Aquaculture value chain analysis in Cambodia

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The information and knowledge produced through the value chain studies are intended to support the Delegations of the European Union and their partners in improving policy dialogue, investing in value chains and better understanding the changes linked to their actions

VCA4D uses a systematic methodological framework for analysing value chains in agriculture, livestock, fishery, aquaculture and agroforestry. More information including reports and communication material can be found at: https://europa.eu/capacity4dev/value-chain-analysis-for-development-vca4d-

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ACRONYMS

AC	- Acidification
AFA	- Agri-Food chain Analysis software
DG DEVCO	- Directorate General International Cooperation and Development
FCR	- Feed Conversion Factor
FE	- freshwater
FGDs	- Focus Group Discussions
FiA	- Fisheries Administration of Cambodia
GDP	- Gross Domestic Product
GWP	- Global Warming Potential
Ha	- hectare
ILCD	- International Reference Life Cycle Data System
LCA	- Life Cycle Assessment
LCI	- Life Cycle Inventory
LCIA	- Life Cycle Impact Assessment
LC	- Life Cycle
ME	- marine eutrophication
MOLVT	- Ministry of Labour and Vocational Training
Mt	- meter
N	- Nitrate
NGOs	- Non-Governmental Organizations
P	- Phosphate
SME	- Small and Medium Enterprise
TN	- Total nitrogenous
TP	- Total phosphorus
VC	- Value chain
VCA4D	- Value Chain Analysis for Development

EXECUTIVE SUMMARY

Context and methodology

In the context of the Multiannual Indicative Programme 2014-2020 of the EU with Cambodia, the European Commission has identified possible actions to be approved in the aquaculture sector (along with the capture fisheries sector). This aims at developing a resilient, competitive, commercially viable and environmentally sustainable aquaculture sector by addressing constraints and opportunities in aquaculture in Cambodia. The ultimate goal is to increase food security and improve nutrition and increase the value added of the aquaculture value chain. According to the approved Action Document, the aquaculture component will support the development and scaling up of successful pro-poor aquaculture systems, as well as the development and dissemination of more sustainable and efficient practices in the commercial sector.

This study contributes to an understanding of the sector as it is today and aims to provide evidence for policy makers, supported by a list of indicators measured quantitatively or based on expert assessments that together provide an answer to four framing questions:

1. What is the contribution of the VC to economic growth?
2. Is this economic growth inclusive?
3. Is the VC socially sustainable?
4. Is the VC environmentally sustainable?

The analytical process has four components:

- <u>Functional analysis</u>: provides a general mapping and description of the main actors, activities, and operations in the chain, an overview of the products and product flows, the major production systems, a description of the main governance mechanisms in the chain, and a short description of (known) constraints and is based mainly on secondary sources and key informant interviews.
- <u>Economic analysis</u>: consists of a financial analysis of each actor type, as well as an assessment of the consolidated value chain. It also assesses the economic performance, and the sustainability/viability for the national economy. Finally it addresses inclusiveness of growth by examining income distribution and employment creation and distribution. Data is derived from secondary data, key informant interviews, and structured questionnaires.
- <u>Social analysis:</u> explores whether the aquaculture value chain is socially sustainable. It also contributes to discussion on whether potential economic growth in the value chain can be socially inclusive. The social analysis draws on multiple information sources, including secondary data and field data from aquaculture producers at different scales, hatchery owners, processors, input suppliers, traders, exporters etc., and other government and non-government stakeholders. The social analysis follows six domains of inquiry: Working Conditions, Land and Water Rights, Gender Equality, Food and Nutrition Security, Social Capital and Living conditions.

- Environmental analysis: evaluates the environmental sustainability of the value chain. The analysis is conducted using Life Cycle Assessment (LCA). The scope of LCA consists of three areas of protection: Human health, Resources and Ecosystem quality, to which a set of environmental impact categories and corresponding indicators are associated. The calculation of relevant environmental impacts in LCA is based on an exhaustive and quantitative inventory of all input and output fluxes over the entire life cycle of the studied system.

For the Cambodian aquaculture value chain analysis, it was decided to limit the scope of the analysis to freshwater aquaculture, thereby leaving out marine aquaculture. The economic analysis focuses on those parts of the freshwater aquaculture value chain that have significant economic contributions, i.e. smallholder semi-intensive ponds, SME intensive ponds, and freshwater cages, and excludes the extensive ponds, the rice-fish farming system, and the other aquatic species, while in the downstream nodes of the chain, coverage is broad. The social analysis focuses on the priority value chains covered by the economic and environmental analysis – smallholder semi intensive ponds, SME intensive ponds and freshwater cages, but the social analysis also considers extensive ponds, rice/fish farming and other small freshwater aquatic species where these form part of local livelihoods. The environmental analysis follows a Life Cycle Assessment approach and uses the following functional units: 1 mt of live weight mixed fish species from semi-intensive ponds at farm gate; 1 mt of live weight pangasius from semi-intensive pond at farm gate; 1 mt of live weight pangasius from intensive pond at farm gate; 1 mt of dried pangasius at processor gate; 1 mt of live weight snakehead from freshwater pond at farm gate; and 1 mt of live weight snakehead from freshwater cage at farm gate.

Framing questions and core indicators

What is the contribution of the VC to economic growth?

Where appropriate, two scenarios have been provided, scenario 1 which uses the official aquaculture production statistics and scenario 2 which uses a more realistic production. Here we provide the summary for scenario 1, the values for scenario 2 are consistently lower. The sustainability of the Cambodian aquaculture value chain is at present relatively weak, mainly due to low profitability of farmers. Some farmer types have very small profit margins, in particular the cage farmers (profit margin of 2.8%). While profit margins among semi-intensive low input polyculture farmers is relatively high (32.9%), this includes the value of fish consumed at home and their cash income from farmed fish is limited. Among the downstream actors, profit margins are highest among retailers (29.8%).

Total direct and indirect value added of the sector has together been estimated at 398.7 million Euro contributing 2.4% to GDP, 9.2% to agricultural GDP and 41.2% to fisheries GDP. The contribution of the aquaculture value chain to the public funds balance is limited (0.69% to national budget), however to the Ministry of Agriculture budget the contribution is 42.6%. There is some contribution from taxes and quota and licenses for licensed imports of feed and seed. At the same time, the government presently misses out on a large volume of unreported / unlicensed imports of both fish and feeds.

The balance of trade taking into account farm fish imports is negative (-131 million Euro), this is due to the high level of imports of both fish and inputs, and the low level of exports of farmed fish. The rate of integration is 83% under scenario 1, above 70% which as a rule of thumb is considered a good rate of integration. Prices for imported farmed fish are consistently lower when looking at prices paid in Cambodia for the same species; however average prices in the global market are consistently higher. This means that the nominal protection coefficient, when compared to prices of farmed fish as it enters Cambodia is higher than 1, while it is below 1 when comparing to international prices. This illustrates that farmed fish exported to Cambodia is of inferior quality and a 'by-product' of the farmed fish sector of the neighbouring countries.

The economic risk analysis examines price risks, logistical and infrastructural risks, policy risks, and food safety and phytosanitary risks, and weather-related risks. A summary of these and other risks is provided in the section below (major issues / risks). Overall, the economic sustainability of the value chain seems under threat due to the low profits made at farm-level, resulting from competition with neighbouring countries. Costs of inputs are high as they are also partially imported, or depend on seasonal supplies (wild capture fish).

Is this economic growth inclusive?
Among value chain actors, farmers earn the least from the aquaculture sector. The annual profit of semi-intensive low input producers are low (94 Euro) but the majority of these producers have a portfolio of livelihood activities (mainly agriculture), and fish farming provides a contribution to their food security. It is the same for extensive and rice/fish farmers that we did not take into account in the economic calculation (because they probably represent less than 5% of total harvested volumes). Net operating profits among producers are highest for the intensive monoculture producers, and highest for traders among downstream actors as these actor types deal with high volumes of product (although traders have a relatively modest profit margin). Prices for farmed fish in Cambodia have seen a downward trend and this puts long-term sustainability of the sector under pressure. Retailers earn most per unit of product.

It has been estimated that the aquaculture value chain (primary actors) generates 80,487 jobs (full-time equivalent) under scenario 1. The majority of these jobs are self-employment or family labour (93% is self-employed), while the remainder is hired labour. The majority of these jobs are at farm-level (63%). Almost all of the wage labour jobs are either labourers for the lifting, loading and carrying and some drivers, and the majority are men. Most wage labour is year-round but there is also some seasonal work. Average wages are between 3.70 and 5.60 Euro per day.

In terms of the inclusiveness of aquaculture development, the poorest people in rural communities are less likely to participate than medium to better off households. This is attributed to lack of land for pond production, limited availability of family labour and lack of finance. Women are proportionately more represented in the semi intensive systems and small cage production than intensive ponds and large-scale cage production. The participation of landless people in aquaculture is through cage production. Therefore, attention to these categories of production will help to benefit women producers and those without land. Inclusivity can be enhanced if interventions relating to credit and finance, technical information and advice for aquaculture are tailored to different scales of operation and made available for women and youth.

Is the VC socially sustainable?

In the analysis of social issues and social sustainability in aquaculture value chains, it is important to understand the different roles of aquaculture in livelihoods which vary according to system and location. This understanding of the circumstances and capacities of different systems and actors will help to tailor programmes and investments to the objectives and capacities of producers.

With respect to *working conditions*, ILO labour standards are included in Cambodian labour law, but aquaculture enterprises mainly operate outside formal labour law and without formal contracts. Aquaculture provides comparatively good wages for workers, but working hours are unregulated. There was no evidence found of forced labour in the aquaculture value chain and no obvious discrimination. The Cambodian Code of Conduct for Responsible Fisheries, CAMCODE, sets out guidelines and good practices, but there is limited awareness of its content. Children’s contribution to work in agriculture is low, on average less than one hour per day, and primary school attendance is high (over 80% for girls and boys). Children mainly do lighter tasks, but in semi intensive systems they may be at risk from chemicals if they assist in pond preparation. Some health risks arise in processing connected with fish waste and waste water. Pollution of water from poor sanitation and industrial effluent are further risks in some locations. Aquaculture can be attractive to young people if they have resources, but other types of employment are generally preferred. Further development of large scale intensive aquaculture may negatively impact vulnerable groups unless working conditions are improved. There is a need to increase awareness of the content of the CAMCODE among fisheries personnel, local government, NGOs and other stakeholders and monitor labour conditions, particularly health and safety, working hours and chemical hazards.

The available information on tenure issues and *land and water rights* in Cambodia does not make reference to Voluntary Guidelines on tenure (VGGT) or the Guide to due diligence, although Cambodian land law reflects many of the principles. The granting of economic land concessions to investors has not necessarily followed these principles. At local level in the absence of competing claims for use of land, farmers perceive their own land tenure to be quite secure. Cage culture farmers generally do not own land. Commercial expansion of aquaculture could have detrimental effects on local communities, who generally have a low awareness of tenure rights and reluctance to seek remedy in case of environmental impacts. The social sustainability of aquaculture value chains will require investors in aquaculture enterprises to fully comply with Cambodian land law with regard to tenure rights, local consultation, social and environmental impact assessment and compensation. This could be supported by awareness raising among district and commune leaders and encouraging local reporting of infringements.

Women are active in aquaculture production, processing, trade and retail. Recognition of women's role in aquaculture is supported by the FIA's National action plan on Gender Mainstreaming and Elimination of worst forms of child labour. Compared to men, women's operations in aquaculture are smaller and more concentrated in the lower input production systems. The development of rice-fish farming and local seed producer networks, were reported to have made a positive difference to women and poorer households. Women's property and inheritance rights are supported in law, but there is limited awareness of rights among women and poor access to legal advice in case of disputes. Women have a high degree of control over family income, although major decisions on expenditure are negotiated among family members. Hours of work are longer for women, while physical intensity of work is greater for men. Despite women's participation in the work force, gender roles are slow to change and the burden of women's domestic work remains. Women are underrepresented in leadership positions. Gender strategies and action plans need active promotion among fisheries personnel and value chain actors, with emphasis on training, practical implementation and monitoring, and resources to support.

Concerning *food and nutrition*, food supplies are generally increasing, with improving rice yields, stable prices and ready availability of fish on local markets. The large volumes of relatively cheap imported fish are an advantage for consumers, but fish producers complained about the negative impact on prices. Aquaculture is valued as a source of food, especially in areas without capture fisheries. Despite high rates of fish consumption, the levels of child and maternal malnutrition remain high. Poverty and lack of education contribute to this. Micro nutrient deficiencies are important, and dietary diversity is limited. The nutritional status of children is affected by waterborne diseases and parasites linked to the poor water and sanitation provision. Poor sanitation and water pollution, which affect aquaculture production and health and nutrition, need action at commune level, particularly around the Great Lake. A sustained programme of improvements in sanitation and latrine construction is needed to reduce infections and improve water quality.

Regarding *social capital*, there are relatively few groups or farmers' organisations at community level. Successful informal aquaculture groups were formed around local fingerling producers and rice fish farmers, mainly through donor funded projects. Market instability and unpredictability contribute to the perceived risk and reluctance to engage in collective enterprise. Processors and traders rely on long established trusted personal relationships and perceive limited benefit from group collaboration. The lack of farmer-based organisations limits the bargaining power of producers in the value chain and inhibits cost effective access to information, training and input markets. Levels of trust in other value chain actors were lowest for cage producers. Within communities, social norms requiring financial contributions to ceremonies and weddings result in extremely high levels of household expenditure. A strategy to strengthen groups to access technical information and inputs could be supported by actions to strengthen group governance. Expansion of seed producer training and networks where there is market demand, would improve access to seed, information and improve productivity. Use of mobile phones and information technology could be a cost-effective way to reach many small producers.

In terms of *living conditions*, infrastructure provision in health, education and housing is generally good. However, water and sanitation are important areas requiring improvement. Payment for health care can create stresses on households as health insurance is not widely available. Attendance at secondary school is influenced by distance and cost. Advice and training are mainly from Fisheries Administration personnel, local seed producers, input suppliers and the media. Access to inputs and services is harder for cage producers, as remoteness of location increases costs and reduces competition. Training and support could be extended to ensure greater coverage of cage producers. People are informed on aquaculture policy by local government and NGOs, but there appears to be little systematic feedback and discussion. Migration (internal and external) is part of rural household livelihood strategies, particularly where resources are limited. There are generally positive outcomes from migration although in some areas it may result in a reduction of food production and shortage of labour at critical times.

Is the VC environmentally sustainable?

The question whether or not the Cambodian value chain is sustainable from an environmental perspective cannot easily be addressed. In general, aquaculture in Cambodia is performed on a traditional and low technology basis. From a sustainability perspective this is not directly considered a risk. However, the lack of efficiency, knowledge (capacity and transfer), level of organisation, and application of best practice farming is considered a risk for sustainable continuation of a large part of the production system.

From a global warming potential (GWP) perspective there are high contributions from production systems operating with inclusion of homemade feed (pangasius and mixed fish) due to GWP emissions from the production of rice (as an important food source). Local sources of fish (trash fish) contribute to a lesser extent; however, the drawback of these production conditions is the depletion of local fish stocks. In general, GWP effects are mainly a result of the feed ingredients (rice); operational processes (transport, energy used in production). They are relatively low in Cambodia, due to the artisanal production processes, and the low use of commercial feed sources. Snakehead cultures harbour most of the extraction effects, whereas mixed fish, and intensive and semi-intensive pangasius production harbour the majority of fresh water and marine eutrophication.

Human toxicity (both cancer and non-cancer effects) is mainly a result of all production processes which require combustion of fossil fuels in the production system. These processes combust toxic components in the air, water and soil. The majority of the processes are not taking place in the aquaculture part of the process, however transport, and rice production do contribute here. Toxicity through the release of antibiotics and medicine is not considered due to the selected model. The release of these components is considered in the freshwater toxicity, which also has a feed back to humans through the use of water. However, the models are not developed specifically for application in Asia, and therefore do not directly consider the use of untreated river water prior to consumption.

Freshwater Ecotoxicity (endpoint) is highest in pangasius semi-intensive and snakehead (both cage and pond) culture. The main reason is found in the release of antibiotics, medicine, and chemicals affecting the ecosystem. These also have a potential feedback to human health. Intensive pangasius culture, and intensive snakehead pond cultures have a high impact on freshwater ecotoxicity, the underlying reason is the use of antibiotics and chemical drugs for in these cultures in a more intensive way then the semi-intensive production systems of pangasius and mixed fish. The snakehead culture in cages has a higher impact for freshwater ecotoxicity, this is also traced back to the application of medicine in the production system. In this respect, the entire industry requires a boost in disease management, at a level of regulation, supplying industry and farmers' level.

Marine Eutrophication is similar in all production chains which use rice products as a primary food source, which are mixed fish pond culture, and pangasius cultures. Paddy rice production is the main contributor of the total N eq output, primary production of rice contributes approximately 2/3 to the total N eq output. This is the case for mixed fish and pangasius cultures.

Other contributions are mainly a result of the digestibility of the feed, and release of undigested nutrients (N) via water, and sediment. In snakehead cage cultures the release of N is higher than in pond systems. The reason is the more direct interaction with the surrounding waters, and thus greater direct release to the natural system. In snakehead cultures the contribution from paddy rice production is substantially lower than pangasius and mixed fish production due to the lower inclusion of rice bran in the feed. All together emissions of N eq are up to 90% higher in the mixed fish and pangasius cultures, mainly due to the feed inclusion. Changes in feed efficiency and sourcing of feed may reduce these numbers.

Freshwater Eutrophication is similar in all production chains which use rice products as a primary food source - mixed fish pond culture, and pangasius cultures. Rice bran has a relatively high phosphorus (P) content, which in turn is not suitable for complete digestion by the fish. This results in emission of P to the environment. In general, P content in fish-based diets is relatively high, however the P content of snakehead feed is relatively low due to the use of trash fish (with a relatively low P content). Improvement of feed sourcing in snakehead cultures, may lead to higher P releases due to the likely increase of P in the feed. Feed management and feed sourcing may contribute to more efficient feed use and thus a reduction of P emissions. In mixed fish and pangasius cultures, feed management, sourcing and composition may favour reduction of feed emissions, since rice bran is high in P content in comparison to many other sources. Human toxicity effects are considered relatively low, and are mainly contributed by rice production, fertiliser production, and transport and diesel use in the total value chain.

The high inclusion of rice as a feed source contributes to human toxicity effects due to the pesticide use in the production chain. Conversion to alternative selections of raw material for the feed would benefit human toxicity effects; however these will also impose competing claims on local sources of raw materials. However, due to the use of rice by products in aquaculture, one could argue that the circular economy is well developed in this perspective.

Resource depletion: one of the main concerns about the environmental sustainability of aquaculture is the pressure on local fish stocks for use as feed in aquaculture. The current situation is under regulated, and there are indications of excessive pressure on the fisheries system (declining catches). Therefore, reliance on local sources needs to be reduced and optimised, and sustainable management of local sources is required. Improvement to the efficiency of feed and efficiency in the use of local sources in the entire aquaculture chain is recommended. In particular, culture practices for snakehead require a reduction of reliance on local resources.

Major issues/risks

Below some major issues and risks are presented in random order.

Commodity prices and competition with imported fish

Commodity prices for fresh farmed fish are presently at a low level. Prices are not volatile, but have seen a slow decline, according to key informants because of severe competition with imported farmed fish from Thailand and Vietnam. The economic analysis has shown that at present market prices, some farmers are operating at a very small profit. This was also confirmed by anecdotes of farmers ceasing fish production to migrate to other countries to participate in wage labour, and also by views expressed by farmers in interviews. Other farmers have decided to delay harvesting as a strategy to cope with low prices. With the decline of production this would potentially also jeopardize businesses of downstream value chain actors, and/or increase the demand for imported farmed fish from traders and processors.

There are clear issues related to uncontrolled imports of farmed fish. Key informants have indicated there is a large volume of unregistered imports, estimated to be between 10-50% of the total volume that is imported. As a result of illegal imports, real data for policy planning is unavailable, and government revenues from licenses and duties are limited. This is a major risk for the economic sustainability of the aquaculture sector. Imported farmed fish is sold at a price below the price of domestically farmed fish (and also below international reference prices). This is likely due to the fact that Cambodia receives fish that is a 'by-product' of the aquaculture sectors in neighbouring countries that is geared towards supplying global markets. Attempting to compete with Thailand and Vietnam on species for which they have an international supply chain and a competitive advantage, seems unreasonable given the present state of the sector and the enabling environment. Further exploration of alternative species and improvement of production systems are recommended. In addition, further development of the enabling environment for the sector is advised to improve competitiveness, however this is a process that requires long-term investments.

Input prices

At farm-level the major cost is feed. At present there is no domestic production of commercial feed, and commercial feed prices are therefore determined by imports. Other sources of protein in home-made feeds are from processing waste, low value capture fish, and low value farmed fish (imported). The supply of low value capture fish is highly seasonal and the extraction of wild fish for fish farming has raised concerns about the long-term sustainability of the fisheries.

Long-term economic sustainability of farmers

The present situation for both semi-intensive and cage farmers is that they operate at a small profit. The present situation of low market prices is likely to result in farmers abandoning their production and converting land used for ponds to other uses. Our key informant interviews have already found examples of this happening.

Animal health and food safety

The Cambodian value chain is very dynamic, and many small-scale actors are involved in the value chain. The trade system is highly informal, and animal health and food safety control measures are not in place. Knowledge exists about the risk of diseases in terms of financial and production risks, however an adequate system to prevent, foresee and avoid disease is not yet in place. At present, the transport systems for fish, both domestically and from imports, contribute to the spread of diseases, by fish and through the water in which they are transported. In most cases, transport of fish and associated water is not regulated, nor is a control and verification process in place. This enables the spread of diseases without any oversight on direction, extent and conditions. There is an extensive range of medication, probiotics and chemicals available in Cambodia. This promotes wide spread use in aquaculture processes (as also seen in the freshwater ecotoxicity data). However, farmers mostly rely on their own (often insufficient) knowledge, and provision of advice from the government or private suppliers. Many farmers indicated that better quality and more accessible knowledge, and the organisation of control and advice throughout the production chain, would considerably benefit the avoidance of disease, and the mitigation of problems. Therefore, a more robust disease management, mitigation and control system is recommended, at the level of producers, the supplying industry, and regulations. In addition, hygiene practices in the chain are highly limited, which could lead to food safety risks. At present there is limited information available about the degree to which this leads to threats to human health.

Use of low-value freshwater capture fish for home-made feeds

The feed for both snakehead and pangasius culture is mainly composed of rice inputs, and trash fish from local fisheries or imports. The local fisheries are often not well regulated or controlled. The extent to which trash fish is extracted without license is not well known, and should be further evaluated based on the current regulations. The benefit of trash fish extraction is that the feed sourcing comprises a low CO_2 eq emission, since the fisheries require relatively low amounts of energy. Furthermore, in economic terms, the use of freshwater fish for home-made feed makes a high contribution to the indirect value added of the aquaculture sector. However, there are potentially high local effects on the ecosystem when extracting small fish in an uncontrolled and non-organised way (as is currently the case), and this type of feed has a particularly high Feed Conversion Ratio in comparison to other feed sources. There are also potential negative economic effects for the capture fisheries sector. In addition, the potential effect of redirecting this fish away from human consumption, particularly for the poor, could be significant (but is not well understood). Reasons for the use of trash-fish are mainly economic, as farmers perceive this feed source to be more affordable (in particular when it is extracted by farmers themselves). Programmes to develop the accessibility of local commercial feed formulated for the species and conditions available in Cambodia are recommended.

Pesticides from Mekong to product and vice versa: accumulation in fish through fresh water trash fish

During the Life Cycle (LC) Inventory, data on pesticides in fisheries products from fresh water fish in Cambodia have not been generated. Data on commercial farming in Vietnam indicates extensive debates on the pesticide and residue uptake by Mekong fisheries and aquaculture. Several studies have indicated that pesticides are not directly a problem in export samples from aquaculture in Vietnam. However, these studies have analysed for production of fillets only, whereas in Southeast Asia almost the entire fish is consumed by humans or enters the aquaculture chain. Besides this, fish produced for export markets are not fed with trash fish from the same basin (but with pellet based feed). There may be a potential risk from the accumulation of residues in feed fish as well as in consumption fish fed with local Mekong species in Cambodia. In particular, the potential concentration of pesticides in the Mekong river basin may pose a risk, since substantial rice production (and associated residues) has a direct influence on fish and the potential accumulation of residues. The extent to which this may pose a human health risk is not known or documented, and can thus not be quantified at present. It is advisable to analyse the content of residues in both feeding fish as well as end products to ensure that no human health issues are introduced with new aquaculture procedures (or species), especially considering a circular economic cycle in which accumulation in the aquaculture products may occur.

Lack of Good Aquaculture Practices

In general, aquaculture in Cambodia is performed on a traditional and low technology basis. From a sustainability perspective this is not directly considered a risk. However, the lack of efficiency, knowledge (capacity and transfer), level of organisation, and application of best practice farming is considered a risk for sustainable continuation of a large part of the production system. Due to the low level of organisation by farmers, the high influence of the supplying industry on the production sourcing materials, and due to high competition in price and quality of imported fish, there is a wide range of pressures on the production chain. The pressures are different in the different regions in

Cambodia. Further investment in farmer support and knowledge transfer, inclusive of both men and women, is needed for the required impact and sustainable development.

Lack of farmer based organisations and capacity

The lack of farmer-based organisations which relates to the complex social and political history of Cambodia, limits the bargaining power of producers in the value chain and arrangements which could benefit both farmers and production conditions. It also inhibits cost effective access to information and training and input markets. There are examples of farmers who are organised mainly in relation to seed supply, which directly benefits the connected farmers. The arrangements are, however, mainly project and donor based, which tend to be of a temporary character. A strategy to strengthen groups with common interests to access technical information and cooperate in input access could be supported by actions to strengthen group governance capacity.

Working conditions

Further development of large scale aquaculture enterprises risks negatively impacting vulnerable groups unless working conditions are improved. There is a need to increase awareness of the content of the CAMCODE among fisheries personnel, local government, NGOs etc. It is important that the conditions of labour employed are monitored, particularly issues around health and safety, hygiene and working hours and hazards of chemical use for producers.

Land and water governance

Weak land and water governance in relation to further investment in and expansion of aquaculture could have detrimental effects on local communities. Further investment in large scale aquaculture should be conditional on following the provisions of Cambodian land law with regard to identification of locations, respect for tenure rights, local consultation and consent, social and environmental impact assessment and compensation and mitigation of livelihood impacts.

Gender and aquaculture

Lack of women's participation in consultation and decision-making processes may risk women's interests being underrepresented. Gender strategies and action plans need active promotion both among fisheries personnel and value chain actors, with more emphasis on training, practical implementation and monitoring, together with the resources to support this.

Nutrition and sanitation

The nutritional status of children is affected by water-borne diseases and parasites linked to the absence of latrines. A sustained programme of improvements in sanitation and latrine construction is needed to reduce infections and improve water quality.

Lack of water

Another risk, which is mainly external, is the lack of sufficient and continuous water supply, especially in particular geographic areas, and the potential effects of longer dry seasons, and shorter and heavier wet seasons. This poses economic risks as we have seen examples of lack of water resulting in investments being eliminated (e.g. a hatchery being forced to sell / consume its broodstock due to lack of water). Zoning plans to better address and guide water availability are advised.

Relevant issues requiring further in depth analysis

The aquaculture value chain in Cambodia was the first study in the VCA4D project and therefore suffered from a degree of inefficiency as all processes were being decided on. This particular value chain has a high degree of complexity with many different systems in which fish is being produced and a high number of species. Limited reliable data was available, which meant the collection of more primary data was required than was initially envisaged. These factors together meant that the amount of time available for the implementation of the study was insufficient to use the methodology and data to the fullest extent.

The following areas of enquiry are in need of more in-depth analysis:
Functional analysis:

- Better understanding of consumers and markets.
- In-depth assessment of food safety risks
- Further assessment of other (local) species for culture that have less competition in the market

Economic analysis:

- Further development of different scenarios of potential economic contribution of the sector 1) if commercial feed is produced locally; 2) if seed is all produced locally; 3) when the sector switches from home-made feed to commercial feeds.
- Better understanding of the economics of home-made versus commercial feeds under different conditions.

Social analysis:

- Improved understanding of land access and labour conditions in large scale aquaculture production and processing enterprises.
- The food security / nutrition effects of the use of freshwater capture fish in home-made feeds

Environmental analysis:

- Better understanding of the environmental effects of extraction of trash fish for home-made feeds. An analysis of the impacts of overall fisheries pressure in the Tonle Sap area, including extraction patterns of fish for aquaculture (domestic and export market) is recommended. The impact of extraction of young fish prior to reproduction, multi- annual fish in high quantities, and one year fish in high quantities should be evaluated. Methods used could be

MSY (Maximum Sustainable Yield) analyses of the entire ecological system and for local ecological impacts. In addition, adequate fisheries management plans, education and enforcement are required to guide this process.

