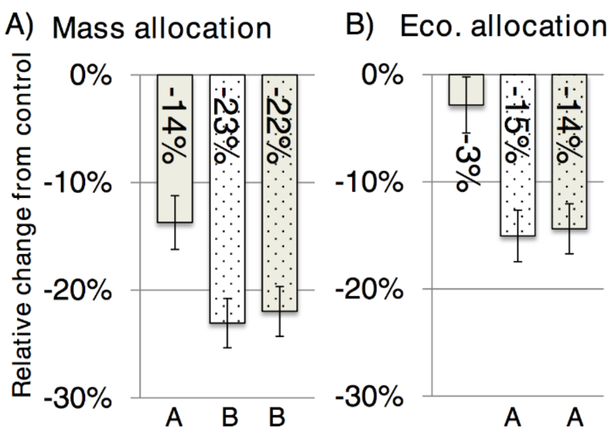


Figure 2: Acidification results in relation to conventional farming (control). Letters indicate significant differences.



Also for eutrophication, all improved farming systems performed significantly better than conventional farming. Surprisingly, G9 alone resulted in significantly lower eutrophying impacts than G9+BMP. With regards to freshwater use, however, BMP was indifferent compared to conventional farming, while G9 and G9+BMP offered significant gains.

All systems provided significant improvements compared to conventional farming with regards to land occupation (Figure 5), G9 providing the largest improvements over BMP+G9 and BMP.

Figure 3: Eutrophication results in relation to conventional farming (control). Letters indicate significant differences.

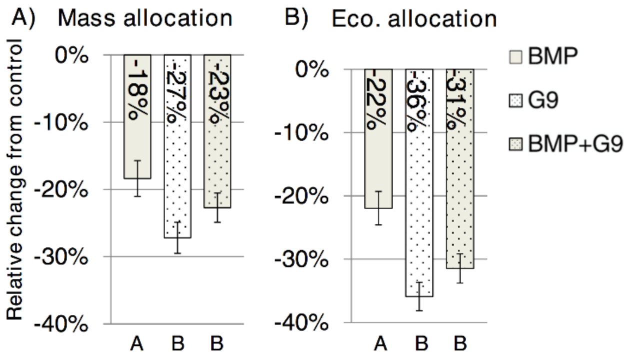


Figure 4: Freshwater consumption results in relation to conventional farming (control). Letters indicate significant differences.

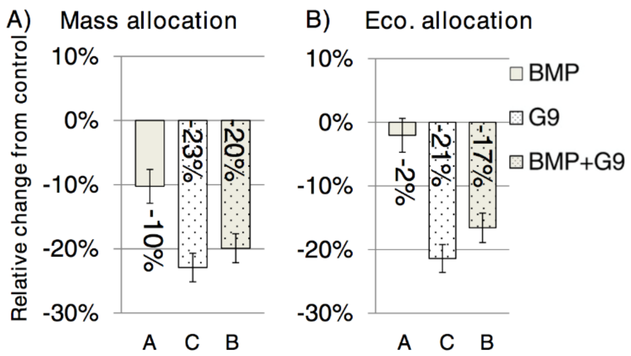
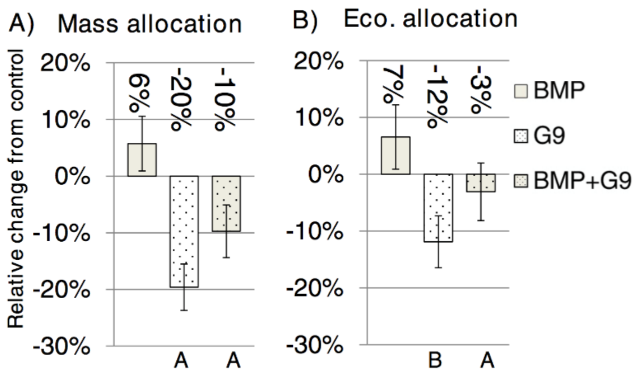


Figure 5: Land occupation results in relation to conventional farming (control). Letters indicate significant differences.



Revisiting the same results but now focusing on the contributions, it is evident that both global warming and acidifying impacts are driven by feed provision (Figures 6 and 7). The second largest source of greenhouse gas and acidifying emissions was farm activities, including energy use on farm and volatilization from ponds. Fishmeal and fish oil had a relatively small contribution to the overall emissions, but this due to their low inclusion in feeds (5.8% and 1.0%, respectively) and assumptions around their origin (emissions could be higher in Morocco and Yemen than the global average used in the assessment).

Figure 6: Contribution analysis of the global warming impacts of one tonne of tilapia at farmgate.

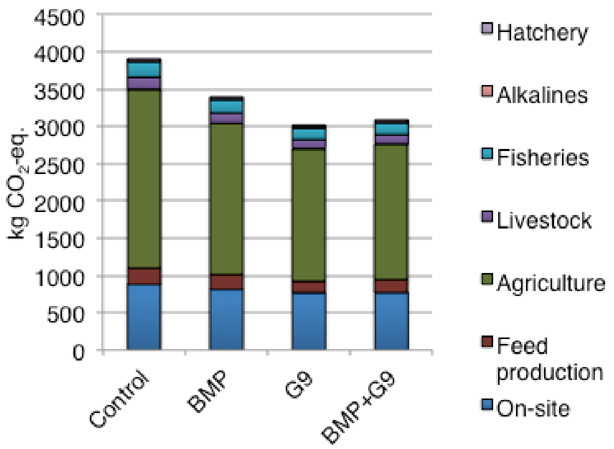
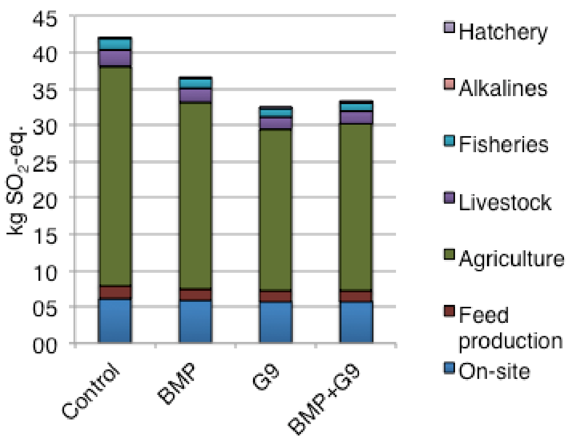