- Better understanding of potential human health risks from the accumulation of residues in feed fish as well as in consumption fish fed with local Mekong species in Cambodia.

1. Introduction and context

1.1 Introduction to the project

This report provides an analysis of the aquaculture value chain in Cambodia. This study is part of a larger project, funded by the European Commission's Directorate-General for International Cooperation and Development (DG DEVCO), entitled "Value Chain Analysis for Development" (VCA4D). The VCA4D project is part of the European Union's "Inclusive and Sustainable Value Chains and Food Fortification" Programme. A four year service contract was given to the Agrinatura network to undertake studies of agricultural value chains through this project, to be implemented by teams of experts put forward by the network's member organizations. The aquaculture value chain in Cambodia is the first study to be performed. The objective of this study is the description and analysis of the aquaculture value chain in Cambodia, using the evidence-based, largely quantitative, toolkit developed/ compiled by DG DEVCO. This diagnosis of the aquaculture value chain is intended to support the European Commission and the Government of Cambodia in structuring their policy dialogue around the strategic issues that presently hinder the sustainable development and growth of the aquaculture value chain in the country.

This study was implemented over a period of 6 months, between December 2016 and May 2017, and included two missions of the team of two weeks each (in December 2016 and February 2017). The team that implemented this study consisted of the following four key members:

- Froukje Kruijssen, Royal Tropical Institute (KIT), the Netherlands, economic expert and team leader
- Adrienne Martin, Natural Resources Institute (NRI), United Kingdom, social expert
- Marnix Poelman, Wageningen Marine Research (WMR), the Netherlands, environmental expert
- Sem Viryak, Cambodia, National expert

In addition, a consultant, Sereywath Pich, supported the conduct of focus group discussions, and a team of five enumerators (add names) conducted interviews using structured questionnaires with key value chain actors along the aquaculture chain.

1.2 Context

In the context of the Multiannual Indicative Programme 2014-2020 of the EU with Cambodia, the European Commission has identified possible actions to be approved in the aquaculture sector (along with the capture fisheries sector). This aims at developing a resilient, competitive, commercially viable and environmentally sustainable aquaculture sector by addressing constraints and opportunities in aquaculture in Cambodia. The ultimate goal is to increase food security and improve nutrition and increase the value added of the aquaculture value chain. According to the approved Action Document, the aquaculture component will support the development and scaling up of successful pro-poor aquaculture systems, as well as the development and dissemination of more sustainable and efficient practices in the commercial sector.

1.3 VCA4D methodology

The methodology used in this study aims to provide evidence, supported by a list of indicators measured quantitatively or based on expert assessments that together provide an answer to four framing questions:

1. What is the contribution of the VC to economic growth?
2. Is this economic growth inclusive?
3. Is the VC socially sustainable?
4. Is the VC environmentally sustainable?

The analytical process has four components:
Functional analysis: provides a general mapping and description of the main actors, activities, and operations in the chain, an overview of the products and product flows, the major production systems, a description of the main governance mechanisms in the chain, and a short description of (known) constraints. The functional analysis forms the basis for the analyses in the other three components. The analysis is mainly based on secondary data, and key informant interviews with both value chain actors and key experts.

Economic analysis: firstly consists of a financial analysis of each actor type (financial accounts, return on investment), as well as an assessment of the consolidated value chain (total value of production, global operating accounts). Secondly, it assesses the economic performance (contribution to economic growth in terms of direct and indirect value added generated, and the sustainability/viability for the national economy (domestic cost ratio, Policy analysis matrix). Finally, it addresses inclusiveness of growth by examining income distribution (business income, wages), and employment creation and distribution. In the economic analysis, the key is to strike the right balance between providing sufficient, robust, and reliable quantitative information for decision making, and keeping data collection efforts to a manageable limit. Data is derived from secondary data, key informant interviews, and structured questionnaires. The analysis should have been (partially) conducted with the support of the Agri-Food Value Chain Analysis (AFA) software, developed by CIRAD, however due to issues with operating the software, the entire analysis was conducted in Excel.

The social analysis explores whether the aquaculture value chain is socially sustainable. It also contributes to discussion on whether potential economic growth in the value chain can be socially inclusive. The social analysis draws on multiple information sources, including secondary data and field data from aquaculture producers at different scales, hatchery owners, processors, input suppliers, traders, exporters etc., and other government and non-government stakeholders. The social analysis follows the six domains of inquiry and their associated questions specified in the methodology and social analysis software; Working Conditions, Land and Water Rights, Gender Equality, Food and Nutrition Security, Social Capital and Living conditions (Annex 5-4). Methods of inquiry were largely qualitative, focused on the main questions, but adapted to the context of smallholder family and SME aquaculture in Cambodia and chosen for their feasibility given the time and resources available. K*ey informant interviews* were held with stakeholders in the value chains and in supporting organisations and *focus group discussions* were conducted with men and women producers and processors across the different aquaculture value chains. Where appropriate, participatory tools such as mapping, seasonal calendars and force field analysis were used. Specific questions were included in the structured questionnaires to contribute to the gender analysis and the nutrition component. These covered family labour and hired labour use in aquaculture production and processing, differentiated by sex and age, and home consumption of fish. The six domains and sub questions were scored in a Social Profile excel spreadsheet.

The environmental analysis evaluates the environmental sustainability of the value chain. The analysis is conducted using Life Cycle Assessment (LCA). The scope of LCA consists of three areas of protection: Human health, Resources and Ecosystem quality, to which a set of environmental impact categories and corresponding indicators are associated. The calculation of relevant environmental impacts in LCA is based on an exhaustive and quantitative inventory of all input and output fluxes over the entire life cycle of the studied system.

1.4 Scope of the analysis

After an initial scoping mission, and the development of a debriefing report, the decision was made in a meeting with DGDEVCO, the EU Delegation of Cambodia, the Fisheries Administration of Cambodia, and the VCA4D Project management unit on 19 January 2017, to narrow down the scope of the economic, social and environmental analysis to cover only freshwater aquaculture, and in particular the key production systems and species. This decision was made to limit the high level of complexity present in the system, and covers the majority of aquaculture production at present. The proposed definition of scope is summarized in Figure 1. The functional analysis will describe all components in the diagram. It will discuss marine aquaculture systems only briefly.

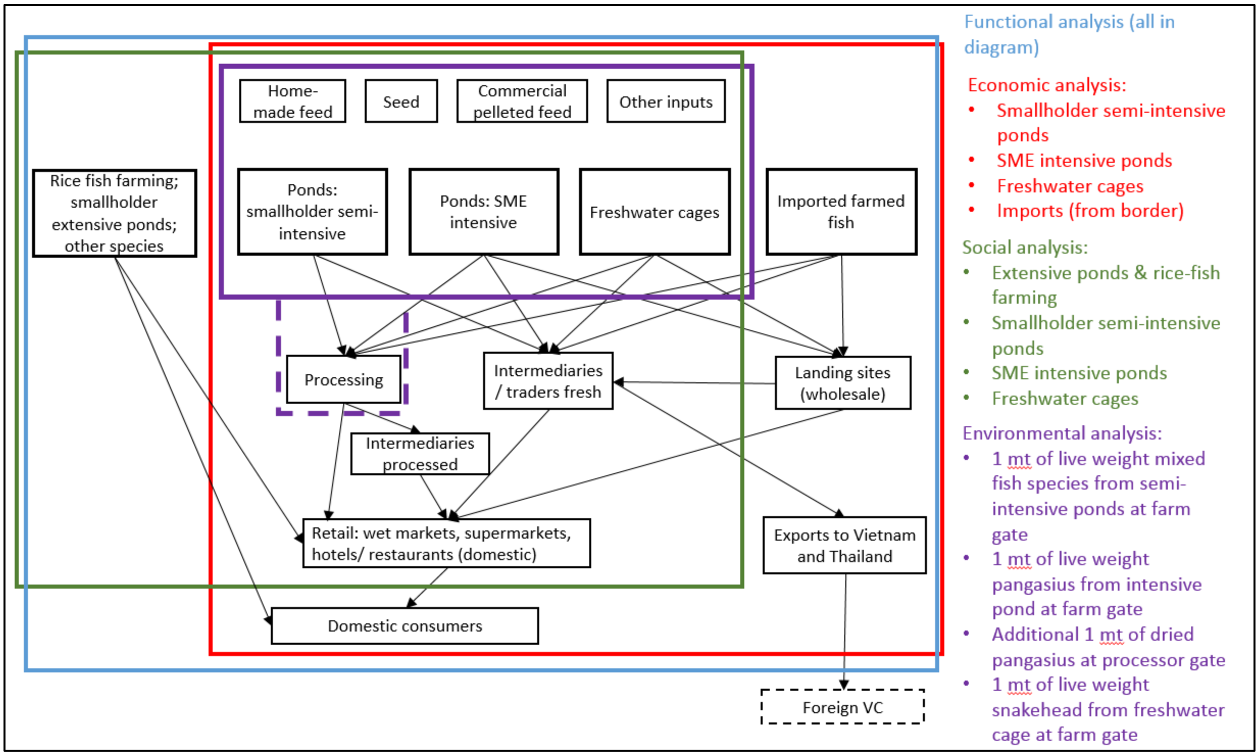


FIGURE1.1. SCOPE OF THE FUNCTIONAL, ECONOMIC, SOCIAL AND ENVIRONMENTAL ANALYSIS

The **economic analysis** will focus on those parts of the freshwater aquaculture value chain that have significant economic contributions. The analysis will therefore focus on three main production systems; smallholder semi-intensive ponds, SME intensive ponds, and freshwater cages, and exclude the extensive ponds, the rice-fish farming system, and the other aquatic species. In the downstream nodes of the chain, coverage will be broad. Attention was needed in particular for processing (volumes, values, prices, employment), intermediaries (traders, collectors) and retail (types, volumes, prices, and employment), as information on these nodes is scant.

The **social analysis** focuses on the priority value chains covered by the economic and environmental analysis – smallholder semi intensive ponds, SME intensive ponds and freshwater cages, but the social analysis also considers extensive ponds, rice/fish farming and other small freshwater aquatic species where these form part of local livelihoods. The social analysis examines existing social conditions and social relationships in the value chains, taking into account the socio-cultural and institutional and policy context for aquaculture and fisheries. It assesses the potential risks and benefits of future development of the different value chains, in particular whether value chain development can generate income, reduce poverty and improve nutrition. It complements the economic analysis in considering income and wage distribution in the value chain, the roles and employment of different social groups and gender.

The **environmental analysis** follows a Life Cycle Assessment approach, for which a selection of aquaculture practices was needed, and it therefore does not include the entire aquaculture value chain. The scope of the LCA has been defined as follows (the functional units):

- 1 mt of live weight mixed fish species from semi-intensive ponds at farm gate
- 1 mt of live weight pangasius from semi-intensive pond at farm gate
- 1 mt of live weight pangasius from intensive pond at farm gate
- 1 mt of dried pangasius at processor gate
- 1 mt of live weight snakehead from freshwater pond at farm gate
- 1 mt of live weight snakehead from freshwater cage at farm gate

The analysis will cover foreground systems, including feed production at farm level. For reasons of simplification, as well as its known relative low contribution to environmental impacts, the impacts of the hatchery are not included in the life cycle inventory. Impacts through nutrients (i.e., total nitrogenous (TN) and phosphorus (TP)) released via sediment (and wastewater) are modelled using digestion models to calculate the fate of input nutrients. Potential toxins released through wastewater are calculated because of an absence of quantitative data on compositions in feed. These indicators are used to identify hotspots in the environmental impact. The background system, defined as the part of the chain outside the gate-to-gate boundary, include industrial processes (agricultural cultivation, chemical production, transport, etc.) necessary to produce and deliver the inputs to the foreground system. Infrastructure is excluded due to its limited contribution towards overall impacts (Ayer and Tyedmers, 2009) and to be consistent with the data sourced e.g., production of fishmeal, fish oil or wheat farming (Henriksson et al., 2015b).

1.5 Data collection

1.5.1 Secondary data

During the course of the first mission it became clear that most experts, including key people at the Fisheries Administration had doubts about the reliability of the data available on levels of aquaculture production and imports of feed, seed and fish. We obtained production volumes from the central level Fisheries Administration who collate data submitted by the fisheries cantonments. Annex 1 contains a list of secondary data sources used.

1.5.2 Primary data

Primary data was collected through key informant interviews, structured questionnaires and focus group discussions. Figure 1-2 shows an overview of fieldwork locations.

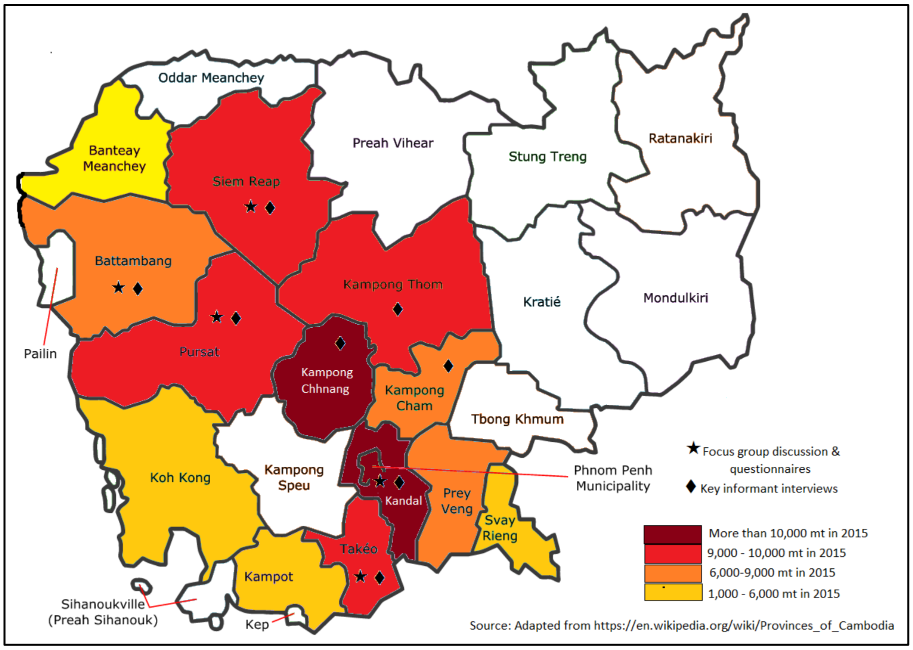


FIGURE 1.2 MAP OF FIELDWORK LOCATIONS

Key Informant Interviews

A range of key informants was interviewed during the two missions identified through existing networks, and advice and guidance of other stakeholders.

	1st mission: 9-22 Dec 2016			2nd mission: 11-24 Feb 2017		
Stakeholder/ VC node	**Men**	**Women**	**All**	**Men**	**Women**	**All**
Feed (pelleted)	4	0	4	0	0	0
Feed (low value fish & fish waste)	1	1	2	2	0	2
Hatchery	2	1	3	1	0	1
Other input suppliers	0	0	0	1	0	1
Equipment	0	0	0	2	1	3
Production	5	4	9	1	0	0
Cage	*1*	*3*	*4*	*0*	*0*	*0*
Pond	*4*	*0*	*4*	*1*	*0*	*1*
Rice-fish farming	*0*	*1*	*1*	*0*	*0*	*0*
Trade	0	2	2	1	1	2
Processing	1	3	4	0	0	0
Retail	0	5	5	0	0	0
Sub-total	**13**	**16**	**29**			
Fisheries Administration			4			8
Experts/ NGOs			6			0
TOTAL			**39**			**18**

TABLE 1-1. OVERVIEW OF KEY INFORMANT INTERVIEWS

Focus Group Discussions

The focus group discussions (FGDs) were held in the same locations as the producer questionnaire data collection (see Table 1-2 and Annex 3, sampling framework details, step 3). The focus group discussions were conducted by the social analysis expert and the local social analysis consultant. Undertaking both quantitative and qualitative data collection from producers in the same districts was intended to maximise the complementarity of different methods and enhance data interpretation. FGDs were held with producers from different aquaculture production systems, at least two FGDs per system covering different regions of the country. This took into account the variation in levels of access to feed inputs and markets, different socio-economic conditions and ethnicity. Organisation of the FGDs was arranged through Fisheries Administration staff in each District through their community and producer contacts. They were asked to convene a small group of 5-8 men and women producers involved in the selected system. For large scale intensive farmers, discussions were held individually. Question 'check lists', slightly modified for different aquaculture systems guided the discussion (Annex 3). A number of participatory tools – mapping, seasonal calendar, force field analysis, were also used.

The purpose of the study was summarised on a consent form and read out to participants at the start of the meeting and printed copies distributed. It was explained that participation was voluntary and could be discontinued at any time and that information given would be kept confidential. Participants gave explicit agreement to participate. The FGD lasted a maximum of two hours.

Province	System	Men	Women	Total
Takeo	Rice/fish, extensive, semi intensive ponds	6	3	9
	Semi intensive ponds	5	-	5
	Rice/fish	4	8	12
	Freshwater prawn	1	-	1
Pursat	Cages	1	6	7
	Intensive ponds	1	-	1
	Rice/fish	3	1	4
Battambang	Semi intensive ponds	5	4	9
	Intensive ponds	1	-	1
Siem Reap	Intensive ponds	10	-	10
	Extensive ponds	3	4	7
	Cages	4	5	9
Phnom Penh	Cages	3	2	5
	Intensive ponds	1	-	1
TOTAL		48	33	81

Table 1-2. Overview of participants in focus group discussions

Focus groups which are referred to in the text are identified by District, Province and aquaculture system: semi intensive (SI); rice fish (R/F); cage and intensive.

Questionnaires and sampling

Because of the lack of reliable and current data on the sector, a decision was made with the Program Management Unit and European Commission to increase efforts in primary data collection. A set of four questionnaires was developed (Annex 3) to be implemented with four types of value chain actors: producers (farmers), intermediaries, processors, and retailers, within the scope agreed, and explained above. A sampling framework was developed to ensure sufficient coverage of variation in species, production systems and geographies. As the sampling framework was based on our best knowledge of the situation in the field in terms of production systems and intensities and numbers of other actors available, the field team had to deviate from this sampling framework in some locations, however completed a larger number of interviews in total than initially planned (228 instead of 196). In addition, 13 interviews were conducted at border points. The planned and actual sample is summarized in Table 1-3 and Table 1-4, for details on decisions made, see Annex 2. Data was entered in Excel, cleaned, and then used in the three respective analyses.

Possible shortcomings of the data include:

- A lack of a randomized sampling framework
- Lack of data recording among about two-third of producers and difficulties of recall
- Some details (such as energy use) were particularly difficult to collect, and are therefore based on assumptions
- Many respondents (in particular, retailers and intermediaries) were busy at the time of interview and therefore interviews were sometimes difficult to conduct.

Province	Species	Planned				Actual			
		Semi intensive pond	Intensive pond	Cage	sub-total	Semi intensive pond	Intensive pond	Cage	sub-total
Takeo	Polyculture	5			5	6			6
	Pangasius	5			5	4			4
	Sub-total	10			10	10			10
Pursat	Polyculture	5			5	5	1		6
	Pangasius	5	5	5	15	9	2	1	12
	Snakehead	0	5	5	10	1	0	2	3
	Giant snakehead	0	5	5	10	5	8	5	17
	Climbing perch		5		5		0		0
	Clarias/ catfish	0		5	5	2	1	5	9
	Sub-total	10	20	20	50	22	12	13	47
Battambang	Polyculture				0				0
	Snakehead	0			0	1			1
	Climbing perch	0	0		0	4	1		5
	Sub-total	0	0	0	0	5	1	0	6
Siem Reap	Polyculture	5			5	5			5
	Pangasius	5		0	5	3		2	5
	Snakehead	0	0	5	5	8	4	6	18
	Giant snakehead	0	0	5	5	3	5	2	10
	Climbing perch	0			0	6			6
	Clarias/ catfish	0		5	5	9		6	15
	Sub-total	10	0	15	25	34	9	16	59
Phnom Penh/ Kandal	Polyculture	0			0	1			1
	Pangasius	0	5	5	10	1	0	4	5
	Snakehead	0	5	5	10	2	0	4	6
	Giant snakehead	0	5	5	10	6	3	3	12
	Climbing perch	0	5		5	2	0		2
	Clarias/ catfish	0	5		5	3	0		3
	Sub-total	0	25	15	40	15	3	11	29
All provinces	Polyculture	15	0	0	15	17	1	0	18
	Pangasius	15	10	10	35	17	2	7	26
	Snakehead	0	10	15	25	12	4	12	28
	Giant snakehead	0	10	15	25	14	16	9	39

Province	Species	Planned				Actual			
		Semi intensive pond	Intensive pond	Cage	sub-total	Semi intensive pond	Intensive pond	Cage	sub-total
	Climbing perch	0	10	0	10	12	1	0	13
	Clarias/ catfish	0	5	10	15	14	1	12	27
	Total	30	45	50	125	86	25	40	151

Table 1-3. Sample summary farmers

		Intermediaries		Processors			Retailers			Total number	
		Planned	Actual	Product	Planned	Actual	Product	Planned	Actual	Planned	Actual
Takeo		6	5				Live/fresh	2	2		
							Processed	2	3		
	Sub-total	6	5		0	0		4	5	10	10
Pursat		6	4	Pangas-dried	5	0	Live/fresh	2	2		
				Pangas-fermented	0	1	Processed	2	2		
				(Giant) Snakehead-dried	2	7					
	Sub-total	6	4		7	8		4	4	17	16
Battambang		4	4	Pangas-dried	0	3	Live/fresh	2	2		
				Pangas-fermented	3	3	Processed	2	2		
				Clarias-smoked	3	4					
	Sub-total	4	4		6	10		4	4	14	18
Siem Reap		6	12	Pangas-dried	0	3	Live/fresh	2	3		
				Pangas-fermented	0	2	Processed	2	2		
				(Giant) Snakehead-dried	2	2					
				Clarias-smoked	0	1					
	Sub-total	6	12		2	8		4	5	12	25
Phnom Penh/ Kandal		6	3	Pangas-dried	5	0	Live/fresh	2	1		
				Pangas-fermented	3	3	Processed	2	1		
	Sub-total	6	3		8	3		4	2	18	8
	Total	28	28		23	29		20	20	71	77

Table 1-4. Sample summary other value chain actors

2. **Functional analysis**

2.1 Product sources

2.1.1 Aquaculture production systems

The following aquaculture production systems specific to Cambodia have been identified, although groupings and descriptions may vary slightly across documents (Joffre et al., 2010; WorldFish Center, 2011; Landell Mills, 2014; Hambrey and Young, 2016; AFD and NIRAS, 2016;):

- Smallholder - low input pond culture (homestead ponds)
- Smallholder - high input pond culture (homestead ponds)
- SME intensive pond culture (commercial farming)
- Freshwater cage (and pen) culture
- Rice-fish systems
- Marine cage culture
- Extensive brackish water ponds (shrimp)
- Freshwater prawn farming
- Crocodile farming
- Other aquatic organisms: e.g. frogs, mud crabs, turtle

To make a value chain analysis of a complex sector manageable and taking into account the agreed scope of the study during the debriefing on 19th January 2017 with DGDEVCO, the PMU and FiA, we have chosen to use a more aggregated categorization as follows:

1. Extensive ponds, rice-fish farming, freshwater prawn and frogs
2. Semi-intensive ponds
3. Intensive ponds
4. Freshwater cages and pens
5. Marine systems
6. Other aquatic species

As indicated, our analysis will focus on the first four systems. The key product being considered in this analysis is therefore farmed freshwater fish in both fresh and processed form. We consider the major species including Striped catfish (Pangasius hypophthalmus), African catfish (Clarias gariepinus), Walking catfish (Clarias batrachus), Giant snakehead (Channa micropeltes), Snakehead (Channa striatus), Silver barb (Barbonymus gonionotus), Nile tilapia (Oreochromis niloticus), and Chinese carps. An overview of all species, their origin and the systems in which they are produced can be found in Annex 4.

2.1.2 Geographical distribution

Aquaculture in Cambodia is concentrated in particular parts of the country, in particular around Tonle Sap Lake and River, while it is found less along the Mekong River upstream from Phnom Penh (Figure 2.1). Marine aquaculture is obviously concentrated in the southwestern provinces that border the ocean. In terms of imports, the north-western provinces receive more imported fish from Thailand while the south receives more form Vietnam, but an informal market network with many intermediaries in the chain results in fish being transported throughout. The province of Battambang is a processing hub, with many processors clustered together in one location, but processing also takes place in other parts of the country. Major urban markets for farmed fish include capital city Phnom Penh, and provincial capitals such as Ta Khmau (Kandal), Battambang, Siem Reap and Kampong Cham.

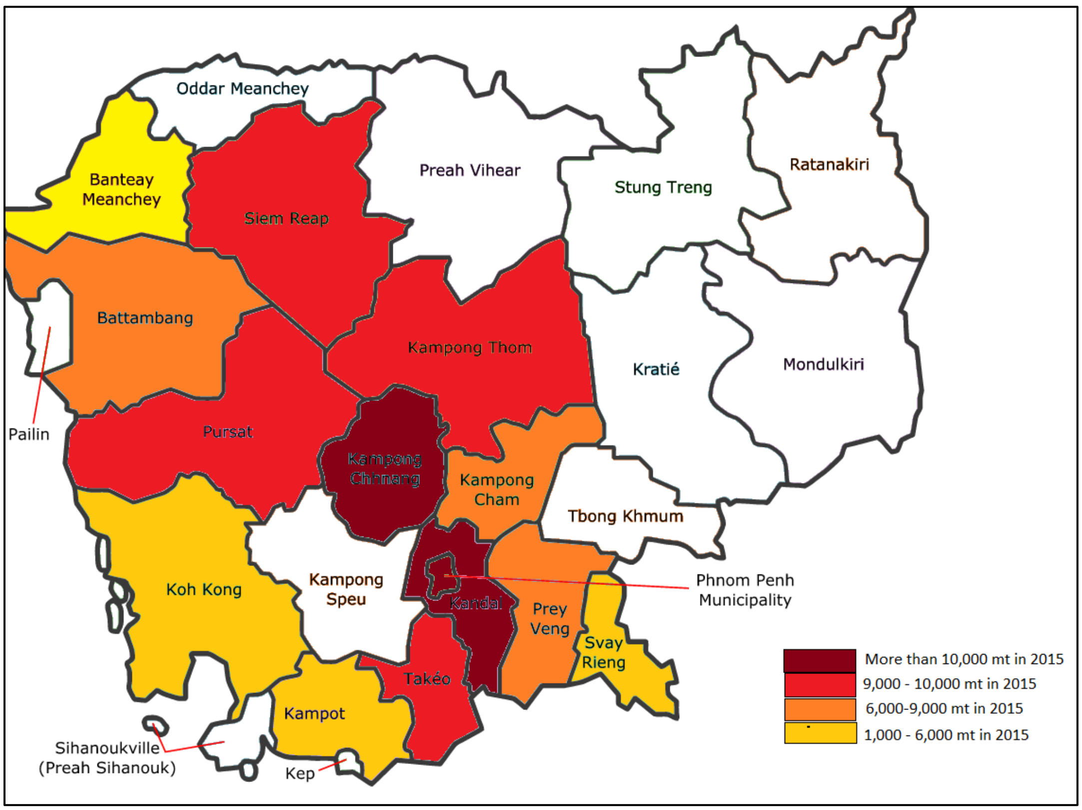


FIGURE 2.1. MAP OF GEOGRAPHICAL DISTRIBUTION OF AQUACULTURE IN CAMBODIA

2.1.3 Production volumes

The Fisheries Administration aggregates production data reported by the fisheries cantonments. provides the official statistics for freshwater aquaculture for 2014-2016. These figures show an annual growth rate of production volumes of about 20%. Key informants however, have indicated that the reality seems to be closer to a stagnant production volume scenario. The strategic planning framework for fisheries (2015-2024) of the Ministry of Agriculture, Forestry and Fisheries (MAFF, 2015) sets out the goals for the development of the fisheries sector in Cambodia, including the target of a "commercially viable and environmentally sustainable aquaculture contributing to food security, socioeconomic development, GDP and export earnings" (MAFF, 2015: 15). Among the indicators are a 20% annual increase in production volumes and farm gate values. There seems to be some pressure on the cantonment fisheries offices to report growth that matches this strategy.

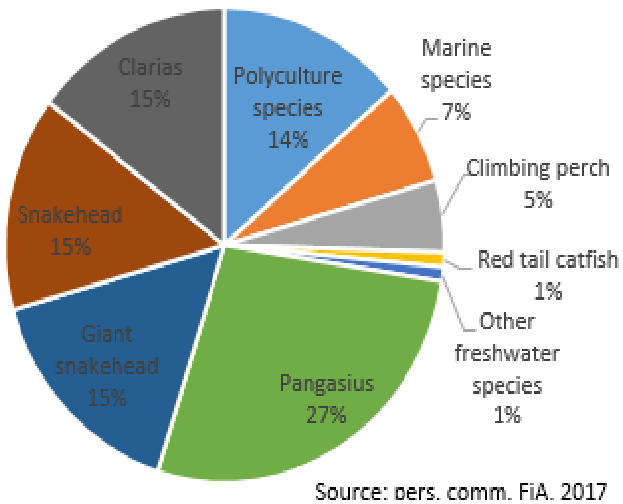
To explore this further, we obtained the cantonment annual reports of 2016 and interviewed fisheries officers in some of the key provinces to examine how estimates are derived and what the potential sources of errors could be, to develop our own estimate of the production volumes. After we obtained the annual reports, we found that those figures were later adjusted upwards to become those presented in 2016 official data column of Table 2-1.

Through information from key informant interviews we have also derived our own estimates of the production volumes. This is based on more realistic potential productivity of farms. Table 2-1 presents an overview of all data described above; i.e. the official central level statistics on production for 2014, 2015 and 2016, the data extracted from the cantonment annual reports for 2016, and our own estimates based on information from key informant interviews. For the economic analysis, two scenarios have been built: scenario 1 using the 2016 official data; and scenario 2 based on the 2016 Cantonment annual reports.

	2014	2015	2016		
	Official data	Official data	Official data	Cantonment annual reports	Our estimate
Phnom Penh	25,500	30,600	25,650	21,840	7,600
Kandal	19,500	24,375	22,000	14,300	8,400
Kampong Chhnang	8,500	10,200	12,000	6,850	961
Siem Reap	7,700	9,625	13,000	10,000	1,560
Kampong Thom	7,550	9,003	22,000	1,280	810
Pursat	7,500	9,000	22,000	1,540	1,000
Takeo	7,500	9,000	9,500	7,680	1,950
Prey Veng	6,500	7,800	8,100	1,590	1,590
Battambang	5,500	6,600	7,500	9,500	1,000
Kampong Cham	5,500	6,600	6,600	3,150	970
Kampot	3,400	3,500	3,200	3,230	1,519
Tbong Khmom	670	838	3,818	1,098	99
Other provinces	14,735	16,001	24,897	No data	-
Total	**120,055**	**143,141**	**170,265**	**82,058**	**27,459**
Annual growth rate		19.23%	18.95%		

Table 2-1. Freshwater and marine aquaculture production volumes by key provinces in MT (2014-2016) – excl. seaweed. Source: Fisheries Administration and own survey data 2017.

Foreign investments are expected in marine aquaculture (a 24 million USD proposal to build the first large-scale marine fish farm in Cambodia has been submitted by Norwegian company Vitamar) which, if granted, is likely to significantly boost production in this system.
The only disaggregation that is available in the official production data that is collected by the Fisheries Administration at the central level is for major categories: i.e. fresh water fish, other species, and marine. In addition some information is available on what is produced in ponds and cages. As for the economic analysis in particular we would like to distinguish between systems and species, we have developed an estimate of the contribution of the different species, and the different systems, based on consultation with Fisheries Administration staff see figures below.



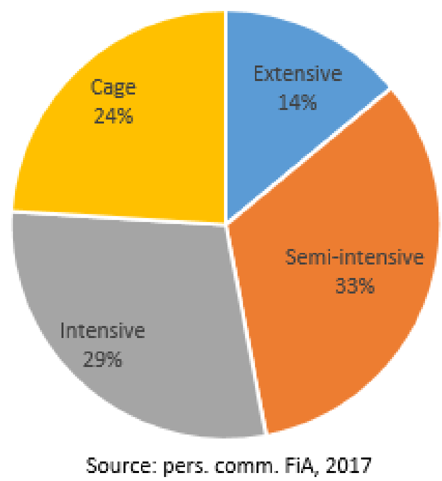


FIGURE 2.2. COMPOSITION OF CAMBODIAN AQUACULTURE PRODUCTION AND IMPORTS

2.1.4 Farmed fish imports

Key informant interviews with market actors and government officials indicate that Cambodian fish farmers are competing with significant volumes of cheap imported farmed fish. There are however no official data for the volumes of fish that cross the border from Thailand and Vietnam. Data from the Fisheries Administration on licenses and related quota, granted for the period 2016-2017, show 35 licensed importers, with a total import license of 202,347 mt for two years (hence about 100,000mt per year). The licenses also specify the fish species, and from this information we derive that about 97% of this fish is from farmed sources. In addition, key informant interviews indicate that significant volumes cross the border without a license and estimates for this vary between 10 and 30% of total volumes. We therefore estimate that imports are about 120,000mt annually.

Imported fish is competing on price with the domestically produced fish, as prices have been quoted of as low as 0.40-0.50 USD/ kg for pangasius (last year 0.55-0.90 USD/ kg) bought at the Thai border (processor interview, 17/12/2016) used for fermenting, and about 1.00 USD / kg for imported pangasius from Vietnam at the landing site, and 2.00-2.50 USD / kg for snakehead (wholesale market interview Phnom Penh, 14/12/2016). Different sources state that Cambodian consumers prefer nationally produced fish, however it is clear that significant quantities enter the Cambodian markets, and this may therefore only be the case for well-off urban consumers that can afford to pay more. It may also in many cases not be possible to distinguish imported from domestic fish.

Key informant interviews indicate that apart from the fact that aquaculture is more developed and matured in Vietnam and Thailand, and the enabling environment conducive, the main reason for the ability of the Vietnamese and Thai aquaculture sector to be so competitive is that their value chain is geared toward supplying the international market with farmed fish. The fish that is exported to Cambodia is most likely of inferior quality, unsuited for the European and US markets, and considered a 'by-product' of production. These products can therefore be sold at considerably lower prices.

2.2 Value chain structure

A value chain is commonly defined as 'the full range of activities that are required to bring a product (or service) from its conception through the different phases of production to delivery to final consumers and disposal after use' (Kaplinsky and Morris, 2001). Given that this study comprises the analysis of the entire aquaculture sector, rather than a specific product, it requires a certain degree of generalization. The analysis is focussed on freshwater aquaculture, freshwater fish in particular, putting less emphasis on marine aquaculture, as well as crocodile. A simplified value chain map is presented in Figure 2.3. Core processes in the aquaculture value chain include production, processing, trading and transporting, and retailing. A number of main product forms are available in the market, including live and fresh, fermented in different variations, dried, and smoked. In addition, processors sell a large variety of different by-products, both for direct human consumption, and as input into feed for fish farming.

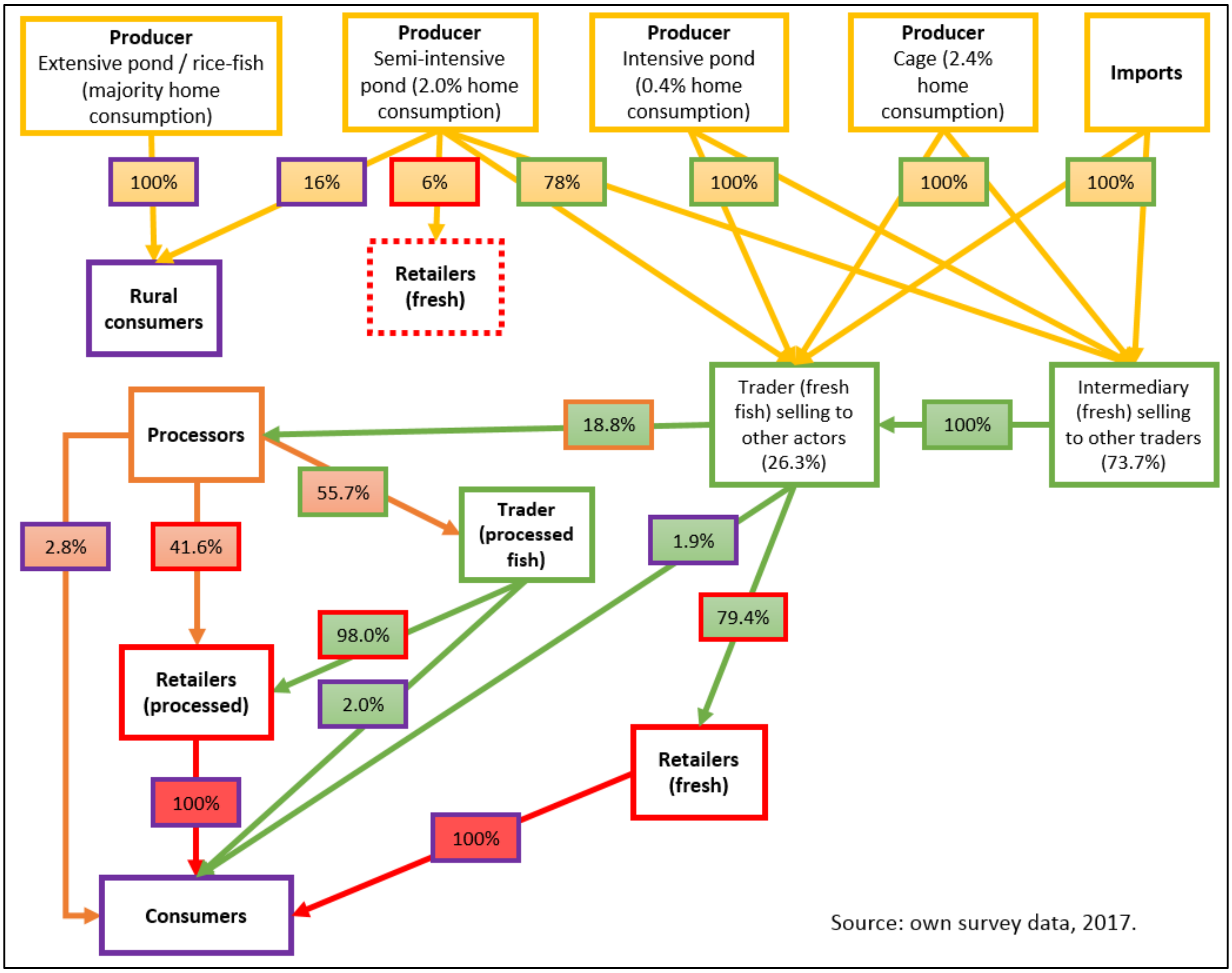


Figure 2.3. Aquaculture value chain map of Cambodia with product flows (shares of product volumes flowing from each actor)

2.2.1 Value chain actors

2.2.1.1 Farmers

The number of aquaculture operations reported varies across different data sources. The official statistics from the Fisheries Administration on aquaculture production (2015) report the number of households involved in aquaculture as 37,024 and the number of workers as 66,654. The Cambodia agricultural census (2013), which in the core module included all households, except those in the urban area of Phnom Penh, reported the number of households engaged in some form of aquaculture as 80,632. It is however not clear whether the term being "engaged in" includes wage labourers or only self-employed. The supplementary modules of this survey only cover households that have an agricultural holding of a cropping area at least 0.03 ha and/or have at least 2 large livestock and/or three heads of small livestock and/or 25 poultry. This means that those households that have cages in open access water bodies and do not have land are excluded from this survey. The supplementary module on aquaculture only covers 26,476 households (roughly one-third of all households involved).

Out of those households, the majority (93%) was said to be engaged in pond aquaculture and only 3% in cage aquaculture. Finally, the Cambodia socio-economic survey (2014) excludes all 'non-normal' households in Cambodia including boat population households. Whether this means that floating villages are excluded is unclear, but this seems likely to be the case. This survey reports the number of households involved in aquaculture as 49,263.

In this report we have grouped freshwater aquaculture farmers into four major groups:

1) Extensive and rice/fish farmers: these farmers use little to no bought inputs, apart from some seed, and mainly use fertilization from animal production, kitchen waste, and crop residue as the main feeding inputs. The vast majority of these farmers uses the output for household consumption and also give away their fish to relatives and neighbours. Only very small quantities (probably less than 5% of total harvested volumes) are sold, mainly in nearby rural markets.
2) Semi-intensive pond farmers: the majority of these farmers have one pond, some have more, with an average total pond area of 0.10 ha. There is great variation in the grow-out period of the different species, but on average semi-intensive farmers have one harvest per year. According to our survey, about two-thirds of the semi-intensive farmers practice partial harvesting, i.e. they harvest smaller quantities throughout the grow-out period rather than a complete one-off harvest at the end of the grow-out period. Out of the overall volumes reported in the survey, 2% of total volume produced by semi-intensive farmers was used for home consumption or given away (excluding what is removed from the pond because of disease or death), while the rest is sold. However, reporting the share of volume consumed at home in overall volumes produced, masks the significant importance of farmed fish for home consumption, in particular among the smaller semi-intensive farmers. When we calculate the share used for home consumption or gifting for each farmer individually and then calculate the average we find that on average semi-intensive farmers home consume or gift almost 13% of the useable harvest. Semi-intensive farmers engage with a larger variety of value chain actors than the other farm types. The share of home consumption is much higher among polyculture farmers than monoculture farmers (33.1% and 7.9% respectively). Many semi-intensive farmers use some commercial feed, mainly at the start of the grow-out period.
3) Intensive pond farmers: Average pond area of intensive farmers in our survey was 0.73 ha. More than half have multiple ponds, on average 2.3 ponds for all intensive farmers. The production of these farmers is mostly market oriented, and 0.4% of the overall volume is used for home consumption or given away. When calculated based on the average share for each individual intensive pond farmers this is 1.0%. They more commonly use hired labour, although family labour is also a major input for these farmers. They use more feeds more intensively, but like semi-intensive farmers their use of commercial feeds is limited to part of the grow-out cycle. Their use of other inputs such as lime, enzymes and medicine is higher than among semi-intensive farmers.
4) Cage farmers: cage farmers commonly have 1 or 2 cages, with an average size of 31 m3. Cage farmers in our sample employed no hired labour. Their use of commercial feed and other

inputs is limited. The main input used is low value fish from capture fisheries. About 2.4% of what is produced by these farmers together is destined for home consumption, the remainder is for the market. Averaging the shares of home consumption this is 3%.

2.2.1.2 Intermediaries

For other nodes of the aquaculture value chain the secondary data are scant. We were unable to locate data on the number of intermediaries involved in the chain. Our survey data suggests that there is a great deal of trade between different kinds of traders. In our sample we found that among those traders that sell to other traders, 80% in volume was also bought from other traders, suggesting that fish passes through several actors before reaching the processor / retailer. Of all fresh fish being handled by intermediaries in the chain, only 20% is actually bought from farmers directly. On average traders in our sample dealt with three different species or products and handled slightly over 500mt per annum. Variations between traders were high however and total annual volume ranged between 11mt and almost 7,000mt.

2.2.1.3 Processors

The official statistics from the Fisheries Administration on aquaculture (2015) report the number of households involved in fish processing (including of fish from wild sources) as 13,347 and workers as 33,546. However, the Cambodia economic census (2011) reports the number of establishments involved in processing and preserving of fish, crustaceans and molluscs (from all sources) to be only 114, with 1,012 people involved. Retail and wholesale trade establishments in this report are reported for the food, beverage and tobacco category as a whole, and these statistics therefore do not provide a good indicator for the number of establishments involved in fish sales.

2.2.1.4 Retailers

The Cambodia economic census (2011) reports on retail and wholesale trade establishments for the food, beverage and tobacco category as a whole, and these statistics therefore do not provide a good indicator for the number of establishments involved in fish sales. The most common type of retailers are found in traditional markets in smaller and larger urban centres, but fish is also sold by retailers from the side of the road, and in a few supermarkets. The larger markets have separate sections for fresh and dried fish, and retailers generally specialize in either fresh/live or processed product, although some fresh fish retailers may also process some fish when its shellfire is close to expiring, as a strategy to avoid complete loss of the product. Apart from locally processed products, some retailers also indicated they bought already processed product from traders that were importing it from Vietnam. There is no data available about the extent to which this happens.

2.2.1.5 Consumers

We were unable to go into much detail with regard to the demand side of the value chain. The types of products available in the chain and the strategies of processors to either work with high quality product from local farmers, or source cheap farmed fish from imported sources, clearly shows the segmentation in the market based on income. Further research is recommended in this area.

2.2.2 Inputs, services, and capital

2.2.2.1 Feeds

Two types of feed are used in the farmed fish sector of Cambodia: home-made feeds, and pelleted commercial feeds. At the moment there is no commercial feed that is produced in Cambodia, although there is at least one company that is now considering it. Almost everything seems to be imported from Vietnam. Statistics are not available from the Fisheries Administration as import quota and licenses for feed imports are handled by a different Ministry, and we were unable to obtain these data. Large and medium sized importers will apply for licenses, however small-scale importers import bags of feed by bus or small vehicle, and therefore are able to import without them. Based on about 10 official importers and an unknown but larger number of small importers we estimate the volumes of imported pelleted feed at about 35-40,000 t/ year. The CAPFish feasibility study however has put this estimate at 10-fold this number, but this is based on an estimate of feed needs, based on production volumes. Some key informants have voiced concerns about quality of feed being imported, others have said the main issue is water quality. We have been unable to confirm or refute any of these concerns. Depending on the species produced, the composition of home-made feeds varies. As protein inputs, both low value small fish (often referred to as trash fish) from capture sources, and seafood processing waste are being used. There are also flows of low value fish both into the country from Vietnam (marine fish), and out of the country to Vietnam (freshwater fish). An interview with one producer of feed from the processing industry in Battambang (a major processing hub) indicated that he processed on average 1mt of pangasius processing waste per day (but up to 4-5mt/ day in peak season).

2.2.2.2 Seed

There are three main sources of seed: local hatcheries, imported sources, and the wild. According to the Fisheries Administration statistics of 2015, there were 307 hatcheries producing 180.5 million fingerlings. Local hatcheries mainly produce carps, tilapia and barb while most of pangasius, snakehead and clarias species are imported from Vietnam. Data from FiA on import licenses and quota show that among the 35 companies that are presently licensed for fish imports, 10 also have a license for the import of fingerlings. Together their quota is for 139 million fingerlings over two years, (or about 70 million annually). These official licenses do not include any (giant) snakehead seed, as the production of snakehead was officially banned, however from the significant levels of snakehead production we found during our survey, and the lack of local production of snakehead seed, it can be concluded that significant numbers of fingerlings are imported informally and key informant interviews confirm this.

There have been concerns about the quality of fingerlings, however we have not been able to confirm this. There seem to be high levels of mortality for snakehead in particular, but also for pangasius, based on the numbers of fingerlings used per unit of output (i.e. polyculture species in ponds 6.2pc/kg; pangasius in semi-intensive ponds 3.5pc/kg; pangasius in intensive ponds and cages 5.8pc/kg; (giant) snakehead in ponds 14pc/kg; and (giant) snakehead in cages 8pc/kg)

2.2.2.3 Other inputs

There are no professional services related to disease. Any products used are imported from Vietnam, or products intended for other uses. The extensive and semi-intensive systems also make limited use of any other inputs.

2.2.2.4 Equipment

Farming and processing equipment such as pumps, and grinding machines are usually imported either new from China, or second hand from Japan. There is however some degree of local assembly where the motors used are imported but the casings are locally assembled. The materials used for this assembly are however also imported.

2.2.2.5 Credit

In our sample, roughly half of the farmers (51%) had obtained a loan for their aquaculture production. The majority of those loans came from a bank (79%) or money lender (14%). For the other value chain actors 55% of processors, 36% of traders, and only 3% of retailers had obtained a loan for their aquaculture business. In all cases, banks were the most common source of credit. Size and duration of the loans varied substantially[1], but interest rates are moderately low; less than 2% monthly on average.

2.3 Products and prices

The Cambodian aquaculture value chain is characterized by a large variety of products. In our survey we focussed on the main products and captured low and high season prices at different stages in the chain. Fresh fish is preferably traded live, and there is little use of ice in the freshwater aquaculture chain, according to key informants because ice indicates a lack of freshness. Several types of processed products are found in the market. These include among others dried pangasius, two types of fermented pangasius, dried snakehead and giant snakehead, and smoked Clarias. In addition, a wide range of by-products were being sold including airbladders and stomachs. An overview of the price structure in the chain is presented in Figure 2.4. Several producers (key informants) indicated that market prices were below break-even price at the time of our field research, and had been for some time.

[1] Farmers: 300,000 – 400 million KHR, average 32 million KHR (8,000 USD); Processors: 4 to 160 million KHR, average 56 million KHR (14,000 USD); Traders: 4 to 280 million KHR, average 54.5 million KHR (13,625 USD).

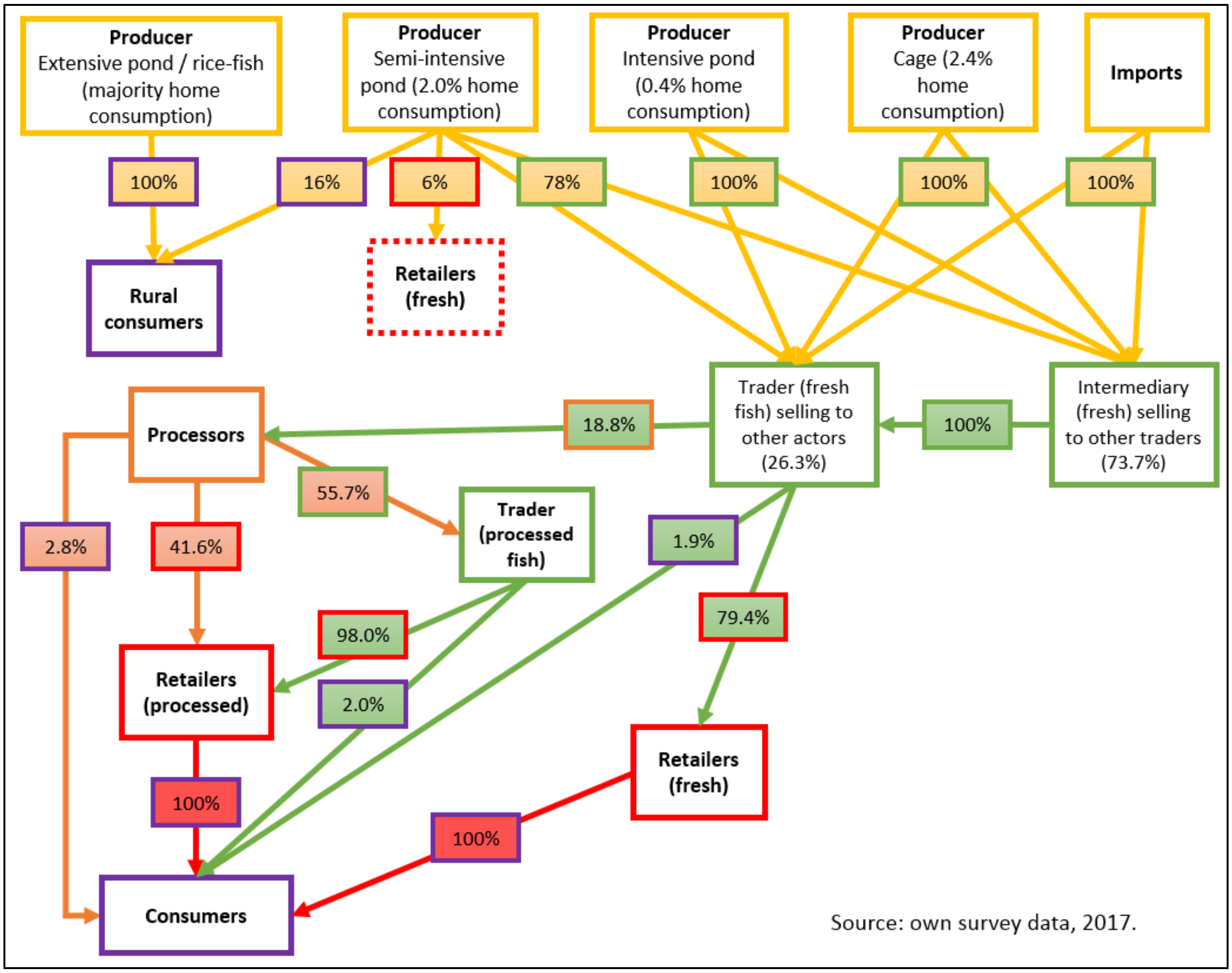


FIGURE 2.4. PRICE STRUCTURE OF THE CAMBODIAN AQUACULTURE VALUE CHAIN IN KHR PER KG (2016)

2.4 Value chain governance

The concept of governance refers to the "inter-firm relationships and institutional mechanisms through which non-market, or 'explicit', coordination of activities in the chain is achieved" (Humphrey & Schmitz, 2004: 97). An analytical framework has been formulated (Gereffi et al., 2005) that yields forms of coordination based on a combination of three variables that can each take the value high and low. These variables are: (1) the complexity of the information and knowledge required to sustain a particular transaction; (2) the ability to codify and transmit this information between the parties; and (3) the capabilities of the suppliers to meet the requirements of the buyer. This results in five possible categories of coordination in individual nodes of the chain (Table 2-2):

1. Market: spot or repeated market-type inter-firm exchanges; both parties' costs of switching to new partners are low.
2. Modular: inter-firm relations involving more specialised suppliers who finance part of production on the part of the customer, but whose technology is sufficiently generic to allow its use by a broad customer base.

3. Relational: inter-firm relations involving multiple inter-dependencies, often underwritten by close social ties.
4. Captive: inter-firm relations involving one-way dependency of suppliers, high levels of supplier monitoring and high costs of switching for suppliers.
5. Hierarchy: classical vertical integration.

Governance type (analytical framework)	Complexity of transactions	Ability to codify transactions	Capabilities in supply-base	Degree of explicit coordination & power asymmetry
Market	Low	High	High	Low
Modular	High	High	High	↕
Relational	High	Low	High	
Captive	High	High	Low	
Hierarchy	High	Low	Low	High
Cambodian aquaculture VC	Low	High	High	Low

TABLE 2-2. TYPES OF GOVERNANCE APPLIED TO CAMBODIAN AQUACULTURE VC. SOURCE: ADAPTED FROM GEREFFI ET AL., 2005.

When strictly applying this analytical framework, the Cambodian aquaculture value chain shows all characteristics of the 'market' governance type. In principle, transactions in all nodes of the chain are low in complexity, and are simply based on fish being traded between two parties without any formal contract or agreement. However, most value chain actors along the chain (with the exception of the retailers) indicate that they regularly deal with the same set of buyers (see also social analysis section Figure 5.2). There are no consequences to switching, but the relational aspects and trust are important in many transactions. Some key informants indicate that in particular farmers without a network with buyers have difficulty finding a market for their products. Many transactions, especially those between farmers and intermediaries, and between retailers and their suppliers, take place based on a phone call in which an order is placed or an offer of fish is made. In some cases there is delayed payment and this is accepted by suppliers if the buyer is someone they know and trust. This trust is built up over the years.

The information that is transmitted in the transaction is simple; species, total volumes, and size or weight per head are in most cases the only characteristics that buyers are interested in. The exception to this is when processors are looking for a particular quality for the production of high quality dried fish. In this case, firmness and colour of the flesh are the key indicators of quality. The ability to codify this information is therefore high. As the extent of requirements of buyers is limited (again with the exception of certain processors), suppliers have sufficient capabilities to meet these requirements. As the requirements of a transaction are typically limited to species, volumes, size, and product (in case of retailers) and there are no other requirements in terms of production practices, hygiene, or antibiotics use, the of level of explicit coordination and power asymmetry is low. Although suppliers typically deal with the same buyers, they usually do supply more than one. Likewise buyers usually work with several suppliers (in some cases over 100). This means that power asymmetries remain relatively low, just as switching costs (Gereffi et al., 2005).

The relational aspect requires further examination. According to the analytical framework, relational coordination occurs in situations when product specifications cannot be codified, transactions are complex, and supplier capabilities are high (Gereffi et al., 2005). As we have concluded, none of this is the case in the Cambodian aquaculture value chain. However, transactions in this chain still seem to exhibit some of characteristics of relational coordination as aspects such as reputation, spatial proximity, and social ties seem to play a key role for both parties in a transaction. Several key informants have indicated that in the end, success for farmers in the chain depends on having a network that links them to the market. Similarly, traders interviewed indicate that their ability to sustain their business depends on it as much as it does for farmers. The complexity of the transaction does not seem to arise from the complexity of information or knowledge related to the product as such, but from the absence of markets and the opportunity for spot market transactions.