Figure 7: Contribution analysis of the acidification impacts of one tonne of tilapia at farmgate.



Through farm run-off water and evaporation from ponds, the grow-out farm dominated eutrophying emissions and freshwater consumption (Figures 8 and 9). The high evaporation rates are driven by Egypt's hot and arid climate, and long grow-out times (9 months). Agricultural products in feeds were the main drivers behind land occupation, with farm sites only accounting for roughly one quarter of the total land used to produce tilapia (Figure 10).

Figure 8: Contribution analysis of the eutrophication impacts of one tonne of tilapia at farmgate.

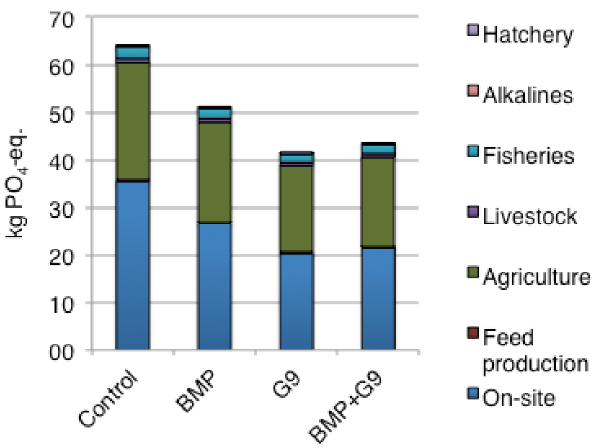


Figure 9: Contribution analysis of the freshwater consumption of one tonne of tilapia at farmgate.

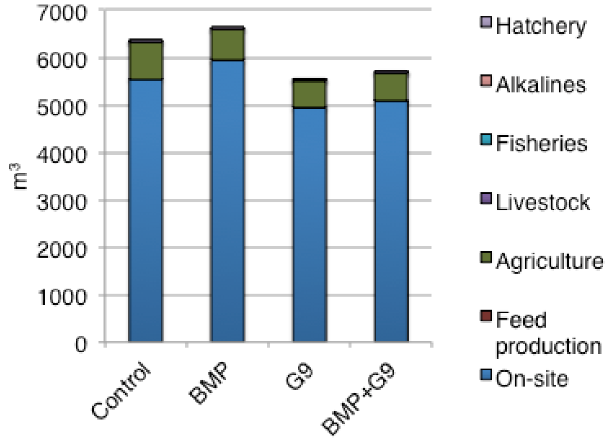
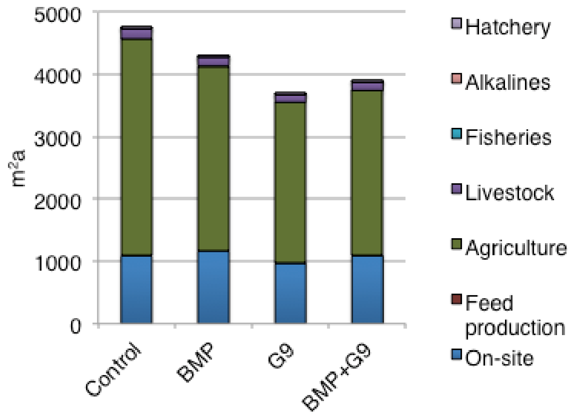


Figure 10: Contribution analysis of the land occupation of one tonne of tilapia at farmgate.



Discussion and significance

This study of Egyptian aquaculture highlighted that environmental impacts were mainly driven by feed use and on-farm practices. The BMP, but foremost the Abbassa improved strain, provided reduction in feed use and other factors that could significantly lower all environmental impacts.

Agricultural products, and especially Egyptian agricultural products, mainly drove impacts related to the provision of feed. Reductions of these impacts could be achieved by limiting fertilizer use on Egyptian maize, rice and wheat farms. Reduced water consumption could also be achieved by reducing the grow-out times for the tilapia. Stocking fingerlings, rather than fry could achieve this. This could also ideally allow for two harvests per year, thereby improving the economic situation for grow-out farmers and reducing land occupation.

The outcomes of this study provide important evidence on ways to reduce environmental impacts that local policymakers can use to help promote improved practices as well as the Abbassa strain. Additional research should also be undertaken to evaluate alternative feed resources, preferably from within Egypt.

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Credits and more information

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Patron: Professor Peter C Doherty AC, FAA, FRS

Animal scientist, Nobel Prize Laureate for Physiology or Medicine–1996

Box 30709, Nairobi 00100 Kenya
Phone +254 20 422 3000
Fax +254 20 422 3001
Email ilri-kenya@cgiar.org

ilri.org
better lives through livestock

ILRI is a CGIAR research centre

Box 5689, Addis Ababa, Ethiopia
Phone +251 11 617 2000
Fax +251 11 667 6923
Email ilri-ethiopia@cgiar.org

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