3. Economic analysis

3.1 Introduction

For part of the economic analysis the Agri-Food chain Analysis software (AFA), developed by CIRAD, should have been used. Unfortunately, due to circumstances this was not possible and therefore the entire analysis was conducted in Excel.

Two scenarios are presented, where appropriate:

- Scenario 1: official statistics of 170,000mt production in 2016 and 120,000mt of imports with a total of 290,000mt of farmed fish, and a contribution of imports of a little over 40%.
- Scenario 2: an estimation according to the cantonment annual reports of 85,000mt of domestic production and 120,000mt of imports with a total of 205,000mt of farmed fish, and a contribution of imports of almost 60%

For both scenarios, we rounded the volumes of production provided in the functional analysis.

3.2 The framing and core questions

Framing question 1: What is the contribution of the value chain to sustainable economic growth?

3.2.1 CQ1.1: How sustainable are the VC activities for the entities involved?

The assessment of sustainability of the value chain activities is based on a financial analysis, which involves assessing the profitability of the key actors identified in the functional analysis. The actors' operating accounts are the main basis of the analysis. Three indicators are used to assess the sustainability of the aquaculture value chain activities; net income, net profit margin, and return on investment. An overview of the specification of how these indicators were derived, can be found below.

Key indicator(s)	Relevant ratios of profitability for each actor type
Specification this study	Net Income: revenues – variable costs - fixed costs Net Profit Margin (%) (Net income / Revenues) x 100 Return on Investment: net income/ total costs
Level	By actor type: • Semi-intensive low input pond production • Semi-intensive high input pond production • Intensive pond production • Cage production • Trader all species • Processor all species • Retailer all species and products
Data used for calculation	Own survey data
Assumptions	• Labour: Only hired labour has been taken into account. Family labour has not been valued • Land: real land costs were included only, this includes annual land lease, and costs for inheritance and purchase of land, annual costs have been calculated based on a 50 year period. • Fish consumed at home and given away is included at market value.

Producers

Table 3-1 shows the annual operating accounts of the four producer types identified, and the average revenues, costs and profits for one average actor in the value chain. The indicators include the value of fish consumed at home or given away.

	Semi-intensive ponds polyculture low input producer 234 kg	Semi-intensive ponds monoculture high input producer 6,274 kg	Cage producer 1,695 kg	Intensive ponds monoculture producer 41,082 kg
Sales	182	7959	2146	64419
Self-consumption	103	154	41	230
Direct subsidies	0	0	0	0
Total OUTPUT	**285**	**8114**	**2187**	**64649**
Feed home made	31	4053	1357	35379
Feed commercial	45	817	176	8225
Fingerlings	21	419	179	1830
Lime	4	23	0	332
Organic fertiliser (own)	0	0	0	0
Inorganic fertiliser	0	8	0	0
Salt	0	5	0	152
Enzyme	0	44	25	241
Water treatment	1	32	14	670
Other inputs	0	2	1	12
Gasoline	2	35	10	240
Electricity	1	8	15	90
Diesel	1	47	1	373
Maintenance	20	18	16	98
Total IGS	**127**	**5509**	**1794**	**47641**
Wages	0	461	5	2345
Financial charges	0	38	1	268
Taxes	6	1107	89	2127
Land	1	32	0	677
Depreciation	57	323	236	899
Total EXPENSES	**191**	**7470**	**2125**	**53958**
Net operating profit	*94*	*644*	*62*	*10691*
*Added value**	*100*	*2,281*	*157*	*16,108*
Net profit margin	*32.9%*	*7.9%*	*2.8%*	*16.5%*
Return on Investment	*49.0%*	*8.6%*	*2.9%*	*19.8%*

TABLE 3-1. ANNUAL OPERATING ACCOUNTS OF KEY PRODUCERS (IN EUR) *ADDED VALUE IS THE SUM OF WAGES, INTEREST, TAXES, LAND AND NET PROFITS.

The analysis of net profits is relevant as it sheds light on cost structure and production efficiency. The lower the net operating profit margin, the less efficient the actor is in converting revenue into profit over a given period. Farming fish is profitable, albeit weakly for some producer types, in particular for cage farmers that operate with a very small profit due to relatively high consumables costs (mainly home-made feed). The net profit margin is highest for the semi-intensive polyculture farmers, however this is the case because we have put a value on the fish consumed at home (at market price), which is 36% of total harvest on average, while for the other farm types this is 2% or less. Not accounting for the value of fish consumed at home would mean that these farmers are operating at a loss. The return on investment is particularly high for the low input semi-intensive farmers, the intensive producers, the processors and the retailers.

Figure 3.1 shows a comparison of the costs per kilogram for the four types of fish farmers (based on an average farmer). Economies of scale that would perhaps be expected for the larger farmers do not seem to occur, but this is likely due to the difference in dominant species between the systems. Depreciation has a relatively large share in total costs for the semi-intensive ponds, and for cage farmers, whereas wages are a relatively larger share for the semi-intensive and intensive monoculture pond farms.

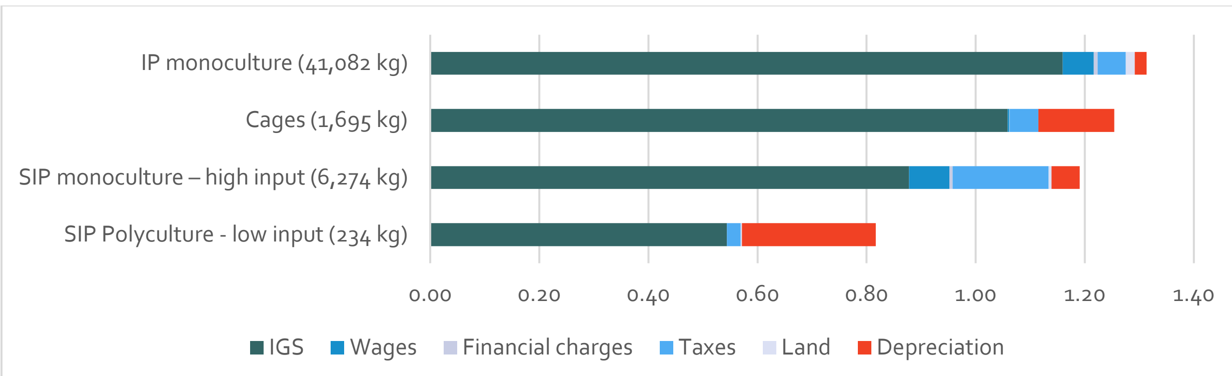


FIGURE 3.1. COST STRUCTURE OF FISH PRODUCED BY THE FOUR TYPES OF FARMERS (EUR/KG)

Figure 3.2 shows that the average price per kilogram of farmed fish received by producers differs between the producer types. This is due to the composition of species being grown, as well as the access to markets. Giant snakehead has the highest price per kilogram, and is only grown by those farmers that are able and willing to feed intensively. Large scale monoculture producers can sell larger volumes, which provides advantages to traders. This price difference explains why the intensive monoculture farmers still have a higher profit margin than the cage and semi-intensive monoculture farmers, despite the fact that their costs per kilogram of fish are higher.

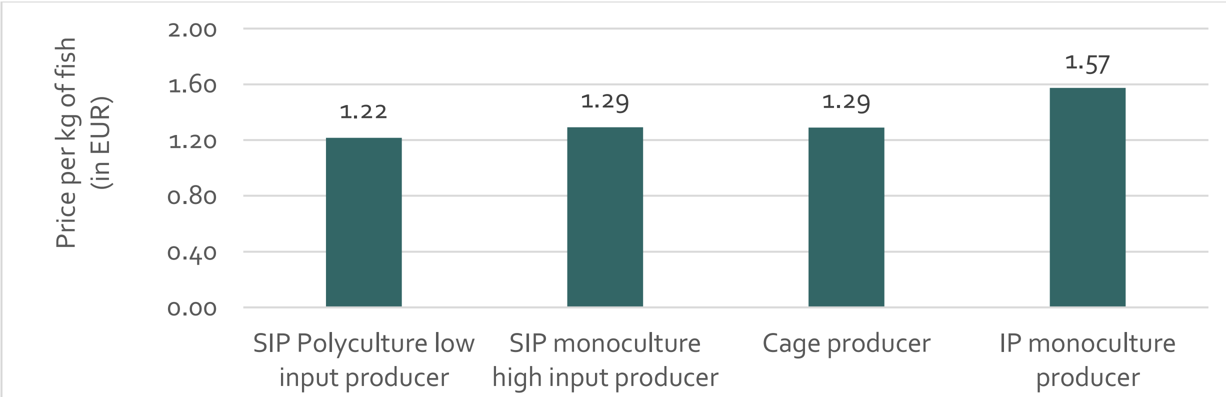


FIGURE 3.2. AVERAGE PRICE OF FISH PRODUCED BY THE FOUR TYPES OF FARMERS (EUR/KG)

Figure3.3 breaks down the intermediate goods and services cost structures for the four types of farmers. Feed is the main input in all systems, accounting for 60.4% of all costs for semi-intensive polyculture ponds, 88.4% for semi-intensive monoculture ponds, 85.4% for cages and 91.6% for intensive ponds. The relatively large share of commercial feed in the low input polyculture ponds is explained by this input being used occasionally as a starter, while home-made feeds are generally made of kitchen scraps and self-produced crops, that are included at no costs For all farm types fingerlings are the next largest cost. The proportion of other costs is largest for the semi-intensive polyculture ponds, which for the most part is made up of costs for maintenance of capital assets. This is likely due to the fact that these farmers postpone the purchase of new equipment for a longer period of time than other farmers.

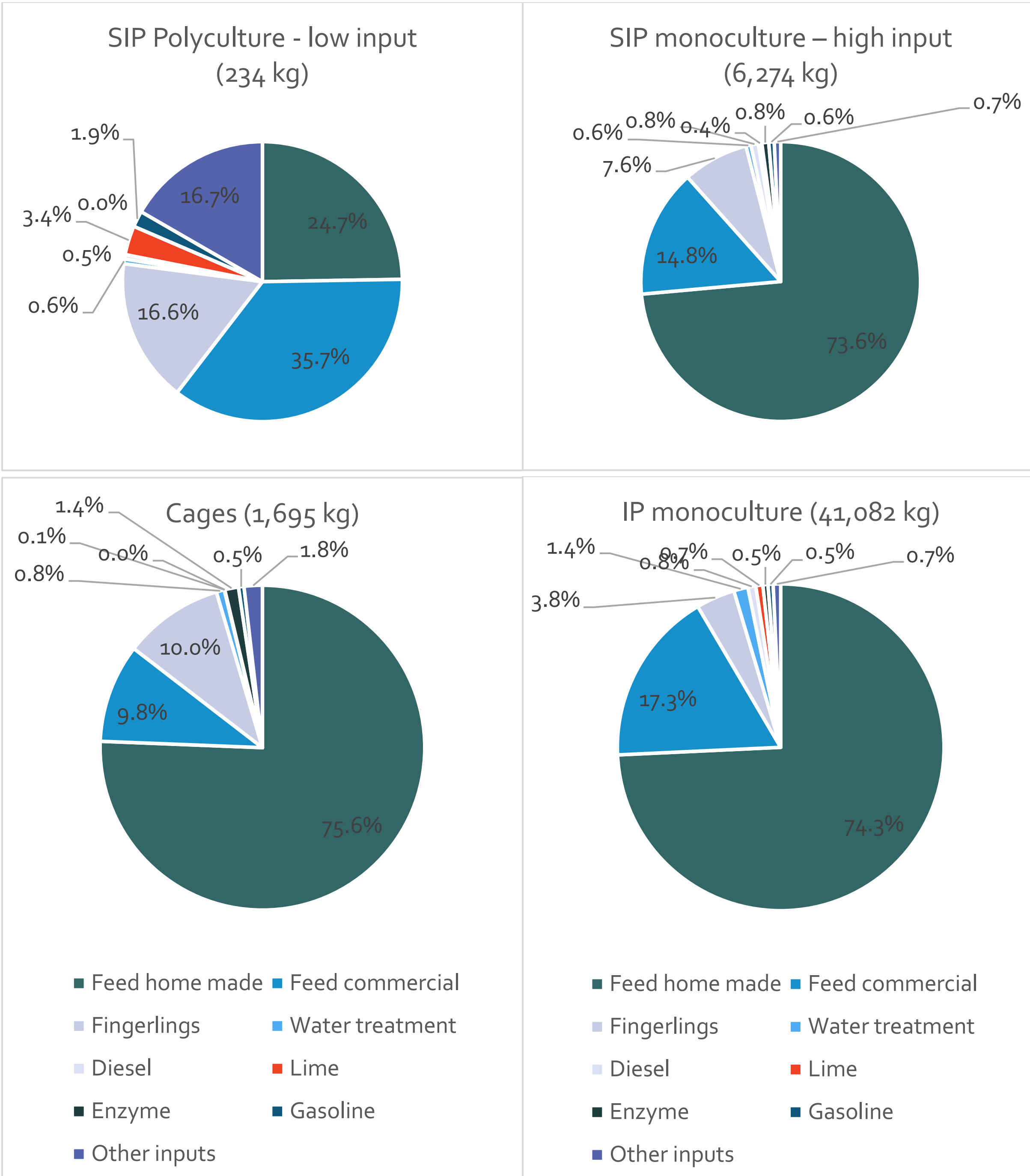


FIGURE3.3. IGS COST STRUCTURE OF THE FOUR FARM TYPES

Traders, processors and retailers

Table 3-2 shows the annual operating accounts for the traders, processors and retailers. All actors have a profit, with the highest profit margins for processors and retailers. Yet, net operating profits for traders are the highest among the three actor types due to the large volumes they handle annually.

	Trader 514.5 mt	Processor 83.5 mt	Retailer 15.5 mt
Sales	825,502	106,409	51,661
Self-consumption	0	0	0
Direct subsidies	0	0	0
Total OUTPUT	**825,502**	**106,409**	**51,661**
Sourcing of fish	**769,593**	**72,019**	**34,817**
Electricity	28	98	12
Ice	254	613	94
Market fees/ rent	61	17	52
Packaging/ bags	85	-	34
Water	133	168	329
MSG	-	372	-
Coal	-	580	-
Salt	-	956	-
Sugar	-	1,555	-
Telephone	134	-	33
Diesel	1,825	11	-
Gasoline	795	35	162
Other	68	37	602
Total IGS	**3,383**	**4,440**	**1,319**
Wages	2,127	3,030	-
Financial charges	575	318	42
Taxes	134	517	1
Land	71	21	84
Depreciation	580	31	1
Total EXPENSES	**776,463**	**80,377**	**36,264**
Net operating profit	*49,039*	*26,032*	*15,397*
*Added value**	51,946	29,919	15,524
Net profit margin	*5.9%*	*24.5%*	*29.8%*
Return on Investment	*6.3%*	*32.4%*	*42.5%*

*Table 3-2. Annual operating accounts of traders, processors and retailers (in EUR) *Added value is the sum of wages, interest, taxes, land and net profits.*

Figure 3.4 shows an overview of the cost structures for traders, retailers and processors. The purchase of fish is for all actors the largest expense (99%, 53%, and 96% respectively). For processors, other important costs include intermediate goods and services, wages, and interest on loans.

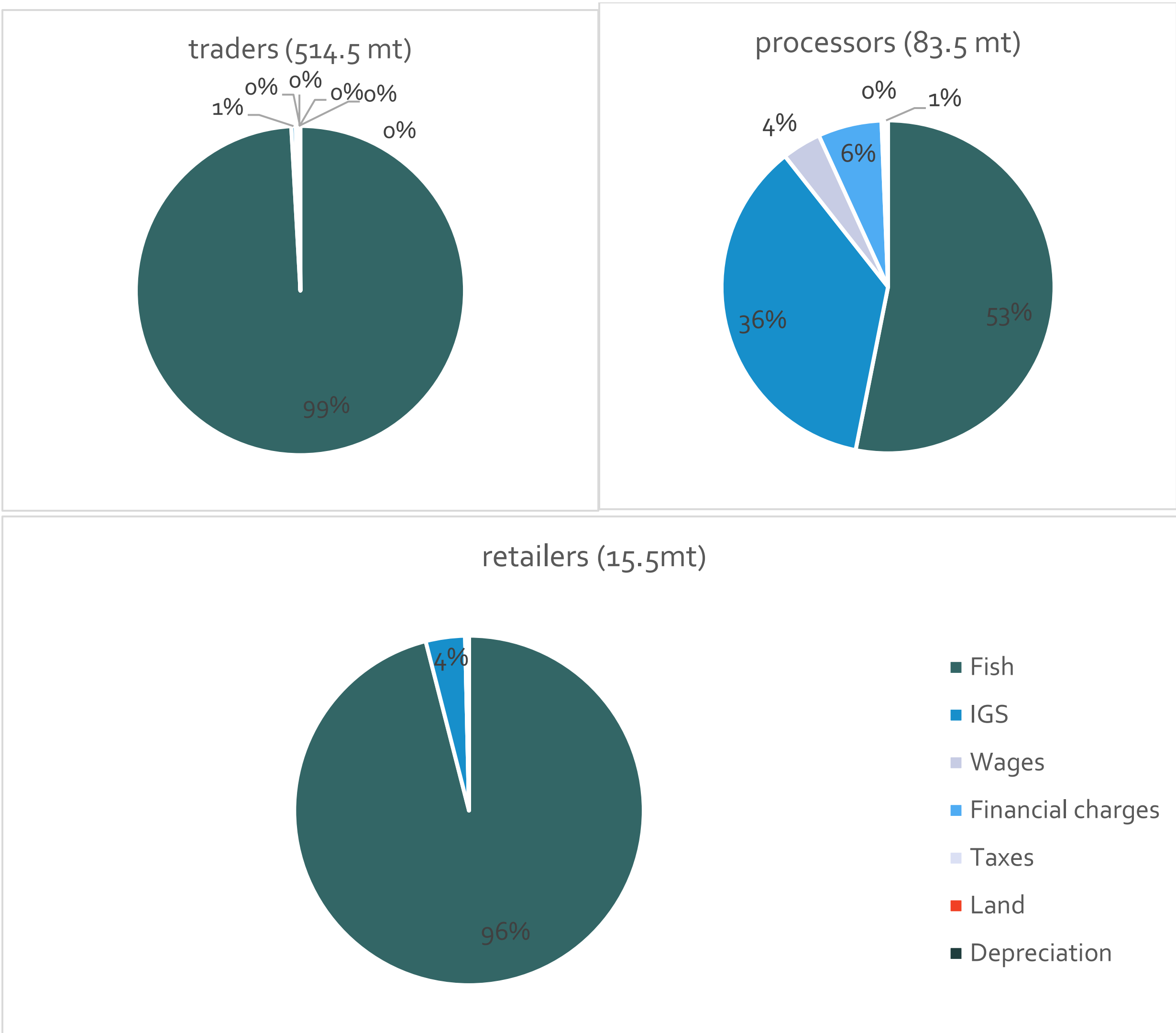


Figure 3.4. Cost structure for traders, processors and retailers

3.2.2 CQ1.2: What is the contribution of the VC to economic growth (to GDP)?

The contribution of the value chain to economic growth is expressed by the contribution to Gross Domestic Product (GDP), which is the total value added produced in the country. The measure of the contribution of the value chain to growth includes: i) direct value added generated by the actors (farmers, traders, processors and retailers, and ii) indirect value added that results from activities induced by the use of intermediate goods and services (IGS) supplied to these direct actors by actors outside the value chain (producing feed, seed, fuel, etc.). The indirect value added is estimated through backward linkages computation, which uses the input-output table for Cambodia from the OECD.

Key indicator(s)	Value added
Specification this study	Direct and indirect value added of freshwater aquaculture under the two scenarios.
Level	Aggregate of freshwater aquaculture value chain as a whole
Data used for calculation	Cambodian Input-output table from OECD (2011) Own survey data Own key informant interview data

The direct value added (VA) by the whole value chain is 308 million € for scenario 1 and 215 million € for scenario 2 (Table 3-3).

	Scenario 1	Scenario 2		Scenario 1	Scenario 2
Intermed. consumption	**171,049,102**	**91,378,020**	Total value of production (revenue including home consumption)	**478,773,498**	**306,799,741**
	107,882,907	53,941,454			
Home-made feed	10,411,995	5,205,997			
Fingerlings	70,724	35,362			
Inorganic fertilizer	701,895	350,947			
Lime	1,949,590	1,296,649			
Electricity	2,220,044	1,629,916			
Ice	1,735,297	1,272,074			
Market fees/ rent	1,935,557	1,419,256			
Packaging/ bags	4,646,124	3,406,149			
Water	278,245	204,880			
MSG	823,091	606,065			
Coal	892,356	603,006			
Salt	1,754,543	1,291,919			
Sugar	2,160,092	1,584,285			
Telephone	3,192,359	2,148,382			
Diesel	5,896,837	4,122,712			
Gasoline	21,856,044	10,928,022			
Commercial feed	1,418,397	719,441			
Water treatment	1,223,005	611,503			
Enzyme					
Total value added	**307,724,396**	**215,421,721**			
Salaries	8,304,475	4,570,521			
Taxes	13,778,529	1,045,504			
Land	2,376,003	6,942,449			
Interest	1,627,887	1,489,527			
Profit	281,637,502	201,373,720			

TABLE 3-3. OPERATING ACCOUNT OF THE VALUE CHAIN (IN EUR)

It represents 64% of the value of production (scenario 1). Almost 92% of this VA are profits for the actors of the value chain (farmers, traders, processors, retailers). The remaining incomes are earned by salaried workers (2.7%), and owners (0.8%), the banks (0.5%), and the Government (4.5%) 75% of the direct VA is incomes for retailers (Figure3.5) under scenario 1 and 78% under scenario 2.

The incomes distributed to producers are 22 million € (scenario 1) and 11 million € (scenario 2) i.e. 7.2% (scenario 1) and 5.1% (scenario 2) of the direct value added of the value chain, and 7.8% and 5.5% of total profits. 41.9% of these incomes are for small producers (i.e. both types of semi-intensive pond farmers and cage farmers).

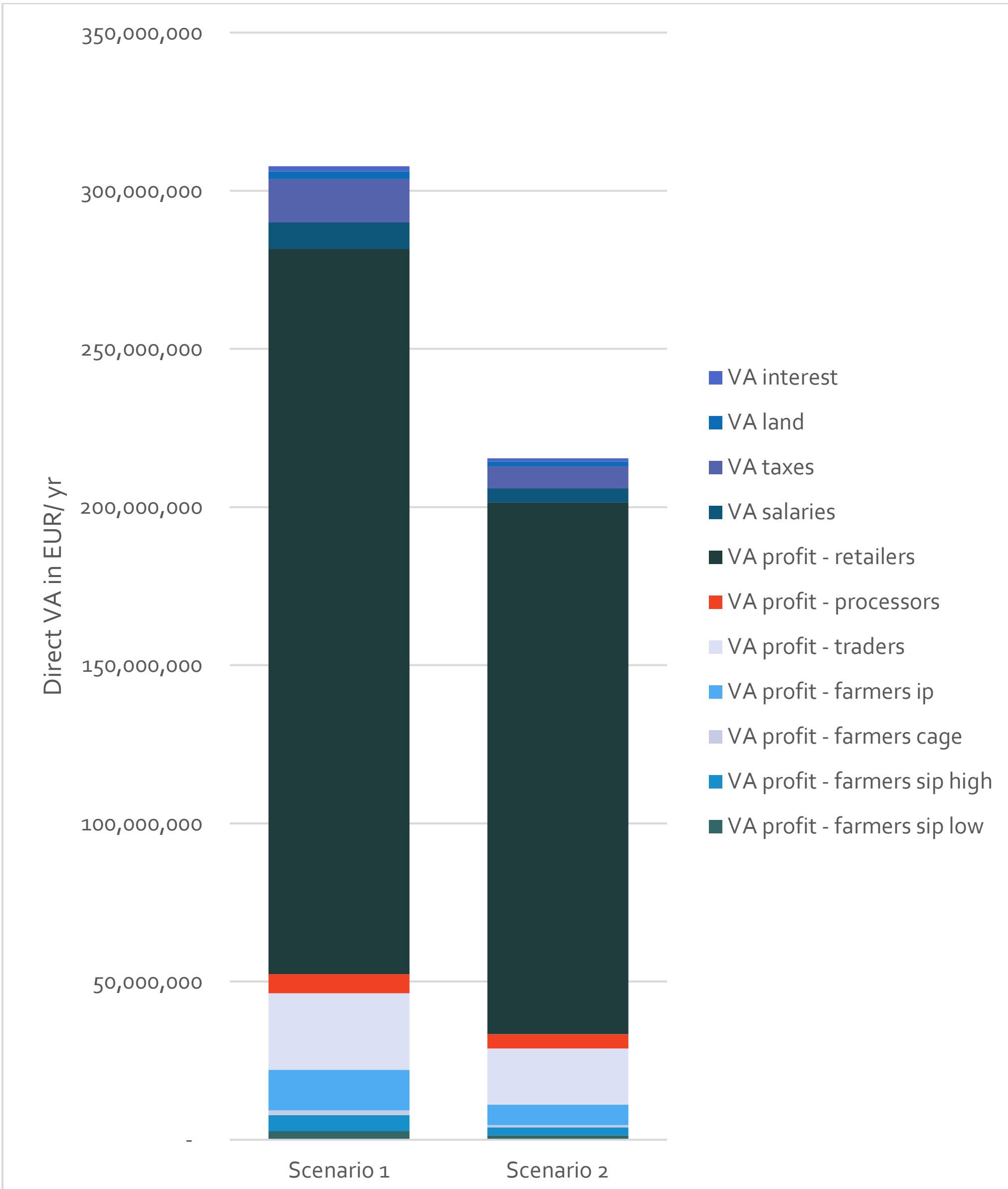


FIGURE3.5. DIRECT VALUE ADDED AND INCOME DISTRIBUTION

The intermediate consumption (IC), which is composed of a domestic and imported component have a total value of 171 million € for scenario 1, and 91 million € for scenario 2 and represent 36% of the value of production (Figure3.6). The main ones are home-made feed (63.1%), commercial feed (12.8% of the total), fingerlings (6.1%), gasoline and diesel (5.3%) under scenario 1. Some IC are totally imported (commercial feed, gasoline and diesel, water treatment, enzyme), others are partially imported (fingerlings, inorganic fertilizer, homemade feed ingredients), the remaining ones are domestic IC. The share of domestic IC is 65% for both scenarios. The value of domestic IC is 110.6 million € for scenario 1 (59.4 million € for scenario 2) and the value of imported IC is 60.4 million € for scenario 1 (31.9 million € for scenario 2).

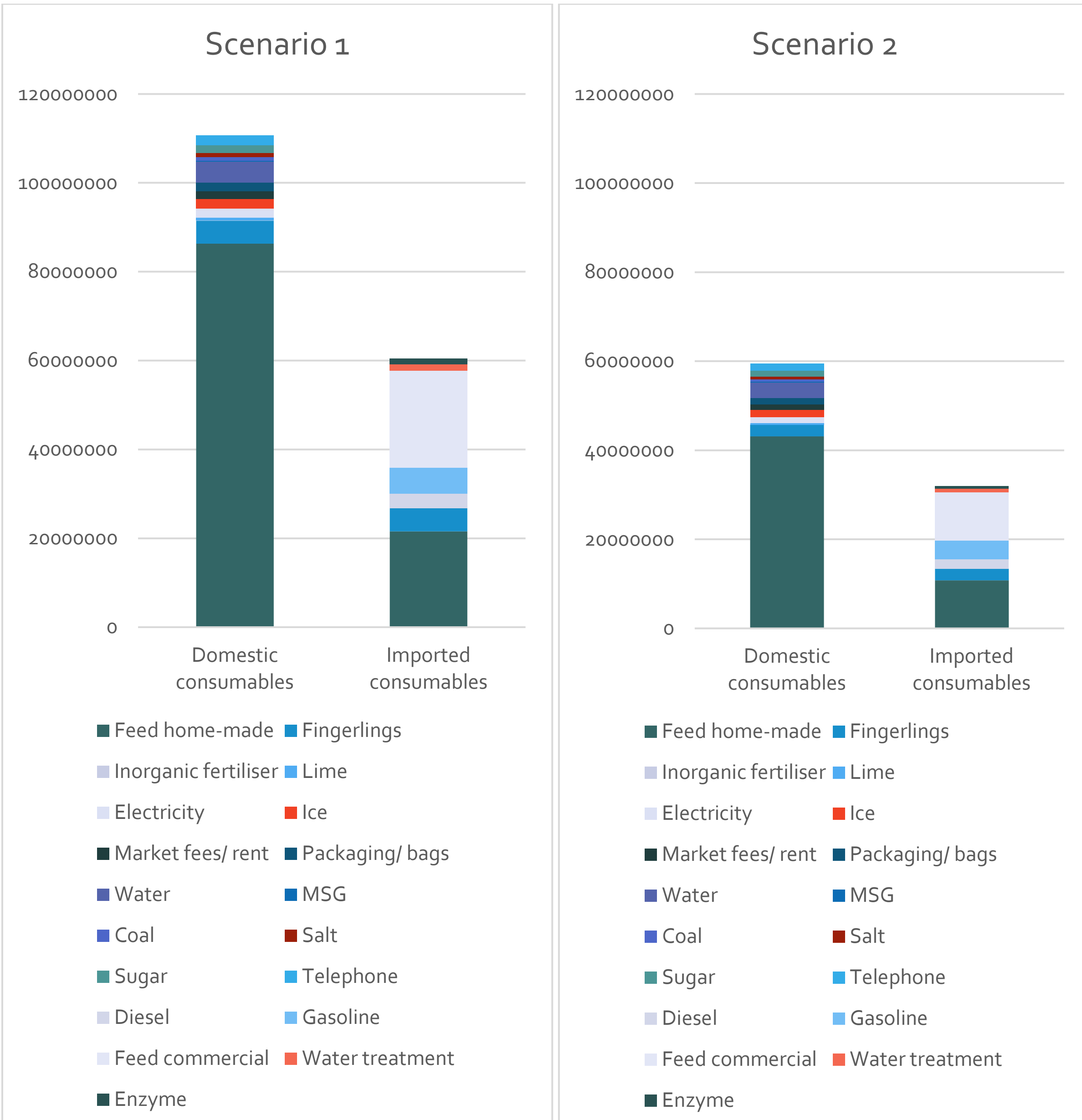


FIGURE3.6. DOMESTIC AND IMPORTED INTERMEDIATE CONSUMPTION DISTRIBUTION

The backward linkage calculations show that the purchases of 111 million € of domestic IC for scenario 1 (59 million € for scenario 2) generate 91.0 million € indirect value added (46.8 million € for scenario 2) and 4.3 million € indirect imports (2.9 million € for scenario 2). Among indirect VA, 39% are salaries under both scenarios (calculations from OECD 2011 - input output tables).

Figure 3.7 provides a summary of the direct and indirect value added for the two scenarios. Total value added is 398.7 million € under scenario 1 and 262.2 million € for scenario 2, with direct value added making up a share of 77% and 82% under scenarios 1 and 2 respectively. The majority of indirect value added is contributed by home-made feed and fingerling production for farmers. Other key consumables that contribute to indirect added value include water and telephone, and fees such market fees and rentals, for retailers and traders. Commercial feeds are completely imported, and this is the same for other production inputs such as water treatments and enzymes. Key consumables such as diesel and gasoline are also imported.

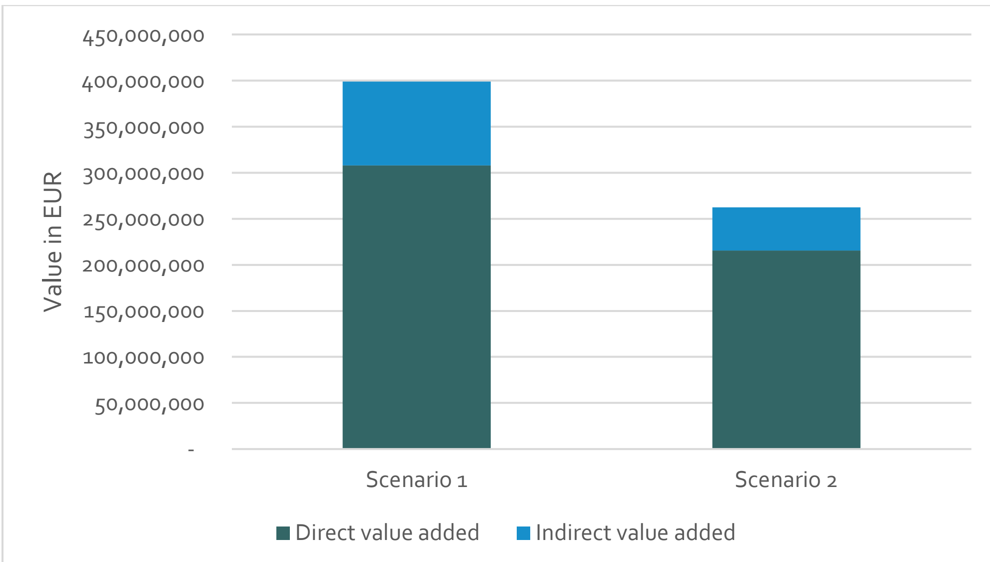


FIGURE 3.7. VALUE CHAIN DIRECT AND INDIRECT VALUE ADDED BY PRODUCTION SCENARIO

3.2.3 CQ1.3: What is the contribution of the VC to agriculture sector GDP?

Key indicator(s)	Value Added shares Rate of integration
Specification this study	Value added shares: Direct and indirect value added of freshwater aquaculture expressed as % of Cambodian agricultural and fisheries GDP under the two scenarios Rate of integration: VA total / Domestic production
Level	Aggregate of freshwater aquaculture value chain as a whole
Data used for calculation	GDP from Cambodian National Institute of Statistics (2015) Cambodian Input-output table from OECD (2011) Official aquaculture production statistics from Fisheries Administration (2015/2016) Production volumes estimates based on own assessment of realistic volumes Own survey data Own key informant interview data

The contribution of value added to GDP, agricultural GDP and fisheries GDP are shown in Table 10. While the contribution of the value chain to overall GDP is limited (2.4% under scenario 1), the contribution to agriculture (9.2%) and fisheries (41.2%) are more significant.

	Unit	Value	Scenario 1	Scenario 2
Direct VA aquaculture	million EUR		307.7	215.4
Indirect VA aquaculture	million EUR		91.0	46.8
GDP (2015)	million EUR	16,316	2.4%	1.6%
GDP agriculture, fisheries & forestry (2015)	million EUR	4,337	9.2%	6.0%
GDP fisheries (2015)	million EUR	967	41.2%	27.1%

Table 3-4. Value chain contribution to GDP, agricultural GDP and fisheries GDP

Due to time constraints we did not develop this further for scenarios under which fish, fingerlings and feeds are completely produced domestically. However, it is clear that the contribution would be more significant with the high levels of imports at present.

The rate of integration with the economy is an indicator of the extent to which the chain depends on domestic production, or its degree of linkage with the domestic economy. The rate of integration for the Cambodian value chain is above 80% under both scenarios. As a chain with a rate of integration above 70% is considered to have good linkage with national economic activity, it is the case for this value chain.

	Unit	Scenario 1	Scenario 2
Total value added VC	million EUR	398.7	262.2
Total consumables imports	million EUR	64.7	34.8
Not allocated intermediate consumptions	million EUR	15.4	9.8
Value chain Output (VA + imports)	million EUR	478.8	306.8
Rate of integration	%	83.3%	85.5%

Table 3-5. Value chain rate of integration

3.2.4 CQ1.4: What is the contribution to Public Funds?

Key indicator(s)	Public funds balance
Specification this study	Taxes, license fees and customs tariffs generated by the aquaculture sector and associated inputs and services minus subsidies given to the sector
Level	Aggregate of freshwater aquaculture value chain as a whole
Data used for calculation	Government budget from Cambodian National Institute of Statistics (2015) Own survey data on licenses, taxes, subsidies Own key informant interview data on licenses, taxes, subsidies

Table 3-6 shows an overview of the contribution of the aquaculture value chain to the public funds balance. There are no subsidies in the sector, however there is some contribution from quota and licenses for licensed imports of feed and seed. At the same time, the government presently misses out on a large volume of unreported / unlicensed imports of both fish and feeds. The contribution of the aquaculture sector is 0.69% to the national budget and 42.6% to the agriculture budget under scenario 1, and 0.36% and 22.1% respectively under scenario 2.

	Unit	Scenario 1	Scenario 2
Taxes and licenses VC operators	EUR	13,778,529	6,942,449
Import quota and licenses feed (about 10 large companies)	EUR	100,000	100,000
Import quota and licenses fish (35 licensed companies)	EUR	350,000	350,000
Subsidies	EUR	0	0
Total contribution to public funds	EUR	14,228,529	7,392,449
Cambodia national budget (2015)	million EUR	2,061.1	2,061.1
MAFF in national budget	million EUR	33.4	33.4
Contribution Aquaculture VC national budget	%	0.69%	0.36%
Contribution Aquaculture VC MAFF budget	%	42.6%	22.1%

Table 3-6. Contribution to public funds

3.2.5 CQ1.5: What is the contribution of the VC to the balance of trade and balance of payments?

Key indicator(s)	Balance of trade
Specification this study	Balance of trade: value of exported aquaculture products minus imported goods and services that contributed to the freshwater aquaculture value chain and farmed fish for domestic consumption under the two scenarios. Rate of integration into the economy: total value added of freshwater aquaculture / consolidated output under the two scenarios
Level	Aggregate of freshwater aquaculture value chain as a whole
Data used for calculation	Official data on quota for imports from Fisheries Administration Own survey data Own key informant interview data

Table 3-7 shows a negative balance of trade for the Cambodian aquaculture sector of 131 million € under scenario 1 and 101 million € for scenario 2. This is unsurprising with a high level of imports (fish, feed, seed and other inputs) and very limited exports.

	Unit	Scenario 1	Scenario 2
Farmed fish imports annual value	000 EUR	66,600	66,600
Imported consumables (direct and indirect)	000 EUR	64,724	34,832
Exports of farmed fish	000 EUR	0	0
Balance of trade	000 EUR	-131,324	-101,432

TABLE 3-7. BALANCE OF TRADE

3.2.6 CQ1.6: Is the VC economically sustainable at the international level?

Key indicator(s)	Nominal Protection Coefficient Domestic Resource Cost Ratio
Specification this study	Nominal Protection Coefficient (NPC): Value of VC total production at market prices ÷ value of VC production at parity prices Domestic Resource Cost Ratio (DRC): opportunity costs of land, labour, capital / output at international reference price - the reference price for tradeable inputs.
Level	Value chain as a whole
Data used for calculation	Key informant interviews Own survey
Assumptions	Import parity price for pelleted feed = actual farm gate price of pelleted feed as all pelleted feed is imported. Import parity price for imported seed = actual farm gate price of snakehead and pangasius seed as all this seed is imported. Export parity price for farmed fish = international reference price, in this case the price of tilapia in Thailand and of pangasius and snakehead in Vietnam. Elimination of transfers

Table 3-8 shows a comparison of international reference prices and domestic farm gate prices for farmed fish. Prices for imported products are consistently lower when looking at prices paid in Cambodia, however average prices in the global market are consistently higher. This means that the nominal protection coefficient, when compared to prices of farmed fish as it enters Cambodia is therefore higher than 1, while it is below 1 when comparing to international prices. This illustrates the earlier statement that farmed fish exported to Cambodia is of inferior quality.

Products	International reference prices (EUR)		Cambodian market prices (EUR)		Nominal Protection Coefficient
Pangasius	average CIF price in CB (wholesale)	0.60 EUR/ kg	farm gate	1.10 EUR/ kg	1.8
Pangasius	international price	1.28 EUR/ kg			0.9
Snakehead	average CIF price in CB (wholesale)	1.11 EUR/ kg	farm gate	1.14 EUR/ kg	1.0
Clarias	average CIF price in CB (wholesale)	0.96 EUR/ kg	farm gate	1.06 EUR/ kg	1.1
Tilapia	average CIF price in CB (wholesale)	0.56 EUR/ kg	farm gate	1.44 EUR/ kg	2.6
Tilapia	international price (whole frozen)	1.83 EUR/ kg			0.8

TABLE 3-8. COMPARISON OF INTERNATIONAL AND DOMESTIC PRICES FOR SELECTED FARMED FISH

As imports of fish are mostly escaping taxes, the production of the value chain is not protected by the government through an import tax. Wholesalers and retailers deal with large volumes of low priced imported fish, and therefore have higher operating profits than that they would be if all their supply would be from domestic farmed fish. This shows the weak sustainability of the value chain within the international economy.

3.2.7 CQ1.7: What are the risks for growth sustainability at the various levels of the VC?

Types of risk	Indicators Cambodian aquaculture VCA	Probability	Severity
Price risk: volatility/ trends in key prices	• Commodity prices (level and volatility): Key informant interviews, and current price levels according to survey data, show the low price level of fresh farmed fish in particular. With imports making up between 40 and 60% of farmed fish available in the market, this is an important price determinant. Prices are not volatile, but have seen a slow decline. This makes fish farming no longer profitable, and we have indication that there are farmers that have ceased their activities. Other farmers have decided to delay harvesting as a strategy to cope with low prices. With the decline of production this would potentially also jeopardize businesses of downstream value chain actors, and/or increase the demand for imported farmed fish from traders and processors. • Seasonal variability of prices: Prices of farmed fish are dependent on the supply of wild capture fish. Our survey data show a difference in retail price between high and low season of 11% on average (2016). Farmers can manage price fluctuations by delaying their harvest, but this incurs extra costs for additional feed, and because of potential fish mortality> In addition farmers are unable to postpone harvesting for too long as loans need to be repaid, and in some cases water shortages will force farmers to harvest. • Costs and prices of key inputs: at farm-level the major cost is feed. At present there is no domestic production of commercial feed, and commercial (pelleted) feed prices are therefore determined by imports. Other sources of protein in home-made feeds are from processing waste, low value capture fish, and low value farmed fish (imported). The supply of low value capture fish is highly seasonal and of concern because of a risk to the long-term ecological sustainability of the fisheries.	High Medium High	High Low High
Logistical and Infrastructural risks: bottlenecks in transport, communications and utilities	• Our key informant interviews have not indicated any severe challenges related to transport. Species such as snakehead, giant snakehead, pangasius and tilapia are often transported live, requiring transport in suitable crates, but no ice or cold chain. Overall, value chain actors part in our survey report limited transport of farmed fish, apart from imported fish. • For farmers, the vast majority of transaction (90% in our sample) takes place at farm gate, and those farmers that do transport fish mostly do so over less than 10km. • Out of transactions conducted by traders 29% is conducted on the spot. These are most likely transactions at the wholesale market (landing site). For 36% of transactions fish is	Low	Low

Types of risk	Indicators Cambodian aquaculture VCA	Probability	Severity
	transported less than 20km, 24% between 20 and 100 km (on average 46 km), and 12% is transported more than 100km (on average 184 km). The overall average is 35km. The main mode of transport are cars, boats or trucks. • For processors 38% of transactions is delivered to them, 50% is transported up to 100km (on average less than 10km), and 12% is transported more than 100km (on average 191 km). • Among retailers, 73% of transactions is not transported. Those that do transport on average do so over 19km, mainly using motorbikes. • Feed and feed ingredients are in many cases delivered to farmers (36% of transactions, or are transported by farmers up to 20 km (59% on average 5 km). Only 2% of feeds or feed ingredients is transported more than 20 km by farmers themselves (42 km on average). Risks seem to be low in relation to supply of inputs with respect to infrastructure.		
Policy risks: regulatory and operational decisions by government entities	• Uncontrolled imports: there are clear issues related to uncontrolled imports of fish, feed, and other inputs. Official data on feed and fish imports and quota that have been licensed, are not easily available as they are managed by different Ministries, which makes decision making around imports difficult. Key informants have also indicated that there are high levels of illegal / unreported. We were unable to come up with an estimate of illegal feed and fish imports but key informants have given us estimates of between 10-50% of the total volume that is imported. As a result of illegal imports, data for policy planning is unavailable, and government revenues from licenses and duties is limited. This is a major risk for the economic sustainability of the aquaculture sector. • Licenses and illegal operations: snakehead and giant snakehead production was officially banned until mid-2016, yet almost half of our producer sample was farming one or both of these species. It seems enforcement of the ban was difficult. Among other value chain actors there is no consistency in terms of licenses and permits. Across the sector there are issues of enforcement. Any existing or new policies would therefore also have limited effect on the sector.	High High	High Medium
Food Safety and Phytosanitary risks: pests/ diseases or presence of	• Disease outbreaks: there is strong indication that diseases are becoming a major issue, and at present professional services to prevent, diagnose and treat disease are almost non-existent. Some input suppliers have received some training and are providing advice. Water quality has been indicated as the main cause of disease. Across our survey sample 9% of fish was removed from the pond because of disease or mortality. This was	High	High

Types of risk	Indicators Cambodian aquaculture VCA	Probability	Severity
microbiological, chemical or other contaminants	particularly high among cage farmers, with on average 16.4% of the total volume removed. • Use of chemicals: there is no enforcement of any rules and regulations with respect to the use of chemicals. With limited knowledge and technical support available overuse, and misuse of chemicals is highly likely. Some key informants also indicated that there are farmers that use products meant for human use or agriculture for aquaculture. • Hygiene practices: hygiene practices and standards at trade and processing levels are poor. In wholesale markets fish is sorted on the ground and while cleaning of markets happens, this is usually done without the use of disinfectants. • The use of fresh water capture fish as feed ingredients is likely to pose a risk for the accumulation of agricultural pesticides from the Mekong River, however there is no data available to assess the degree of this accumulation. While accumulation in fish flesh is limited, fatty and organ tissue might pose a risk for pesticide accumulation. The degree to which this poses a risk to human health depends on the parts of the fish that are consumed. Key informant interviews indicate that parts like stomachs and airbladders are indeed used for human consumption.	Unknown High Unknown	Medium High Unknown
Weather-related risks	• Number of extreme weather events per year (floods and drought): At farm level, some parts of the country are limited in the production of fish by availability of water. Some farmers and hatchery owners in Takeo province in particular, were severely hampered by drought in recent years. Some hatcheries lost their broodstock due to a lack of water. Extensive and semi-intensive farmers may use their ponds as water storage and at time of drought the production of fish will be sacrificed for rice and other crops. The degree to which this affects farmers depends on their proximity to a source of water supply (channel, river) and their ability to store water. The risk of drought is also not uneven across the country.	Medium	Medium

Table 3-9. Risk analysis matrix Cambodian aquaculture VCA

3.2.8 CQ2.1: How is income distributed through the VC levels and actors?

Key indicator(s)	Total Farm income Total Wages (all nodes)
Level	By actor type: • Semi-intensive low input pond production • Semi-intensive high input pond production • Intensive pond production • Cage production • Trader all species • Processor all species • Retailer all species and products
Data used for calculation	Own survey data
Assumptions	Opportunity costs have been included as follows: • Land: real land costs were included only, this includes annual land lease, and costs for inheritance and purchase of land, annual costs have been based on a 50 year basis. • Fish consumed at home and given away is included at market value.

Table 3-9 above show the composition of direct value added in the chain. The largest share of value added is taken by retailers. While each deals with small quantities and for each the profits are limited, there are many retailers in the market.

Figure 3.8 shows how different types of costs are disaggregated for an average value chain actor. Consumables are the major cost all actors, with the exception of the low input producers, for whom labour is the major input cost. For traders, retailers and processors a major costs component of consumables are the costs for sourcing fish from other value chain actors.

The following costs and profits distribution for each type of actors shows that in spite of a high level of costs, processing fish is very profitable compared to the other actors of the value chain (except for the traders). In addition, intensification is not always cost-effective: if we compare intensive producers to high input semi-intensive ones, their costs are only 7 times more and their profit are 17 times more. But, if we compare high input semi-intensive producers to low input ones, their costs are 39 times more and their profit only 6 times more. High input semi-intensive producers are less efficient than low input ones because of the high cost of some inputs, and the limited scale of production.

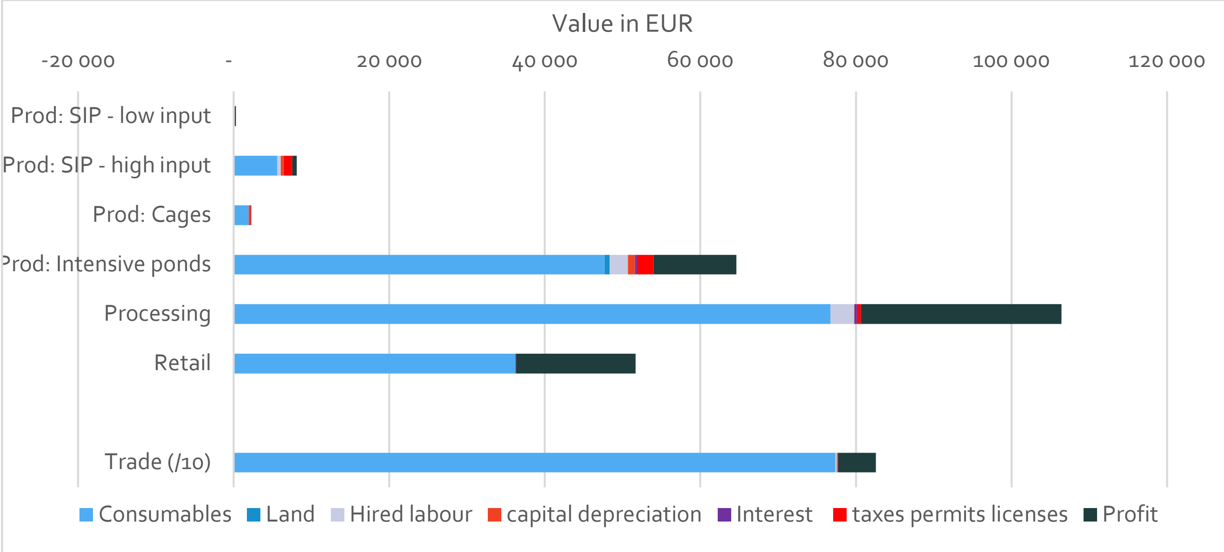


FIGURE 3.8. COSTS AND PROFITS BY ACTOR

Source: own data. Note: individual traders handle significantly larger volumes. To show traders in the same graph we have divided the values for traders by 10.

3.2.9 CQ2.2: What is the impact of the governance systems on income distribution at various levels of the VC?

As there is only one governance type in the chain, we have not developed any scenarios related to governance type.

3.2.10 CQ2.3: How is employment distributed in the VC?

Key indicator(s)	Net number of jobs
Specification this study	Number of jobs expressed in full-time equivalent
Level	By value chain actor and for the chain as a whole
Data used for calculation	Own survey data

Overall, the value chain generates 80,487 jobs under scenario 1 and 47,236 jobs under scenario 2 (Figure 3.9). The majority of these jobs are self-employment or family labour, while only a small proportion is hired labour. Almost all of the wage labour jobs are either labourers for the lifting, loading and carrying and some drivers. The majority of wage labour is year-round but some is seasonal.

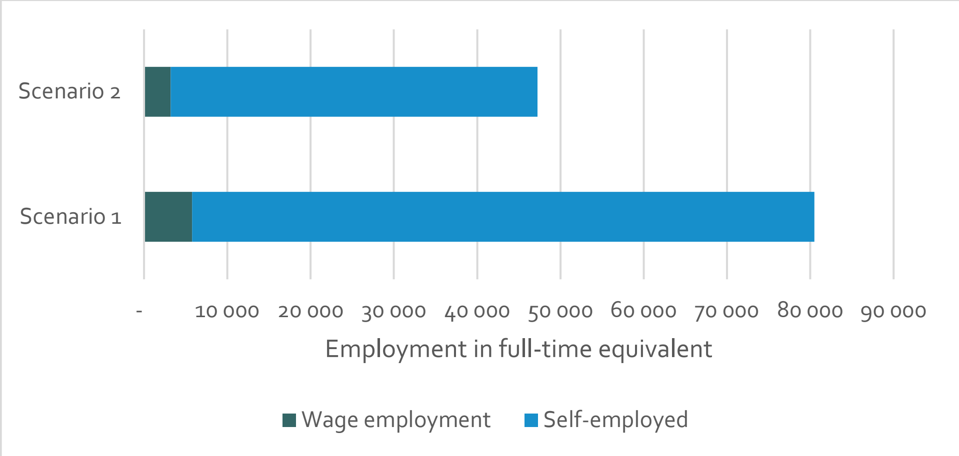


Figure 3.9. Employment in the aquaculture value chain in full-time equivalent under two scenarios by type

Figure 3.10 provides an overview of the wage and self-employment generated by the aquaculture value chain aggregated by value chain node. Self-employment generated is largest in the production node of the chain, followed by the retail node, while wage employment is highest for the production node.

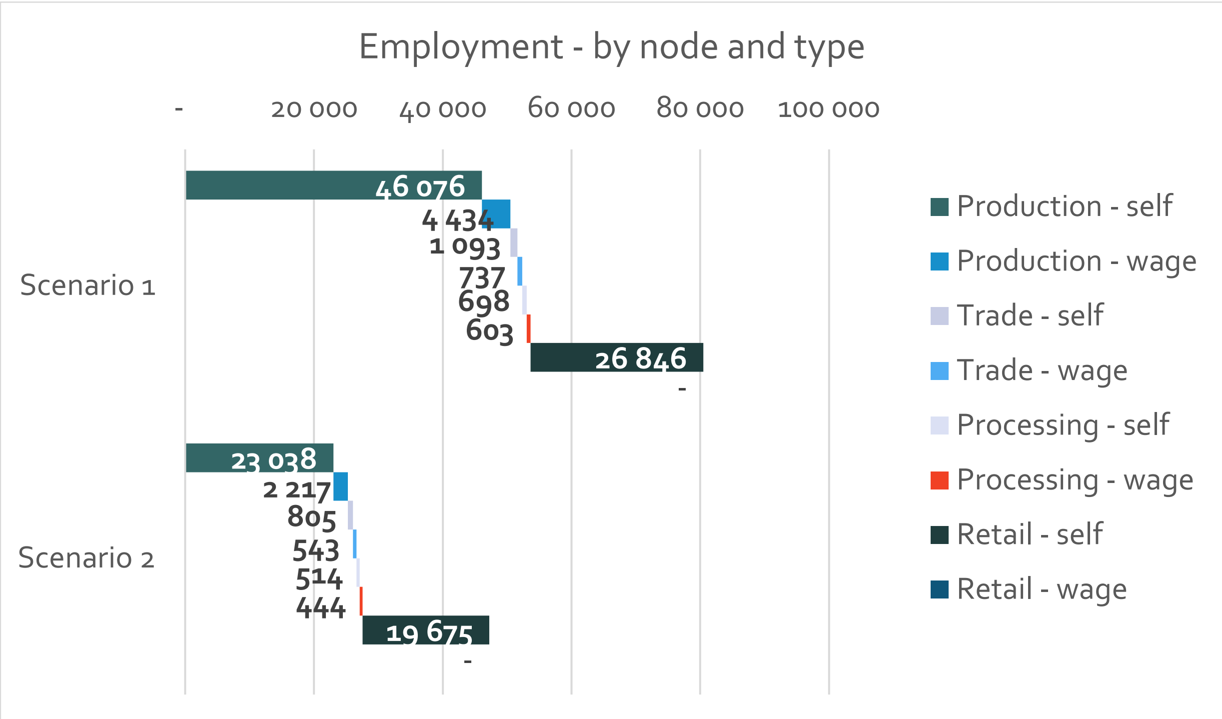


Figure 3.10. Employment in the aquaculture value chain in full-time equivalent for two scenarios by VC node

Note: this figure is not fully at scale.

Table 3-10 provides more detail by showing wage and self-employment by type of value chain actor.

		sip low input	sip high input	cage	intensive	trade	processing	retail	total jobs
Average volume	mt/actor	0.2	6.3	1.7	41.1	514.5	83.5	15.5	
Scenario 1									
Wage employment/ actor	fte/actor	0.0	0.3	0.0	1.6	1.5	2.6	0.0	
Wage employment/ unit	fte/mt	0.00	0.05	0.01	0.04	0.00	0.03	0.00	
Total wage employment	Fte	0	2281	289	1,865	737	603	0	5,773
Self-employment/ actor	fte/actor	0.6	0.9	0.8	1.3	2.2	3.0	1.8	
Self-employment/ unit	fte/mt	2.73	0.14	0.47	0.03	0.00	0.04	0.12	
Total self-employed	Fte	18,577	6,894	19,069	1,535	1,093	698	26,846	77,107
Total employment	Fte	18,577	9,176	19,358	3,400	1,830	1,300	26,846	80,487
Scenario 2									
Wage employment/ actor	fte/actor	0.0	0.3	0.0	1.6	1.5	2.6	0.0	
Wage employment/ unit	fte/mt	0.00	0.05	0.01	0.04	0.00	0.03	0.00	
Total wage employment	fte	0	1,141	144	932	543	444	0	3,203
Self-employment/ actor	fte/actor	0.6	0.9	0.9	1.3	2.2	3.0	1.8	
Self-employment/ unit	fte/mt	2.73	0.14	0.53	0.03	0.00	0.04	0.12	
Total self-employed	fte	9,288	3,447	10,732	768	805	514	19,675	45,229
Total employment	fte	9,288	4,588	9,679	1,700	1,348	957	19,675	47,236
Average wages	EUR/ day	-	4.46	1.06	5.59	3.76	3.68	-	

Table 3-10. Wage and self-employment by actor and total for two scenarios

At farm-level, hired labour at semi-intensive pond farms is limited, 0.3 hired workers on average (26% women) and 0.2 full-time equivalent. There was no hired labour found among cage farmers, while intensive pond farms employ on average 2.0 hired workers (8% women) and 1.6 full-time equivalent. Wage employment in trade is limited with 1.6 workers on average and 1.5 full-time equivalent per business. These are mostly men (only 5% women). Business owners or managers in among traders were however 70% women. In almost all cases more than 1 family member in the household also worked in the business. Employment in processing is slightly higher with 3.8 workers on average and 2.6 full-time equivalent. At this value chain level employment is more female dominated, with 66% of employees being women and 62% of business owners or managers. Retailers do not hire much wage labour. Average wages are between 3.70 and 5.60 Euro per day (not including the outlier observed for cage farming that is based on only one observation).

3.3 Conclusions of the economic analysis

Where appropriate, two scenarios have been provided, scenario 1 which uses the official aquaculture production statistics and scenario 2 which uses a more realistic production. Here we provide the summary for scenario 1, the values for scenario 2 are consistently lower. The sustainability of the Cambodian aquaculture value chain is at present relatively weak, mainly due to low profitability of farmers. Some farmer types have very small profit margins, in particular the cage farmers (profit margin of 2.8%). While profit margins among semi-intensive low input polyculture farmers is relatively high (32.9%), this includes the value of fish consumed at home and their cash income from farmed fish is limited. Among the downstream actors, profit margins are highest among retailers (29.8%).

Total direct and indirect value added of the sector has together been estimated at 398.7 million Euro contributing 2.4% to GDP, 9.2% to agricultural GDP and 41.2% to fisheries GDP. The contribution of the aquaculture value chain to the public funds balance is limited (0.69% to national budget), however to the Ministry of Agriculture budget the contribution is 42.6%. There is some contribution from taxes and quota and licenses for licensed imports of feed and seed. At the same time, the government presently misses out on a large volume of unreported / unlicensed imports of both fish and feeds.

The balance of trade taking into account farm fish imports is negative (-131 million Euro), this is due to the high level of imports of both fish and inputs, and the low level of exports of farmed fish. The rate of integration is 83% under scenario 1, above 70% which as a rule of thumb is considered a good rate of integration. Prices for imported farmed fish are consistently lower when looking at prices paid in Cambodia for the same species; however average prices in the global market are consistently higher. This means that the nominal protection coefficient, when compared to prices of farmed fish as it enters Cambodia is higher than 1, while it is below 1 when comparing to international prices. This illustrates that farmed fish exported to Cambodia is of inferior quality and a 'by-product' of the farmed fish sector of the neighbouring countries. As it is very difficult for the Government to regulate the entrance of fish to Cambodia, one recommendation would be to improve the knowledge of market segmentation in order to take the quality into account in the strategies through policy dialogue (information of consumers, quality control, targeting external markets segments for quality fish).

Among value chain actors, farmers earn the least from the aquaculture sector. The annual profit of semi-intensive low input producers are low (94 Euro) but the majority of these producers have a portfolio of livelihood activities (mainly agriculture), and fish farming provides a contribution to their food security. It is the same for extensive and rice/fish farmers that we did not take into account in the economic calculation (because they probably represent less than 5% of total harvested volumes). Net operating profits among producers are highest for the intensive monoculture producers, and highest for traders among downstream actors as these actor types deal with high volumes of product (although traders have a relatively modest profit margin). Prices for farmed fish in Cambodia have seen a downward trend and this puts long-term sustainability of the sector under pressure. Retailers earn most per unit of product.

It has been estimated that the aquaculture value chain (primary actors) generates 80,487 jobs (full-time equivalent) under scenario 1. The majority of these jobs are self-employment or family labour (93% is self-employed), while the remainder is hired labour. The majority of these jobs are at farm-level (63%). Almost all of the wage labour jobs are either labourers for the lifting, loading and carrying and some drivers, and the majority are men. Most wage labour is year-round but there is also some seasonal work.

Overall, the economic sustainability of the value chain seems under threat due to the low profits made at farm-level, resulting from competition with neighbouring countries. Costs of inputs are high as they are also partially imported, or depend on seasonal supplies (wild capture fish). Price and policy risks, as well as potential food safety risks are considered to be significant. Employment in the chain is significant but only in terms of self-employment.

4. **Social analysis**

The Social Analysis presents findings on the six major issues and the related sub-questions. The analysis draws on different sources of information. Key informant interviews and Focus Group Discussions (FGDs) during the field visits for this study, have given insights into the different practices, motivation and values of producers and processors in different types of system. These were complemented by analysis of socially relevant data gathered through the questionnaire surveys and from secondary data and available reports. The six issues and associated questions are addressed in turn. A complete list of the questions for analysis is included in Annex 5, Table
A5-4.

4.1 Are Working Conditions throughout the VC socially acceptable andsustainable?

This issue explores the social acceptability of working conditions. It covers the provisions and conditions with respect to labour rights, including the ILO international labour conventions and the ICESCR and ICCPR, freedom of association and collective bargaining, contracts, forced labour and discrimination. It considers child labour and the degree of school attendance in case children are working in any segment of the value chain, and the extent to which they may be exposed to harmful jobs. Job safety along the value chain is considered, including the degree of protection from accidents or health damage in the course of their work. Lastly, this section considers the attractiveness of jobs in the aquaculture sector, in terms of levels of remuneration and appeal to youth.

The Ministry of Labour and Vocational Training (MOLVT) is responsible for the enforcement of labour law, for improving and ensuring hygiene, health, security and good working conditions at the factories/enterprises, inspecting enterprises and following-up on labour law enforcement and provisions related to working conditions, occupational safety and health and the general social welfare of workers/employees.

4.1.1 Respect of labour rights

The 8 fundamental ILO labour conventions are 1) freedom of association 2) right to organise and collective bargaining, 3 & 4) forced labour/abolition of forced labour, 5) minimum age for work, 6) worst forms of child labour 7) equal remuneration for men and women for work of equal value 8) no discrimination on the basis of race, creed or sex. These rights are included in Cambodian labour law 1997 which also covers working hours, paid leave and special leave, child labour and children's right to education, women labour, safety and health and settlement of disputes, and sexual harassment (Kong, 2012).

Aquaculture is mainly conducted by independent small and medium enterprises, in which production is undertaken primarily using family labour. Larger operations have a number of permanent labourers, but the workforce is generally less than 8 persons. The sector draws on the informal labour market and does not provide written contracts. Hence, they operate largely outside the formal labour law. While the labour law covers in principle, the provisions of the labour conventions, the actual operation of the law and enforcement measures are less clear.

The Cambodian Code of Conduct for Responsible Fisheries, CAMCODE, (FIA 2011) developed by the Fisheries Administration is based on the Code of Conduct for Responsible Fisheries CCRF (FAO 1995). It is a set of voluntary guidelines and a checklist of good practices for all stakeholders in the fisheries sector. However, there appears to be limited awareness of the content of the CAMCODE among fisheries personnel and fisheries stakeholders.

The guidelines address key policy concerns such as poverty reduction, gender, transparency, accountability, harmonisation, working conditions, and participation in the policy process. They contain a clear statement of the importance of fisheries to vulnerable groups; '*The development, management (including allocation) and conservation of the aquatic resources of Cambodia should fully recognise the importance of those resources to the most vulnerable groups in rural society and should, where appropriate, act to support, enhance and protect the livelihoods of those people. In particular the needs of the poor, women and marginalised groups need to be specifically considered.' (para 5.2.5).*

The guidelines recognise the role of women in harvesting, aquaculture, processing, trade, purchasing preparation and provision of fish for household consumption and the importance of mainstreaming gender in all aspects of fisheries management, development conservation and use. It outlines the rights of fish workers of freedom from harassment, unfair pressure and corrupt practices and supports consultations and stakeholder participation in decisions concerning laws and polices relating to fisheries management, international lending and aid. It states the objective of maintaining the nutritional and economic value, quality and safety of fish products, and the reduction of waste and negative impacts on the environment. It acknowledges that fisheries development responds to multiple objectives which vary according to scale, and also the need for improved land tenure for aquaculture, especially among poor and vulnerable groups.

Freedom of association and collective bargaining are included in the Cambodian Labour law of 1997, but there have been some recent changes. A new trade union law approved in April 2016 has made changes to how unions are formed, operated and dissolved. This primarily affects workers in garment and footwear industries which are the main sectors unionised. The new law has been the subject of discussion with some questioning its compliance with ILO Convention 87 on freedom of association and protection of the right to organize, and ILO Convention 98 on the right to organize and collective bargaining.

With respect to contracting, the aquaculture value chain is not characterised by formal contracting of labourers, who are often recruited through personal networks rather than the formal labour market. Arrangements are based on verbal agreements with their employers. Hence there are no enforceable contracts.

There was no evidence of forced labour in the aquaculture value chain. Pressure on workers to increase overtime has been identified in the garment industry.

Since the value chain is not characterised by formal employment, employment of hired labour is likely to follow local norms and social networks. These may obscure certain types of discrimination against specific categories of people. In case of expansion in larger-scale higher capital intensive commercial production, employment opportunities are likely to favour men.

4.1.2 Child Labour

Cambodia has ratified the UN Convention, on the Rights of the Child, the ILO minimum age convention and convention of the worst forms of child labour. There are a number of policy documents and Ministerial proclamations which reinforce the need to reduce child labour, particularly its worst forms[2] and specify responsibilities of employers of young people. The Cambodian National Council for Children and its subcommittee on child labour is the main coordinating institution.

The minimum age for employment is 15. Children are permitted to engage in light work provided it is not hazardous and they are also attending school. However, there is no compulsory educational requirement so children under 15 who drop out of school are particularly vulnerable in the labour market. The majority of children work in the informal sector, within the household or in family businesses. There are no child protection laws covering these contexts.

'*The Guidelines on addressing child labor in the fisheries sector in Cambodia*' (FIA 2016) are intended to provide guidance for the elimination of child labour in fisheries sector and aquaculture in Cambodia, improve understanding of the scope and factors leading to child labour in fisheries and identify the definition and division of child labour and good practices and priority actions. They emphasise the need for monitoring and data collection on the issue.

FIA has developed an Action Plan for gender equality promotion and child labour elimination in the fisheries sector 2016-2020 (FIA 2015). This includes awareness raising among line agencies and organisations involved in fisheries, strengthening the capacity of national fisheries staff assisted by development partners, mainstreaming child labour issues and providing training and support for risk assessments. It further notes the importance of enhancing access to education by developing educational facilities in fishing communities and improving livelihoods to reduce poverty. The plan requires resource allocation for its implementation.

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[2] e.g. Policy and strategic framework on Childhood Development and Protection in the Agriculture sector 2016-2020. Dec 2015. Prakas on Procedure for recruitment of young workers/employees at enterprises/ establishments. MLVT 2015.

School attendance data from the Cambodia Demographic and Health Survey 2014 show rates of net attendance at primary level (6-12 years), of 81% for boys and 83% for girls. Gross attendance rates are higher as they include children attending school irrespective of their age, as a proportion of the relevant age group, whereas the net attendance rate is the percentage of children attending *from the age group* corresponding to the same level. Of the provinces visited for field work in the course of this study, the rates are highest for Battambang and Takeo for both boys and girls.

Age	Male		Female	
	Net attendance rate	**Gross attendance rate**	**Net attendance rate**	**Gross attendance**
6-12	81.4%	95.7%	83.4%	94.5%
13-18	42.4%	52.6%	44.3%	54.2%

Table 4-1. School attendance by sex Source: Demographic and Health Survey, 2014.

Net attendance at secondary level (ages 13 to 18) is 42% for boys and 44% for girls. Of the provinces visited for this study, the rates were highest in Takeo for girls and boys (58% and 67%) and lowest in Pursat (24% and 34%).

Focus group discussions reflected the figures for primary education with all reporting that both boys and girls attend primary school from the ages of 6 to 12. However, the majority of children in these locations finish school at grade 9 when they are 15-16 years old. Some do continue until grade 12 and a few go on to university or go to work for the government. The drop out at high school level is higher in locations more distant from secondary schools where the cost required for transport, books, clothes and food becomes difficult for poorer families to find. Girls' continuing education may be particularly restricted by parents' unwillingness to let them travel unaccompanied. There was no indication from the focus groups that children's education was limited by a requirement for them to work.

Concerning children's exposure to harmful jobs, the law prevents children under 18 from being employed to do hazardous work, however as noted, it does not cover hazardous work in family businesses which constitute a high proportion of aquaculture businesses. Hazardous work includes work with dangerous machinery, equipment or tools, or handling of heavy loads; work in an unhealthy environment or with hazardous substances, work in difficult conditions such as long hours, night work, physical, psychological or sexual abuse, work underground, at dangerous heights or in confined spaces. Children from 12- 15 years can undertake light work such as feeding fish, taking care and cleaning the pond, cage or pen with proper skill training, controlling water, taking notes, washing dirty clothes, processing, packaging, prepare material and gears for fishing, and holding carrying and transporting light materials for carrying fish. These activities should only be in free time or at the weekend. Children 15-17 years should work no more than 48 hours per week. There should be no use of chemical substances.

The producer survey showed that children in 23% of producer households made some contribution to aquaculture work, working for an average of about 1 hour per day. Participants in focus group discussions described the work undertaken by children – helping with digging channels, feeding fish, finding firewood to cook the fish feed, help in sorting fish for feeding. Children also assist in fish processing at home, and some work together in family groups during the dai fishery season, removing fish heads and tails. The main risks to children in aquaculture are from activities around pond preparation – digging and particularly the liming of ponds. Other chemicals used in small scale aquaculture such as water treatments, enzymes, 'medicines' and urea are applied by the pond owner. Larger aquaculture enterprises employ labour and say they do not involve children.

Communities combining fishing and aquaculture may constitute more of a risk as fishing is one of the priority sectors for elimination of the worst forms of child labour. The communities visited which combine aquaculture and fishing said that they do not allow children to go fishing. After school they help in housework and sometimes help carry feed to the fish in cages.

4.1.3 Job safety

The degree of protection from accidents and risks of health damage in aquaculture value chains was explored with producers and processors. Most aquaculture activities are family based, or run by an individual entrepreneur. They are not subject to any legal framework regulating health and safety. All producers met were asked about health and safety issues. Few health issues were reported. In some locations the ponds attract mosquitoes, but solar lights suspended over the ponds are used to attract them and provide additional fish food. Some producers reported having minor accidents, bruises, cuts and grazes, for example when hammering in poles. Most do not use protective clothing, but some people wear boots, especially at night when there are snakes about.

The edges of ponds are often netted to prevent accidents. Children are taught to swim, and it is recognized that "*when you have ponds you have to take care of the children*" (FDG Sout Nikom, Siem Riep, extensive).

In terms of hygiene, at the processing facilities visited in Battambang and Phnom Penh there was a lack of general cleanliness in the work space, particularly regarding the handling of fish waste and waste water. The processors' survey of 29 facilities found that 76% had toilet facilities, 80% washing facilities (625 with running water). All but one provided soap for washing. 76% provided gloves, but only 24% protective clothing, 3% boots or shoes and none provided hats.

4.1.4 Job attractiveness

Levels of remuneration in aquaculture and their relation to local standards are among the determinants of its attractiveness for employment. Of the aquaculture producers included in the survey, only 16% hired labour. The average remuneration per worker was between 150 to 200 USD per month. In some cases accommodation, food and medical care were also provided. Aquaculture thus provides a comparatively good wage; the minimum monthly wage in the textile and footwear industry is 153 USD per month. However, working hours in aquaculture production and trading enterprises are unregulated (although interviews suggest working hours allow for periods of leisure time) and provision of holidays and other worker benefits are at the employer's discretion.

To explore whether conditions of work are attractive for youth, focus group discussions were asked whether youth were interested in aquaculture and whether it constituted a future opportunity:

> *"Youth prefer 'smart jobs' e.g. city work, factory work, which is 'smooth and smart'. This is the case for both boys and girls. Some work in Phnom Penh and garment factories. A few have gone to South Korea and Thailand" (FGD, Tramkak, Takeo SI)*
>
> *"Young people generally don't want to leave the village to find work but there is no option. In the whole commune there are about 20 people in Thailand. Most stay with their families. Parents [must be] willing for them to go" (village head, Krakor district, Pursat)*
>
> *"They try to focus on study. They see difficulties in fish. Some youth have gone to Thailand, and one to Korea". (FGD Prasat Bakong, Siem Reap, Cage)*

Aquaculture can be an attractive proposition for young people if they have access to capital and are supported by their parents. Several businesses visited combining fish feed supply and growing fish and in one case, a hatchery, were run by young men with family support.

4.2 Are land and water rights socially acceptable and sustainable?

4.2.1 Adherence to VGGT

This topic examined whether companies/institutions involved in the value chain declare adherence to the Voluntary Guidelines on the responsible Governance of Tenure (VGGT). The available information on Cambodia and tenure issues makes no reference to the VGGT as such. The implications of land tenure for aquaculture, particularly smallholder aquaculture, are significant as access to land is essential for pond aquaculture, rice fish farming and for current cage aquaculture producers who are interested in acquiring ponds and scaling up. Rights of private land ownership were established in 1985 and reinforced by further decrees in 1989 and 1992 (Hel, 2012). After 1993, the Kingdom of Cambodia recognised the right of private ownership of Khmer citizens, with further legislation in 2001 and 2007[3]. Under the 1989 land distribution, male headed and women-headed households received titles, but since the area was based on household size, the latter generally received less land. Currently average land ownership is 1.3 ha per household and many households have little more than the plot on which their house is constructed. In the lowland areas of Cambodia, land pressure is more intense, particularly for younger households who have inherited small amounts of land from their parents holding allocated in 1989. Only around 10% of the 1989 titles are registered, because of high costs

[3] There is private land, state public land (includes forests, courses of navigable or floatable water, natural lakes, banks of navigable and floatable rivers and seashores), state private land, collective land (monasteries) and land belonging to indigenous peoples.

and bureaucracy, creating a distinction between possession and property rights which are socially recognised and approved by the Commune head and private ownership acquired through the cadastral procedure (Diepart 2015).

VGGT principles for responsible investment include 'doing no harm', safeguarding against dispossession of legitimate tenure right holders and causing no environmental damage. Investments should be made working in partnership with relevant levels of government and local holders of tenure rights to land, fisheries and forests. They should contribute to policy objectives of poverty eradication, food security and sustainable use of land, fisheries and forests. There should be transparent rules on the scale, scope and nature of allowable transactions in tenure rights with safeguards to protect from risks. Expropriation should be only where rights are required for a public purpose, which should be clearly defined. Rights of all legitimate tenure right holders, especially vulnerable and marginalized groups, should be respected by acquiring the minimum resources necessary and promptly providing just compensation in accordance with national law.

A number of sources suggest that while Cambodian land law reflects these principles, the process of granting economic land concessions to investors has not necessarily followed them (USAID 2011; Diepart, 2015);. Cambodian Law on Economic Land Concessions (ELCs) (2005) establishes the legal and regulatory framework for the grant and management of concessions of land for large-scale, market-oriented development. Close to one million hectares of land in rural Cambodia (approximately 7% of all land outside of protected areas) have been granted to private companies as economic land concessions for the development of agro-industrial plantations, such as rubber. The law requires the land to be registered as state private land; there should be public consultations and environmental and social impact assessments. State public land can be reclassified as State private land[4] under certain conditions. There has been an expansion in such re-classifications, including in areas occupied or utilized by local or indigenous communities, most of whom do not possess land titles, and in some protected areas (CCHR, 2013). Noting additional drivers of change - large scale logging and deforestation, expansion of irrigation and climate change - Un *et al* (2015) conclude that mechanisms for ensuring farmers' secure land ownership are not in place and that landlessness, land scarcity and land ownership rights are challenging issues among rural communities. In 2012 a moratorium was place on ELCs, however, a number of ELC contracts were signed after May 2012 on the grounds that permission for this had been given prior to the moratorium).

Social Land Concessions (SLCs) which the government has promoted to address the problem of landlessness and near landlessness can be initiated through commune councils or relevant ministries. However, these cover less than 4 percent of the total area granted as ELCs.

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[4] State land with a public interest is called "state public land". In contrast, "state private land", defined simply as all state land that is not state public land, can be legally privatized.

In terms of rights to water, the lack of local institutions to regulate the use of and access to water resources has been identified as a factor which increases the vulnerability of the most resource-poor households (Joffre and de Silva 2015). Governance and collective action are important in order for benefits to reach resource-poor and vulnerable households that are dependent on common-pool resources such as fisheries and water for drinking. Access to water is becoming more complex with the emergence of water markets with private sector and community-based stakeholders supplying water.

A further question explored was whether in cases where large scale investments for land acquisition are at stake, the involved companies/institutions apply the 'Guide to due diligence of agribusiness projects that affect land and property rights'. The Guide to Due Diligence requires contactors to ensure that legitimate tenure rights of individuals and communities, including where applicable those with customary tenure systems, should be recognised, respect and protected (article 8.2). Projects should have a published feasibility study and an environmental and social impact assessment. Consultation with local people and communities should take place without manipulation, interference, coercion or intimidation and those potentially affected should have access to prior information before a decision is made. It appears from experience with land concessions that these provisions are not consistently applied.

4.2.2 Transparency, participation and consultation

Levels of prior disclosure of project related information to local stakeholders, participation and consultation of all individuals and groups in the decision-making process are highly variable, depending on local relationships. Prior consent is not an obvious criterion in any of the laws or guidelines.

Some examples from the communities visited, which are not controversial, are probably a good indication of how the introduction of new enterprises works. In the case of small and medium scale enterprises such as a rice mill, livestock fattening and chicken farms, the investor bought land from families in the village and the decisions were witnessed and approved by the commune council. In the case of the rice mill, the families selling were said to benefit from the high price offered which allowed them to purchase land elsewhere. Often available land is identified for investors by a middleman. In some cases, the village head calls a meeting and it might be discussed in the commune council monthly meeting which is open for people to attend. However, not all decisions are discussed in meetings. The environmental impacts of enterprises are difficult for smallholders to deal with. An example was given of a pig farm established five years ago in one of the villages in Siem Riep. The proposed investment was not discussed originally. In the last 2 years they have been experiencing problems from the pig farm – liquid waste is running into their paddy fields and affecting the rice. They have not complained to the commune council because it seems the owners have local connections. *"This is a kind of understanding – those people have some relatives here*" They try to be patient and deal with it informally, rather than through official complaint. They thought that for an external investor going through the province administration, there would be some control, probably at district or commune level.

A second example concerned river pollution from garment factory effluent whcih affected cage aquaculture producers. They moved their cages temporarily to a location where the water was cleaner. They informed the fisheries officers and the commune. "*The factory owners know [the problem] but they still continue. If occurs some months in the year, not year round, particularly during March to May when water currents are stable*". (FGD, Phnom Penh, cages)

Thirdly, a large intensive pond owner described a problem of waste oil from a nearby garage polluting his pond during heavy rain. He did not inform the owner, but changed the water in his pond. It was a state garage. Others also had problems, but it was temporary.

These examples show the general orientation of producers to try and influence the situation informally, hoping that the problem passes.

There is a limited <u>level of accessibility of intervention policies, laws, procedures and decisions to all stakeholders of the value chain</u>. The legal issues around land tenure are not widely understood by producers or processors in the value chain. Fisheries Administration staff make efforts to communicate fisheries policy to communities engaged in fisheries so there is a reasonable level of understanding and awareness, for example, around the ban on snakehead production and its recent lifting.

4.2.3 Equity, compensation and justice

The questions on this topic explored the extent to which <u>locally applied rules promote secure and equitable tenure rights or access to land and water,</u> and whether, in cases <u>where disruption of livelihoods and expropriation occurs, alternative strategies have been considered and a system is in place for fair and prompt compensation</u> (in accordance with the national law and publicly acknowledged as being fair).

The situation regarding land access and land tenure is important for smallholder aquaculture producers, as their limited access to land limits their capacity to expand and diversify their production. Smallholder landholdings are very small compared to the large land areas given in the ELCs. The majority of aquaculture pond producers met in focus group discussion owned a hectare of land or less. For older people, this was land distributed in the 1980s and for younger people, land was inherited on marriage. Some had bought additional land. Nationally, 80% of households own less than 1 ha (CSES, 2014).

One commune visited, in Battambang Province, people said that previously they had 'soft' land titles, but now their whole commune has had a cadastral survey. In other communes, people had locally recognised land rights only. There was no suggestion that they felt vulnerable as a result, but neither had their land rights been challenged. Several groups reported that some people in their communes had sold land and work as local or migrant wage labourers. The main reasons for selling were to afford health treatment, or in case of divorce. This is consistent with other studies which found 75 percent of all land sale transactions were motivated by factors that were non-productive (health reasons, basic household expenditure and debt payment) (Diepart, 2015).

In the case of floating villages or more recent settlements around the lake, people do not own land, but they can use common land between their houses. The 1980s distribution was only for mainland households. Some purchase land if they have money. Access to living space for floating houses (many with fish cages underneath) is in principle, open and without registration, although some people protect their space.

Cambodian labour law requires compensation to be paid in case of expropriation. In additional, the CAMCODE is specific about the need to provide appropriate alternative livelihoods in case these are disrupted by changes in laws or policies. "Where changes in laws or policies affecting fisheries may lead to diminished access for the poor and vulnerable and for family or small-scale fishers, these should not be introduced without adequate provision for alternative livelihoods.'

However, it is not clear that alternative strategies have been considered, developed or promoted. CEDAW monitoring group have concerns that women are subjected to displacement and eviction owing to large scale land concessions and urban development. Relocation sites are lacking in infrastructure and services.

As far as provisions to address stakeholder complaints and for arbitration of possible conflicts caused by value chain investments, there are five conflict resolution mechanisms in existence in Cambodia: the Commune Councils, the Administrative Committees, the Cadastral Commission, the National Authority for Land Conflict Resolution, and the judiciary. There does not appear to be an independent dispute resolution mechanism and access to remedy (CCHR 2013).

4.3 Is gender and social inclusion throughout the VC acknowledged, accepted and enhanced?

Gender equality refers to the equal rights, responsibilities and opportunities of women and men and girls and boys. The policy context in Cambodia is generally supportive of gender equality, women's economic empowerment and tackling gender based violence. Cambodia is party to the Convention of Elimination of all forms of Discrimination Against Women (CEDAW) ratified in 1992, and the Universal Declaration of Human Rights. The principles were incorporated in the three successive phases of the Rectangular Strategy for Growth Employment, Equity and Efficiency and the National Strategic Development plans, the latest 2013-2018. Strategic plans for Gender equity and Women's Empowerment have been produced every 5 years since 1999, the latest, Neary Rattanak IV 2014-2018, proposes a programmatic approach for economic growth and women's economic empowerment, access to social services and protection, women in public decision-making and politics, policies and programmes; climate change, greengrowth and disaster management, Institutional strengthening and capacity development (Ministry of Women's Affairs, 2014a). A Policy and Strategy on Gender Mainstreaming was developed for the Ministry of Agriculture Food and Fisheries (MAFF) in 2006. Institutional commitments to gender equality have been strengthened through the operation of Technical Working Groups on Gender across and within line ministries and sub-working groups on Women's Economic Empowerment and Gender based violence.

Factors limiting women's ability to engage in and benefit from fisheries and aquaculture relate to the lack of recognition of and low value attached to work done by women, limited access to essential resources, ponds, new technologies, education, information and skills and limited influence on decision making beyond the household. These three dimensions of recognition, representation and redistribution (Fraser, 2008) are useful for examining the position of women in Cambodia and within fisheries and aquaculture value chains specifically. With a strong emphasis on family based enterprises in rural Cambodia, the specific roles and needs of women are at risk of being side-lined if supportive interventions are directed to men (World Bank, 2009). Representation of women on national and local decision making bodies is important to influence fisheries and aquaculture development priorities and approaches. Value chain participation is dependent on assets, particularly in getting started; not only financial and physical assets, but social connections and human capital. The redistributional aspect concerns how resources are made accessible to women as well as men – for example, land, education, technical skills, and finance.

The National Action Plan 2015-2020 for Gender Mainstreaming and Elimination of the Worst Forms of Child Labour in the Fisheries Sector (FiA 2007) addresses some of these concerns, aiming to increase gender awareness of FIA staff at all levels; integrate gender analysis, include sex disaggregated targets and data; increase the number of women that have sufficient qualifications for management position and advance their careers in FIA; increase the ability of rural women to access, manage and benefit from fisheries resources and services; and improve communication linkages between relevant departments and other stakeholders (FiA, 2007). A training module was developed and initial gender training was implemented, but dedicated funds to repeat the training were lacking. Front line fisheries staff met on field visits were aware of the strategy, but had not received any training. The Gender working group of FiA with a representative from each division is responsible for facilitating and monitoring the implementation of the plan. More recently an updated plan for 2016-2020 has been produced, which also addresses child labour issues. Effective implementation of the plan requires:

- Funding to be allocated for budgeted actions associated with each objective
- Support for effective training and monitoring and reporting at provincial levels.
- Technical advice and capacity building for women in fisheries value chains
- Better understanding of women's productive role in fisheries and small-scale aquaculture, (particularly pond production and fingerling production) and the value of women's time.
- Dissemination of information and advice on child labour issues in fisheries and aquaculture.

4.3.1 Economic activities

In terms of participation, women are not excluded from segments of aquaculture value chain. However, poverty is a factor. Focus groups mentioned that some households were deterred from participating in aquaculture by shortage of land, labour and capital to invest. This is particularly the case for women headed households. The preference of poorer rural households was to concentrate on rice production and other income sources such as wage labour; *"small households don't engage with aquaculture, they prioritise rice". (*Tramkak, Takeo SI).

They are also involved in Community Fisheries, depending on location. The field visits conducted in this study did not identify widespread interest in growing other aquatic species, such as frogs. Examples of successful freshwater prawn cultivation encountered were capital intensive.

Costs of production in aquaculture are analysed in the Economic Analysis section of this report. It is likely that the start-up costs required for aquaculture are difficult for low income groups to achieve. However, initiatives such as the development of rice-fish farming and local seed producer networks growing high quality fingerlings, were reported to have made a difference to participating households who received some assistance in the establishment and stocking of their ponds.

An important factor in these semi intensive systems is the flexibility for households to provide homemade feed from their own agricultural resources to complement or replace the purchase of pelleted feeds. The seasonal calendar shown in the nutrition section indicates that for pond producers, the early phases of growth which benefit from pelleted feed, coincide with the period of greatest economic pressure. Cage aquaculture is also practiced at varying degrees of intensity, from small producers relying on their own waste from processing or capture fish to those with high levels of purchased pelleted feeds. Intensive ponds and cages are associated with better-off households and multiple-enterprise households. Rice-fish systems are flexible in terms of capital requirements for feed purchases, "*you can still get a good yield of fish from the rice fish system even if you don't give feed. In ponds we give more feed; we can get more fish, but it needs more money*" (FGD, Bakan District, Pursat. R/F & SI).

Fish processing and trading have high proportion of women participants. For these activities access to capital is insufficient; social networks based on personal knowledge and trust, established over years are necessary to secure stable demand and regular supply (Kusakabe, 2016). Challenges of small scale fish trading include lack of capital, risk of spoilage, and vulnerability to fee collection when transporting fish (Kusakabe 2008).

Cambodian women have a relatively high rate of participation in the workforce (77.5%) with the highest participation in the 25-34 age group (85%). These participation rates have changed little since 2004 (CSES 2014). Women are more likely to be working on their own account/self-employed (54%) compared to men (45%) and fewer are paid employees. In rural areas 50% of women and 45% of men were 'skilled agricultural, forestry and fishery workers'. This is reflected in the level to which women are active in aquaculture value chains. Women are active in aquaculture value chains as producers, managers, processors, traders and retailers. Women run their own aquaculture operations and are also involved as part of a family based activity. Women are involved in cage production, often in semi mobile floating villages as well as pond aquaculture within agricultural communities. They also undertake small-scale capture fisheries, collection of aquatic plants and animals. Women are particularly active in the post-harvest sector. (MAFF CBNRM 2008.) They run processing businesses and are employed as workers in processing businesses.

The 2014 socio-economic survey estimated that 2% of households were involved with aquaculture, but this figure was not disaggregated by gender of household head. The Agricultural Census 2013[5] found that 51% of household members working in aquaculture were female and 49% male. However, more males than females were working full time (62% of full time workers) and more females than males were working part time (71% of part time workers) in all age groups. This is consistent with the multiple roles of women in both productive and reproductive spheres. Hired labour in aquaculture was 63% male and 37% female. Around half the workers were full time. Working hours were 21 hours per week or less for 87% of men and 78% of women.

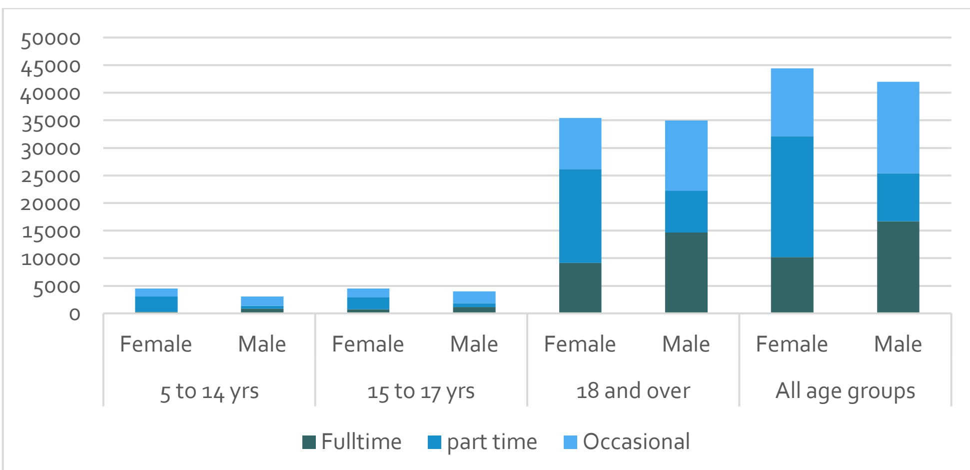

FIGURE 4.1. GENDER, AGE GROUP AND INVOLVEMENT IN AQUACULTURE

Source: Agricultural Census, 2013.

The Questionnaire Survey (2017) of aquaculture producers found similar results to the census - overall 54% of household members working in aquaculture were male and 46% female; 78% of adult men and 60% of women. Of children aged between 6 and 18 years old, 15% of girls and 14% of boys were contributing to aquaculture production.

5 The Agricultural Census supplementary module covered households with agricultural holdings and hence excluded landless cage aquaculture producers.

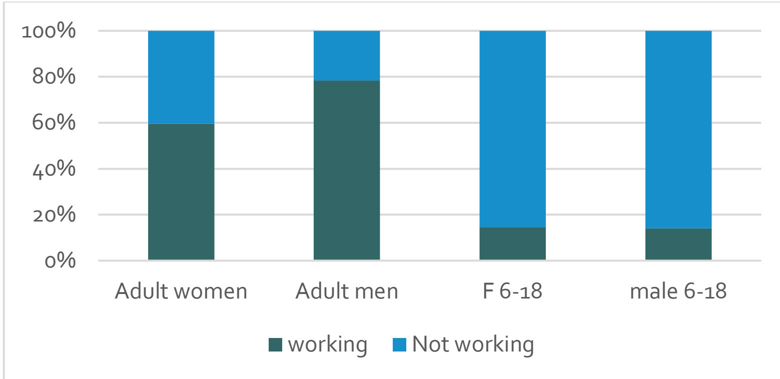

FIGURE 4.2. HOUSEHOLD MEMBERS WORKING IN AQUACULTURE PRODUCTION

Source: Value Chain Questionnaire Survey, 2017.

The survey found women producers in all categories of aquaculture, although far fewer in intensive pond production. An important distinction between male and female producers is the scale of operations, reflected in the amounts sold. Women's operations are generally producing smaller volumes of fish and the proportions of fish consumed and given away are correspondingly smaller than among male producers.

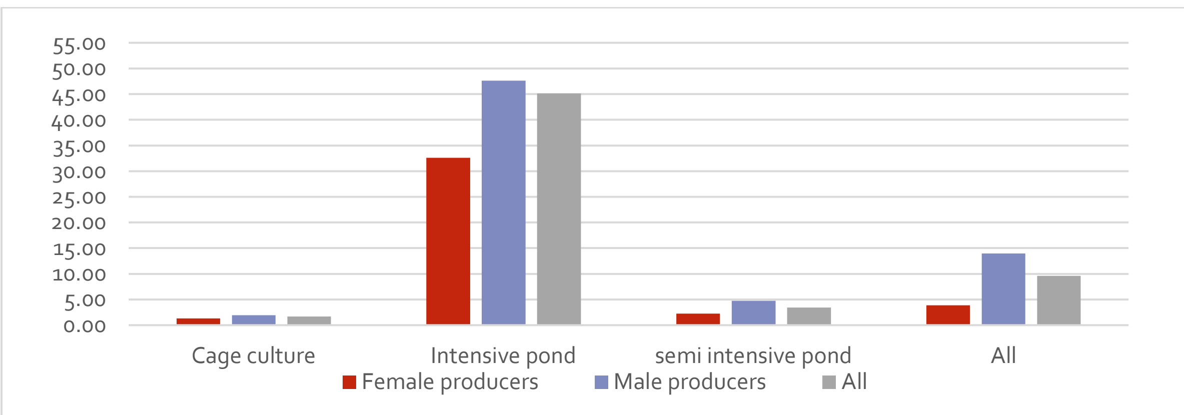

FIGURE 4.3. AVERAGE SALES ('000 KG) BY AQUACULTURE TYPE AND GENDER

Source: Value Chain Questionnaire Survey, 2017.

The majority of production was undertaken based on household labour without employing workers. Only 25 (15%) of producers employed labour, and of these, 6 were women producers, 5 with semi intensive and one with an intensive pond. It appears unusual to hire labour for cage production. The majority of men producers hiring labour were intensive pond producers, employing 2 to 3 labourers. Only 14% of the hired labourers were women. Expansion of commercial aquaculture production would tend to favour permanent male labour. Aquaculture production is not a generator of employment as such, particularly not for women. Women are more commonly employed in fish processing and trading. In most processing enterprises, the processing work - cleaning fish, drying, fish paste etc. is mainly done by women, and the loading and unloading and transport work done mainly by men. Among the 29 processors interviewed for the Value Chain study (16 male and 13 female processors), 18 were employing labour, with twice as many women employed as men. Women intermediaries and traders appear to employ labour less frequently compared to men.

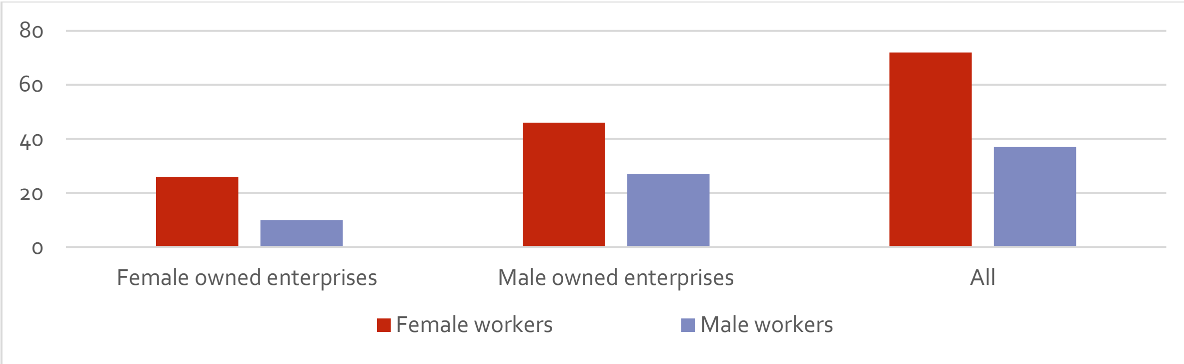

FIGURE 4.4. GENDER AND EMPLOYMENT IN PROCESSING ENTERPRISES.
Source: Value Chain Questionnaire Survey, 2017.

4.3.2 Access to resources and services

A particular focus was on whether women have ownership of land, and assets other than land and whether their land rights were equal to those of men. Non-land assets can be joint or separate property. Household assets are generally considered joint assets, particularly as when new households are established on marriage, both the bride and groom's side will contribute to the asset pool. Focus groups in Takeo highlighted the importance of transparency in this arrangement. Social norms require equal contribution by families of the bride and groom.

> *"There is equal spend on the male and female sides at weddings. They share house building costs 50/50. If the woman's side already provides a house, it's taken into account in lieu of cash. The property is split equally if there is a divorce." (FGD, Tramkak, Takeo R/F & extensive)*

Decisions on joint property require agreement of both spouses. Civil code 2007 article 2, provides women and men equal inheritance rights. Women can inherit land, rice fields, houses and other property. About 12% of land is owned by women headed households, 80% of whom own less than 1ha (CSES 2014). Although men and women have equal rights to land, actual practices are influenced by several factors, including limited awareness of rights among women and poor access to legal advice in case of disputes. A key provision is the registration of land title in 'undivided' ownership between husband and wife. Women have equal rights in contracts and administration of property, equal treatment in land and agrarian reform resettlement and housing and the same rights in marriage as their spouse with respect to ownership, management, enjoyment and disposal of property including on divorce. However, because of lower levels of awareness among women, their vulnerability to pressure for land sale may be greater, for example, for payment of debts, or for commercial agricultural investments and housing development.

> *"voice and choice cannot be exercised if there is no awareness of issues and rights, thus awareness and communication are key to gender equitable land governance." (*Daley and Mi-young Park, 2011:20*)*

There are also reports of loose implementation of the law on signatures to undivided property ownership ((Hel, 2012).

Women's access to credit and other services was explored in the questionnaire survey and in focus group discussions. Figure 4.5 shows that 43% of women producers, 60% of the women processors and 38% of women intermediaries interviewed in the Questionnaire Survey reported taking a loan. A higher proportion of women processors and intermediaries, took loans than the men. 84% of loans taken by women were bank loans, 14% from money lenders and 2% from other sources such as village credit organisations. Sources of credit for men were banks (74%), money lender 15%, trader 5% and 6% 'other'.

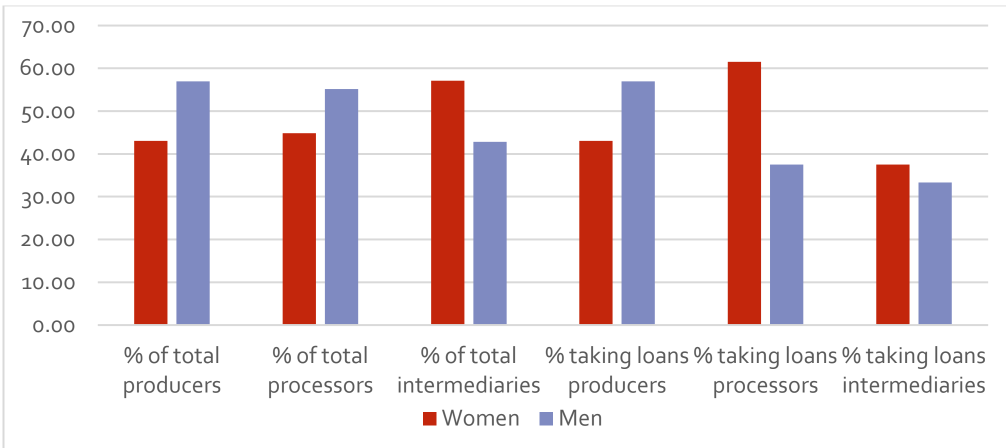

FIGURE 4.5. GENDER AND ACCESS TO CREDIT
Source: Value Chain Questionnaire Survey, 2017.

Initiatives to support aquaculture development have varied in the emphasis given to targeting and promoting the participation of women. Efforts to develop market-oriented smallholder pond aquaculture, the promotion of rice fish systems, and seed producer networks have in principle sought to involve women producers, particularly where they have been part of a funded programme. In focus group discussions in Takeo and Battambang provinces, both women and men in pond aquaculture indicated they had advice and training from Fisheries Administration personnel, and from their local seed producer. Several also highlighted the media (radio and TV) as sources of information. Access to services and inputs is harder for cage producers who frequently rely on each other for information and advice. They also had limited access to input providers, partly as a result of their location (Pursat and Siem Reap).

4.3.3 Decision making

Different members within households, men, women and young unmarried adults, often specialise in different activities such as running a shop, pond or cage aquaculture, rice farming, making food products for sale, mechanic, wage labour etc., but each are considered to contribute to the overall household income and livelihood. There is considerable family collaboration and reciprocal help in aquaculture activities.

Specific questions under this topic covered the extent to which women take part in the decisions related to production; how far they are autonomous in organisation of their work and crucially, whether they have control over income and can earn independent income.

Women with their own aquaculture ponds and cages are the main decision makers concerning their production. Men and women generally describe their practice as joint decision making, for agriculture (crops and livestock) and aquaculture. For decisions on market trading, women are more influential (CSES, 2104).

Women have varying degrees of autonomy in organisation of their work depending on the level of specialisation. Where women are active in aquaculture in their own right, they organise their own work, however, they are influenced by gender norms and family circumstances.

Regarding income, the common practice is for pooling of household income under the management of the woman. Women generally control the household money and take care of the financial management. Other studies have reported that women are acknowledged as more competent in financial management (MAFF and CBNMR 2008). This was consistently reported in the focus group discussions of rice fish and semi intensive and cage producers in different regions of the country. Arrangements may be more variable among larger scale intensive producers, processors and traders. In some cases men and women work together in their aquaculture business, sharing tasks and responsibilities.

Because of their role as managers and holders of the family purse, women were said to have considerable control over family income and their own contribution to this. Money from enterprises managed by unmarried young adults in the household is also given to the mother to manage. One study found that 47% of married women earned their own cash incomes and were involved in decisions on income use even if it was not earned by them (CSES, 2104). However, managing household finances does not necessarily mean that women are independent decision makers on expenditure. They manage the daily living expenses (93% reported this – CSES 2014), but major decisions on expenditure are discussed and negotiated among family members, and final decisions are by consensus. If they borrow money the decision must be agreed by husband and wife and witnessed by 3-5 people[6].

Because women mainly hold the money, they have a considerable degree of influence. Women's perspective was that their control was important to secure household needs:

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[6] Focus groups in Tramkak Takeo R/F and SI, Prasat Bakong Siem Reap, cage, Sout Nikom, Siem Reap extensive, Russey Keo, Phnom Penh, cage.

"There's no way men hold the money, because women are responsible for everything at home. Men spend money the wrong way". (FGD, Krakor, Pursat, cage)

"Sometimes I have to ask my husband to give me the money so I can manage it, because I have to spend for food and for the children". (FGD, Sout Nikom Extensive)

This suggests that men do not necessarily hand over all the money earned:

"When the money is in the wife's hands it is difficult to ask for it back, [so] I keep some back…. it is a strict bank." (Man in FGD, Tramkak, Takeo SI).

This arrangement has potential for conflict in times of scarcity, as pooled resources are drawn on for household and individual needs and not all needs can be met.

Juxtaposed to these presentations of the situation of women as having relative economic empowerment, are the traditional cultural stereotypes of women which embody submissiveness, and evidence of male dominance in the household. Surveys show an acceptance of a level of domestic violence (CDHS 2014). 46% women agreed with at least one reason why a man may be justified in beating his wife. 22% of ever married women have experienced physical, emotional or sexual violence, with higher rates where husbands have a lower educational level and there are higher numbers of children (MoWA 2016). Few cases go to court and are often settled informally at community level with small payments to victims or the family. The National Action Plan to prevent violence against women (MoWA 2014c) has prioritised legal protection for women and girls, mainstreaming women's rights into formulation and implementation of laws and promoting effective service delivery to survivors of violence against women.

Women take part in decisions on the purchase, sale or transfer of assets. A major part of savings is used to set up the households of children at marriage, through support to acquiring land, a house or a business. Decisions on sale of land or house are required to have the consent of both husband and wife. Women are involved in decisions on household purchases (79% reported this, CSES 2014)

4.3.4 Leadership and empowerment

The social analysis asked whether women are members of groups, trade unions, or farmers' organisations. There were relatively few groups and farmers' organisations reported in the communities visited. Those that exist have been formed by various NGOs around specific projects or interests such as organic rice cultivation, aquaculture, livestock, women's health etc. Some of these groups e.g. Centre d'Etude et de Développement Agricole Cambodgien (CEDAC) offer savings and credit facilities, in which women play a prominent role. Women participate actively in community fisheries groups (MAFF/CBNRM 2008).

A more significant indicator of women's leadership and empowerment is the extent to which they hold leadership positions within the organisations of which they are a part. Commune and district councils are required to have female membership and most have at least two women members. Women are members of community fishery groups and the community fishery committees have to have a woman member present in meetings. Nevertheless, despite the involvement of women in groups as participants/beneficiaries, they are less likely to occupy leadership or decision making positions (Khim et al 2002) and they are reticent in influencing decisions. Focus groups[7] confirmed that women were represented on village and commune councils, but not in main leadership positions, although some were vice leaders. In relation to representation of different ethnic groups – people of Vietnamese origin are represented on the council in areas where they constitute a significant proportion of the population, but generally by men.

A further question considered was whether women have the power to influence services, territorial power and policy decision making. Despite their role in the economic sphere, women have lacked political influence (Frieson, 2001). A number of reasons for this have been suggested – women's lower levels of literacy[8] and educational status and the perception that leadership involves a 'round the clock role' considered in local culture to be unsuitable for women. The government's National Program for Sub-National Democratic Development 2010-2019 (NP-SNDD), includes a quota system and political reforms in local decision making. By 2012, women's representation in the National Assembly had increased, as had the number of women deputy governors and members of provincial, district and commune councils. There is some evidence that transaction costs for women trader (customs, tariffs etc.), are higher than for their male counterparts in cross border trade (Kusakabe et al 2006, in Weeratunge et al 2016).

Women gave some examples of their participation in meetings called by commune and district leaders. There is encouragement of women members of councils to speak in public. *"Women do speak up and are encouraged to do so. We cannot discriminate" (*Tramkak, Takeo SI*). W*omen members of the community fisheries groups and the fish seed producer networks talk in public. However, beyond the community level, women have a limited role in public life, although recently there have been steps to increase women's representation in the national parliament and among civil servants.

4.3.5 Hardship /Gender roles and division of labour

The extent to which the respective overall work loads of men and women are equal (including domestic work and child care) was explored. Studies which have attempted to assess labour time have found that women work for longer hours. (MAFF and CBNRM 2008) and men have more recreational or rest time. An important distinction is drawn in local understanding between the hours of work and the intensity of work. Overall, women work longer hours than men, but consider the fact that men perform physically heavier work to explain their need for greater rest and leisure time. The gendered division of labour, while relatively flexible, assigns women the domestic roles of food preparation and

[7] 3 groups in TramKak district, Takeo province; a floating village in Krakor District, Pursat, Sout Nikom District, Siem Reap and Russey Keo, Phnom Penh.

[8] 72% women 85% men overall, 67% women and 82% men in rural areas. (2014 CSES)

child care (MAFF and CBNRM 2008), although some men also cook and look after children. One of the constraints on women's economic development is the extent of their working hours. While they have taken up opportunities for earning income, '*the problem is the increase in women's workload. There has been a lack of transformation in gender roles, in particular the domestic burdens on women (*key informant interview, Phnom Penh*).*

Women and men are both involved in agriculture and aquaculture. Men do more of the heavy tasks such as land preparation, digging and liming ponds, loading agricultural produce etc. although the role divisions were not rigid. Generally, women in male headed households are <u>not undertaking the most strenuous tasks</u>. The situation for women heads of households is different and depends on the extent to which they can afford to hire male labour or use <u>labour saving technologies</u> such as machinery for digging.

In cage aquaculture, women undertake all production activities. In many cases, their husbands and sons are involved in capture fisheries which take place at night. Women sometimes go fishing with their husbands, but more commonly have other economic activities, such as marketing the fish and cage cultivation, based on the floating home or near their house. Both husband and wife are involved in feed preparation for cage cultivation.

In discussion with aquaculture producers, most presented their activities as a family activity in which all family members participate.

> *'There is flexibility in work, all participate, children help when they are free from school. We often work together and help each other' (*FGD, Tramkak Takeo R/F& extensive*)*
> *'We help each other – including the children. Men do the heavier work'. (*FGD, Tramkak Takeo SI *)*
> *In preparing ponds the husband and wife work together. The man does most of the heavy digging work (*FGD, Thma Koul, Battambang SI*)*

Intensive pond producers handling large volumes of feed, tend to employ male labour. In these better off households, women '*don't do the hard work', they are mainly looking after the house',* although they may take over the management when the husband is away. In some intensive households, the wife had her own separate business, e.g. operating a shop, selling cloth in the market etc.

Activity	Men	Women	Children
Digging pond	Hand dug - mainly men, or hired mechanical digger		
Preparing ponds	Both contribute - man does most of the heavy work		Children help in some locations
Liming	Men only or men and women "you have to be careful as it can affect your health		Children help in some locations
Digging channels	All contribute		
Feed preparation	Preparation of feed and collection of feed inputs and fish waste.	Preparation of fish food	Collect feed inputs and firewood for cooking
Feeding	Flexible family labour, women and children help. Whoever is free can help in feeding the fish (pond and cage). Larger producers depending on fish waste and small fish, hire labour for transporting it		
Pond maintenance	All family members. When the main pond manager is away, other family members take care of the pond.		
Harvesting	Family and neighbours (the latter given fish as payment). Hired labour for larger enterprises		
Marketing	Mainly women for village sales and local markets. Intensive producers selling in Phnom Penh, mainly men		
Collectors and wholesale trading	Men and women, separately or jointly, women most often manage the finance		
Processing	Salting, loading and unloading mainly by men	Cutting and preparing and marketing fish	Help in preparation
Input supplier	Mostly men		
Retailers		Mostly women	

Table 4-2. Gender roles in Aquaculture. Source: Focus group discussions and key informant interviews.

There are seasonal variations in the work load which is especially heavy during the rice farming season. For processors and traders, their work is more intensive in the main fish capture season and then during the peak aquaculture production.

4.4 Are Food and nutrition conditions acceptable and secure?

This section examines the food security and nutritional circumstances in communities which are engaged in aquaculture and the current and potential role of aquaculture in food security. Food security is defined as the extent to which '*all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life*' (FAO definition agreed at World Food Summit 1996). Four dimensions of food security are covered – food availability; food access, including access to adequate resources to acquire appropriate foods; food utilization, including food preparation and feeding practices, intra household food distribution, dietary diversity, water quality and sanitation which affect nutrition) and stability over time, including seasonal and annual variation in supply and prices.

The aim of the Cambodian National Nutrition Strategy 2009-2015, was to reduce protein energy malnutrition and micronutrient deficiencies, especially vitamin A, iron, zinc and iodine among young women and children. It recognized the need to strengthen leadership, multi sectoral collaboration, resource allocation and community involvement. However, it did not address how nutrition, health, agriculture and fisheries links could be strengthened. The National Strategy for Food security and Nutrition NSFN 2014-2018, approaches food security and nutrition as cross- cutting issue (CARD TWG-SP and FSN 2014). Its objectives cover access to nutritious food, reduction of child and maternal malnutrition, and improving the stability of food supply.

4.4.1 Food availability

There was some evidence that local production of food is increasing and available on the local market. The rice area harvested has shown a year on year increase from 2004 to 2012 then a slight reduction in 2013 and 2014. Overall production has more than doubled over this period and yields have increased from 1,977 kg/ha in 2004 to 3,264.7 in 2014. Farmers in focus group discussions reported increases in production and yields from rice cultivation as a result of improvements in farming methods. Productivity of rice has improved through access to new technology such as new varieties and management practices. However, this is dependent on location and adequate rainfall. Rice-fish farmers in different districts described the benefits of this system for rice crop yields and labour reduction for weeding.

Overall fish production in Cambodia has shown a small increase since 2012. The estimated total production in 2014 was around 490,000 tonnes of freshwater/river fish, 120,000 tonnes of marine fish and 120,055 tonnes from aquaculture (MAFF, 2015). Official estimates for aquaculture production in 2015 and 2016 were 143,141 mt and 170,265 mt respectively. There are issues with the reliability of estimates of aquaculture production, which could be considerably lower than the official figure. In addition, fish imports are estimated at more than 100,000 mt per year and there is ready availability of fish on local markets. While this is an advantage for consumers, fish producers complained about its negative impact on prices.

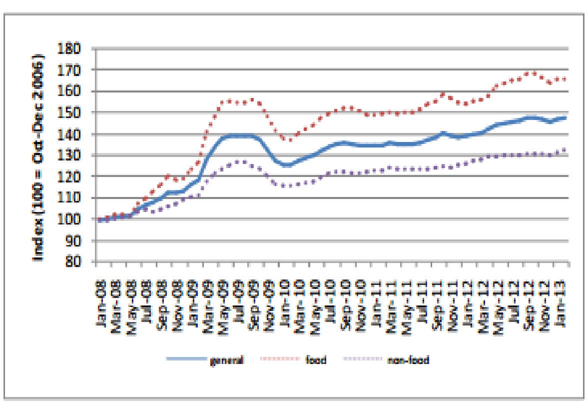
Most producers met in focus group discussions said that food supplies and access to food have been improving. Most districts visited were well served with markets and for communities on the Great Lake there were floating shops (Kra kor district, Pursat, Cage). The agricultural census (2013) found that the majority (76%) of households engage in a combination of capture fishing with crop cultivation and raising of livestock/poultry. More than 90% of agricultural households engaged in fishing did so mainly to meet their household consumption needs. The extent of self-provisioning is considerable; in the 12 months prior to the agricultural census, 83% of households' consumption of rice and cereals was from their own produce and 20% of the fish consumed from their own capture or culture (Agricultural Census, 2013). The status of local food production is therefore critical for availability of food to rural households.

Several producers noted the decline in availability of wild fish; *"People can still find wild fish but they are small in size and only in the wet season. Some species have disappeared*." (FGD, Bakan District, Pursat. R/F & SI). This is one of the factors reported as encouraging interest in aquaculture and its growing importance as a food source; "*we did not go into it for the money*" (TramKak, Takeo SI). A further reason is to provide fish for consumption in the dry season and reduce household expenditure. However, results of the Value Chain Study producers' survey show relatively low reported rates of household fish consumption from their own aquaculture. The quantities may have been underestimated, particularly from ponds where the producers have been encouraged to develop more commercial production.

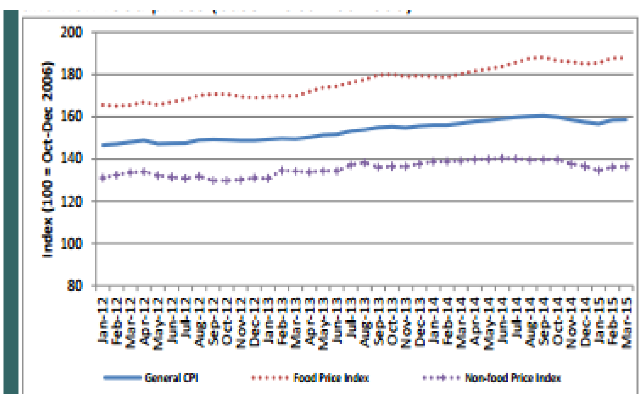
4.4.2 Accessibility of food

Questions on whether people have more income to allocate to food and whether relative consumer food prices are decreasing were explored in focus group discussions and analysed from secondary data sources. The Cambodia food price and wage bulletin tracks prices of food commodities and wages rates to analyse food purchasing power. After a steep rise in 2009 and fall in 2010, the indices for general consumer prices, food prices and non-food prices showed modest increases between 2012 and 2015.
Average retail prices for rice have fallen or remained stable, while daily wages for unskilled labour have gone up over the same period in both rural and urban areas, with improving 'terms of trade' between wages and the cost of rice. The wholesale price of mixed rice has not increased markedly since 2010.

Some aquaculture producers met in Takeo province, reported being able to afford more food than in the past, but some said that food prices were increasing. Cage farmers in Phnom Penh agreed that there was more food available, "*but unless you have money you can't find*" (FGD, Russey Keo, Phnom Penh cage). Food price levels are particularly critical for cage producers without access to land and who secure their food needs through sale of fish.



Source: National Institute of Statistics



Source: National Institute of Statistics

FIGURE 4.6. RELATIVE CHANGE IN GENERAL CONSUMER PRICES, FOOD PRICES AND NON-FOOD PRICES (JUNE 2008-MARCH 2015. (BASE =OCT-DEC 2006) (EXTRACTED FROM CAMBODIA FOOD PRICE AND WAGE BULLETINS)

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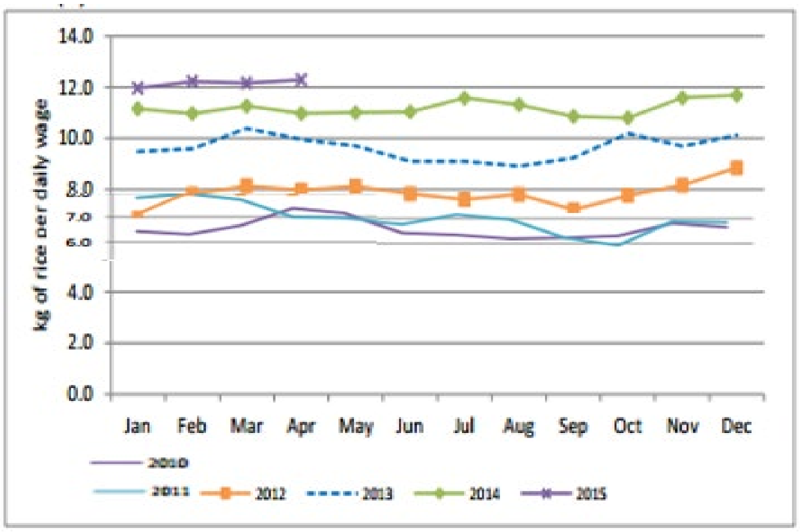


Figure 4.7. Terms of trade: unskilled rural labour and rice (kg of rice purchased for average unskilled daily wage. Source: **(**Extracted from Cambodia Food price and wage bulletins**)**

4.4.3 Utilisation and nutritional adequacy

A number of sources highlight the paradox that in Cambodia, despite high rates of fish consumption, levels of child malnutrition are high (Vilain et al, 2016; Vilain and Baran, 2016), contributing to illness and infections, delayed development and poorer educational performance. Key drivers of child malnutrition in Cambodia are maternal malnutrition, underweight and anaemia; low dietary diversity for women, especially lack of iron rich food; low birth weight, suboptimal infant feeding and delayed initiation of breastfeeding; diarrhoea, fever, intestinal parasites among children under 5 years old; poor drinking water quality, and inadequate sanitation and hygiene practices. The mortality rate for children under 5, is 35 deaths for 1000 live births, down from 54 in 2010. Mortality rates are much higher for children of uneducated mothers (79) and the poorest households (76), and in rural areas (52) compared to urban (18) (CDHS 2014).

Cultural beliefs and practices also influence consumption patterns, limiting intake or restricting certain foods (e.g. fish paste, green leafy vegetables, meat) during pregnancy, breastfeeding or in the complementary feeding period, with consequent loss of nutritional diversity and micro nutrients (Vilain et al, 2016; Global nutrition report, 2015; Wallace et al 2014). Food preparation practices also influence nutritional content – vitamin A is lost in processing, and removal of fish heads[9] before cooking reduces nutritional content. Economic pressures encourage poor households to sell fish, or forgo other high-quality foods in order to use their money to secure their staple food, rice (Wallace et al 2014). Other sources point to the legacy of the Khmer Rouge years in terms of social and cultural disruption and loss of food related knowledge (Global nutrition report, 2015).

[9] More than 65% of households remove the fish head when preparing for consumption (Brooks and Sieu. 2016)

Trends in nutritional status are taken as indicators of whether nutritional quality of diets and dietary practices are improving. Nutritional status in Cambodia is tracked through the Cambodia Demographic and Health Survey, conducted in 2000, 2005, 2010 and 2014. For many nutritional indicators, mothers' education and household poverty levels have a significant influence. There were no differences in status for the nutritional dimensions in children according to sex.

In 2014, the incidence of stunting in children under 5 was 32%, down from 40% in 2010. The main risk factors were maternal underweight, mother's education and household wealth quintile. Rates of stunting among the poorest households were 42% compared to the richest, 19%. Rates in rural areas (34%) were higher than in urban (24%). (CDHS 2014). The incidence of wasting in children under 5 had slightly decreased in 2014, but at 10% was higher than in 2005. 24% of children under 5 were underweight – again only a slight improvement on 2010. Incidence was higher in poorer households (31% and 28%); where mothers had no education (30%) and in rural areas (25%) compared to urban (15%). More than half the provinces had rates above the national average.

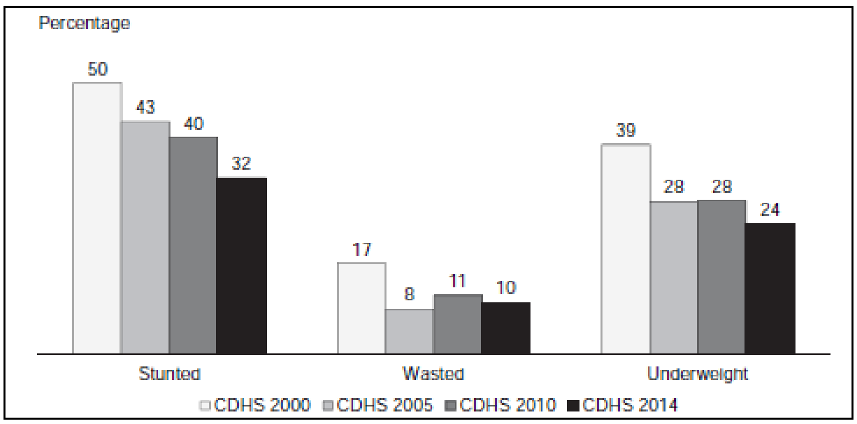


Figure 4.8. Trends in nutritional status of children under age 5, 2000- 2014

Source**:** CDHS 2014. (The report recalculated data for 2000 & 2005 using 2006 WHO child growth standards.

The nutritional status of women is an important indicator given the relevance of women's weight to child stunting and wasting. For women of childbearing age, 14% were underweight in 2014 – a decrease from 19% in 2010. Conversely, the proportion who are overweight (18%) has been increasing particularly in urban areas (23%) and in the highest wealth quintile (CDHS 2014).

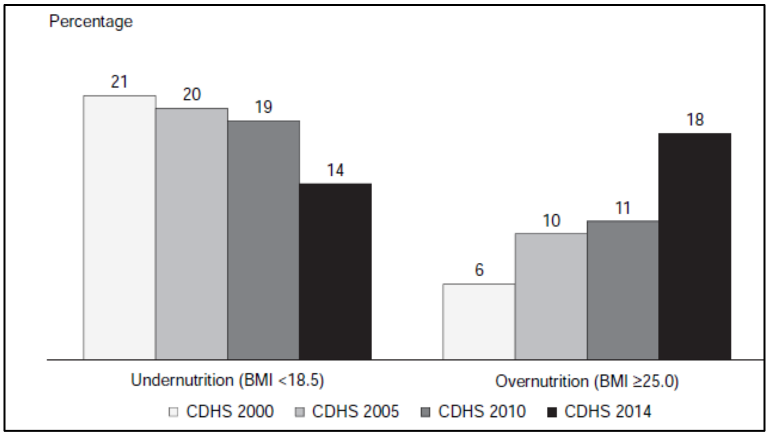


Figure 4.9. Trends in nutritional status of women age 15-49
Source: CDHS 2014.

Micronutrient deficiency is recognised as contributing to childhood morbidity and mortality. It is a target of the Cambodian National Nutrition Strategy. The CDHS 2014 showed good uptake (71%) of Vitamin A supplements and consumption of Vitamin A (85%) and iron rich foods 82%) for children under 2 years old. 94% of women with a birth in last 5 years had taken iron tablets or syrup during the pregnancy and 75% had taken deworming medication. Anaemia is a serious public health problem. In 2014, 56% of children under 5 years old were anaemic (30% mildly, 25% moderately and <1% severely); 45% women of reproductive age and 53% of pregnant women were anaemic (CDHS 2014). Prevalence in both women and children was higher in poorer and less educated households and in rural compared to urban areas. Rates of anaemia are relatively unchanged since 2010.

Zinc deficiency, hookworm infection and haemoglobin disorders were significantly associated with anaemia in children. Wieringa et al, 2016 recommend that supplementation be broadened to include zinc and folic acid, as well as effective anti-hookworm measures which can help to address the 40% of anaemia not caused by nutritional factors.

In terms of nutritional practices, 30% of children aged 6-23 months are fed appropriately and met minimum standards based on all three infant and young child feeding practices (CDHS 2014). This had improved from 24% in 2010. However, diversity of diets could be improved – only 48% received foods from the minimum number of food groups for their age. The main limiting factors are a lack of understanding about the food groups and limited willingness to take the extra food preparation steps (Chung et al, 2016).

There is general agreement on the nutritional quality and contribution to diets of small freshwater fish, in particular providing micronutrient requirements, calcium, vitamin A, iron, zinc and iodine and high-quality fat and fatty acids/omega 3 (Thilstead et al 2010; Vilain et al, 2016; Bogard et al, 2016). A monitoring study of fish refuges found an overall decrease in micronutrient rich small fish consumption from November 2012 to 2014. Data from the late 1990s show small fish making up 50-80% of all fish eaten in the peak fish production season. Research on the potential to increase the presence of native fish in pond aquaculture (comparing carps and small fish, with carps only) showed no significant differences in yield, but there was an overall increase in nutritional quality. Small fish can be harvested over time, supporting home consumption and contributing to nutrition and health. In contrast, pond producers have been encouraged to remove wild species prior to stocking their ponds. The Value chain study producer survey found that Pangasius was the species most frequently grown by respondents in semi intensive systems, Giant snakehead was most frequent in intensive systems, and Clarias, Snakehead and Giant snakehead in cage culture.

Poor water and sanitation provision contribute to poor nutrition. Incidence of diarrhoea is higher in poorest households, those without an improved drinking water source and those using non-improved or shared toilet facilities (CDHS 2014). Drinking water provision has improved, but 24% of households continue to rely on surface water or unimproved sources. Sanitation provision has also improved, but 47% of households still practice open defecation, contributing to the incidence of diarrhoea, parasites and hookworm which weaken nutrition (Global nutrition report, 2105). It also contributes to the problem of polluted waters, especially for cage culture in floating villages.

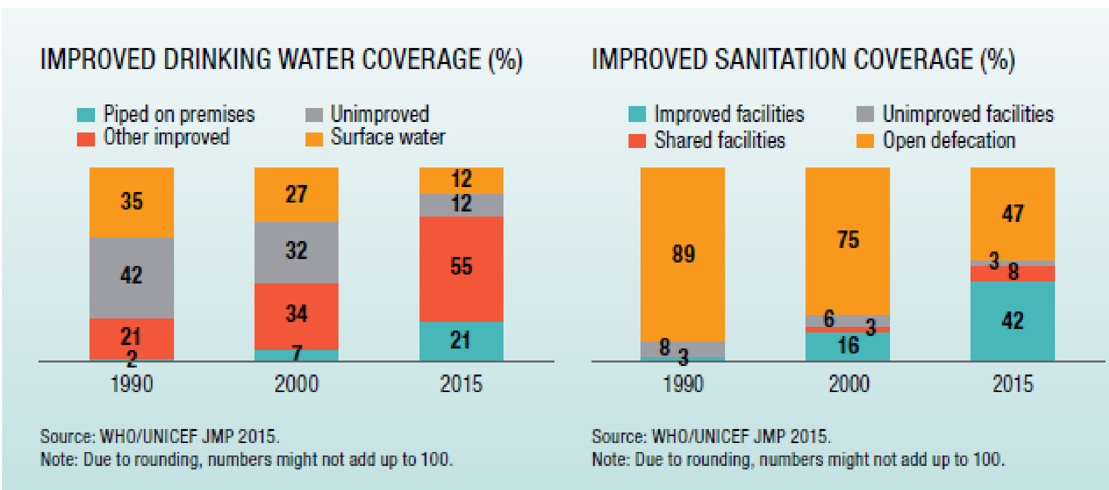


FIGURE 4.10. CHANGES IN IMPROVED DRINKING WATER AND SANITATION COVERAGE, 2000-2015

Source: Global Nutrition Report, 2015.

Evidence on whether dietary diversity is increasing was mainly gleaned from secondary sources. Household food consumption is dominated by rice, which is consumed on a daily basis (an average of 302g/person/day, IFReDI 2013). However, Cambodia is the largest consumer of freshwater fish per capita in world (Vilain et al 2016) and fish and aquatic resources provide 37% of total protein intake per person and 76% of animal protein of which 49% is from freshwater fish, 20% from marine fish and animals, 5% from aquatic animals and 2% from aquaculture. Aquatic resources contribute 12% to energy intake, 37% of iron and 28% of fat total intake per person (IFREDI 2013). Meat (pork and beef) and poultry consumption are about one third of fish consumption, providing 24% of animal protein intake.

Fish is eaten cooked fresh, dried, smoked and as fermented fish paste and fish sauce. Fish are eaten 5.3 days per week, fish sauce 3-4 days per week and fish paste 2-4 days per week (Mousset, 2016; Vilain et al, 2016). Income-insufficient households consume relatively more rice than other households and are also more frequent consumers of aquatic resources such as snails, shellfish, crabs and snakes compared with other meats (Mousset et al 2016).

Several sources highlight the lack of vegetables in Cambodian diets. Consumption of vegetables at 92gm per capita per day is less than 50% of recommended daily intake. The consumption of vegetable oil is also low, at 8g /person/day, or less than 50% of the total fat consumption. (Vilain et al 2016).

Diversity of foods consumed and changes in diets were discussed in focus groups. People reported that they now had more information about food; for example the importance of lowering the fat content of their diet and how to avoid diabetes. Some individuals have made changes because of specific health problems – heart trouble etc. In terms of family diets, the consumption of pork has reduced and they consume more fish than they used to. There is less contamination of food. There is also organic production of rice. Information is got from the radio and other media, through Ministry of Health which suggest that nutrition information campaigns are having some effect.

There is more diversity in the foods consumed – they have new foods such as noodles and food sources such as coffee shops. They used to eat cold rice in the morning, now they can have hot noodles, rice porridge and chicken. They feed children rice porridge, vegetables and fish, particularly from larger fish such as tilapia where they can more easily extract the bones. They also feed smaller fish to children but must remove the bones.

Cage culture farmers on the Great Lake said they have always depended on fish - what they eat depends on what they catch from the wild. Most children are breast fed for a year. Only a small number are given milk powder; the weaning foods are rice porridge, with vegetables such as carrots with dried fish. New food and drink options are available. One group said they now consume more soft drinks, but if they had money they would buy fresh vegetables, chicken and beef.

> *"For the rich people, they can find many new food options – in social gatherings before, they used to drink locally-made rice wine or rice whisky; now they drink beer. There are many shops to access [new food items], but there's the question of affordability. Fish consumption depends on supply – when you have more, you eat more. We sell the big fish and keep the small fish for home consumption". (*FGD, Prasat Bakong, Siem Reap, Cage)

There are varying estimates of fish consumption from 43.2kg/person/year (Mousset 2016), to 63 kg/person/year (IFReDI 2013). Information on consumption of fish from different sources (capture v aquaculture) or combinations of sources is generally lacking. There are some differences in the patterns of fish consumption within the different aquaculture production systems. The Value Chain Study producer survey 2017 asked producers to estimate the total amounts sold, the volume harvested for home consumption and the amount given away to neighbours and relatives. They were also asked about the pattern of harvesting – whether partial over time, or once off. This was highly variable, some harvesting 20-30 times and others once or twice. One cage producer explained his belief that you should not harvest during the growing period but only at the end. 74% of producer households interviewed consumed some of the fish they had grown and 68% gave some away to friends and relatives. More semi intensive households (79%) consumed their farmed fish than cage (70%) or intensive producers (63%).

Overall, the amount consumed as a proportion of total production net of losses, was less than one per cent, but this varies between producing households and between the different systems. More semi intensive producers (79%) reported consuming their own fish than intensive producers (63%), but the latter group consumed larger quantities.

For households consuming fish from their aquaculture, they consumed an average of 34.3kg per household and 4.75 kg of fish per capita for cage growers, 52 kg per household and 8 kg per capita for semi intensive farmers and 147 kg per household and 22 kg per capita for intensive farmers. These figures are from the questionnaire survey and may have underestimated the consumed amounts. In focus group discussions some semi-intensive producers reported consuming up to 50% of what they produced.

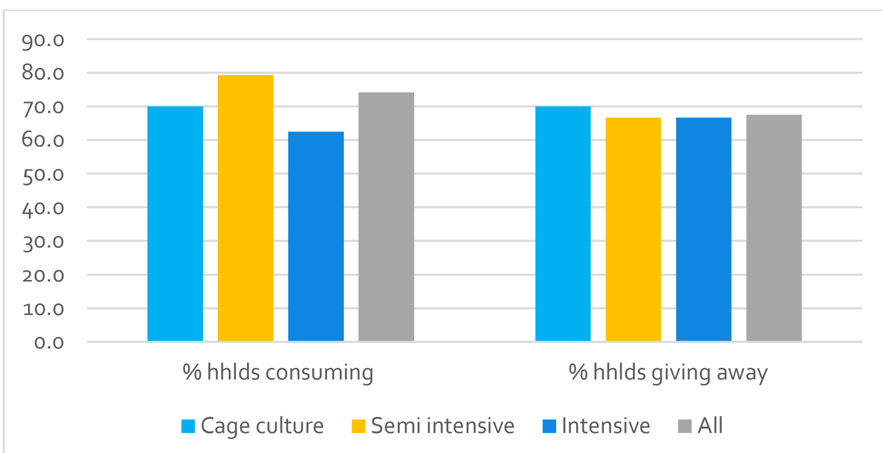


Figure 4.11. Percentage of households in aquaculture consuming and giving gifts from their own production

Source: Value Chain Questionnaire Survey, 2017.

There was not much difference in the proportion of households giving fish away comparing the different systems. An average of 27kg per household for cage growers, 34.5 kg for semi intensive and 104.4 kg for intensive producers was given away. Some producers give fish to hired labourers, for example, during the rice harvest. Households with more social connections were likely to consume and give away more:

"men consume more than women- when drinking with friends". They do not sell their fish, but share with relatives and neighbours. (FGD, TramKak Takeo R/F & extensive)

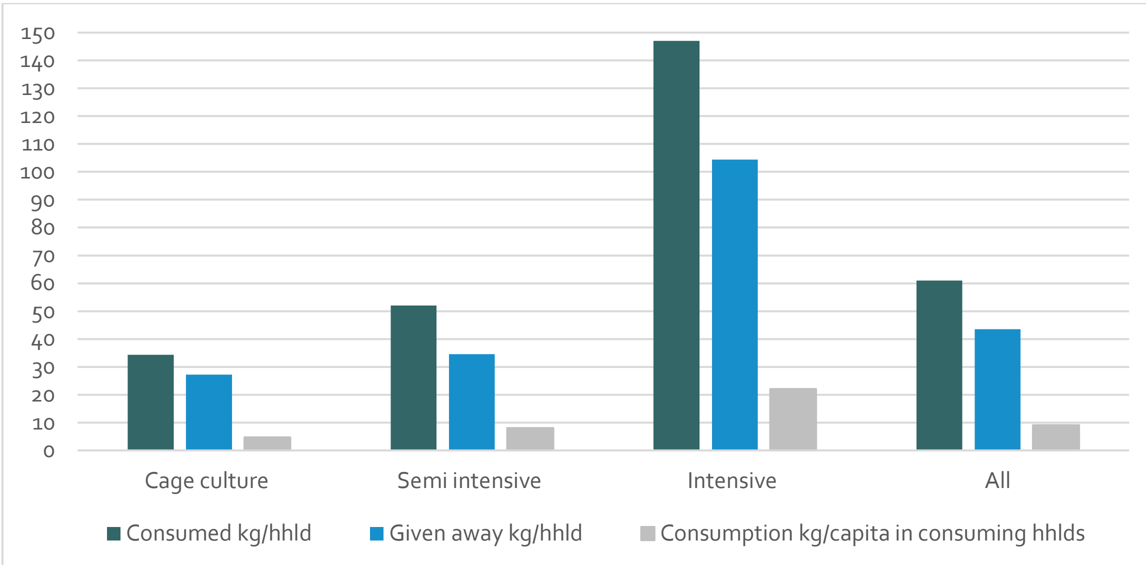


FIGURE 4.12 . HOUSEHOLD FISH CONSUMPTION AND GIFTS FROM OWN AQUACULTURE (CONSUMING HOUSEHOLDS)

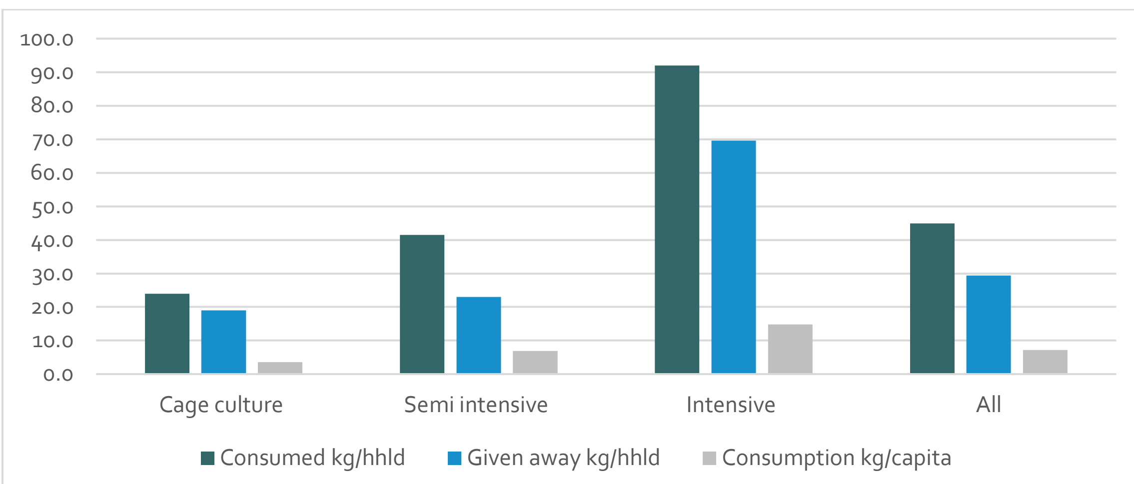


FIGURE 4.13. HOUSEHOLD FISH CONSUMPTION AND GIFTS FROM OWN AQUACULTURE (ALL HOUSEHOLDS)

Rice fish farmers also capture and consume and sell wild fish caught in channels in the paddy fields in addition to the fish they have stocked.

Rice-fish and semi-intensive farmers at several locations in Takeo reported the benefits of aquaculture providing tastier better quality fish for home consumption and sharing with relatives, reduced household expenditure and a higher quantity and more frequent consumption;

*"we can eat more fish any time, even at night if you feel like it. Previously we bought meat, now we eat fish around five days per week. We feel healthier. Maybe we eat beef or chicken once per month". (*FGD TramKak Takeo, R/F & extensive)

"Accessing fish is convenient – the ponds are nearby. We have an appetite for fish and can eat fish every day, but we could not eat meat every day".
*"[we have] better fish in the home, to take care of relatives when they visit, reduce household expenditure; declining wild fish availability. We did not go into it for money." (*FGD, TramKak Takeo SI)

Cage producers in Phnom Penh said that they ate more fish than 10 years ago. Extensive producers who mainly depend on wild fish populating their ponds, use them for home consumption and local sale. Examples were given of up to 200kg per year (Sout Nikom, Siem Reap, extensive)

4.4.4 Stability

Stability of food supply and the frequency of periodic food shortages (because of inadequate supply or high cost) are important indicators of nutritional security. 16% of households reported food insecurity and shortages in the 12 months prior to the Agricultural census (2012/13). The majority of these shortages lasted not more than 3 months, but 24% reported food insecurity for longer than 3months, with more female headed households reporting this (27%) than male headed households (23%). The main reasons were low production, shortage of capital and land, crop loss and damage, high cost of food, low production though illness and disability, and a limited food budget due to loss of job. The latter was an important reason for food shortages of more than 3 months. Strategies to cope with shortages included borrowing money, wage labour outside the farm, sales of non food crops and assistance from relatives.

Farmers in Takeo province said they felt food secure. Some are trying to reduce their food intake. They indicated that one of the benefits of aquaculture was that households can access fish in the dry season which was not possible for those living far from the lake. They said there was not really a hungry period – they had food to eat. They buy rice for 2-4 months of the year and sometimes help out other households with rice which is paid back at harvest time or pay back is not required.

The seasonal calendar described by semi intensive farmers highlights September and October as months of hardship - poor accessibility because of flooding, high prices, and shortage of cash. These factors put stresses on households and increase the incidence of domestic arguments. Cash available for rice production and stocking at the start of the aquaculture cycle depends on what savings are remaining from the rice harvest sales.

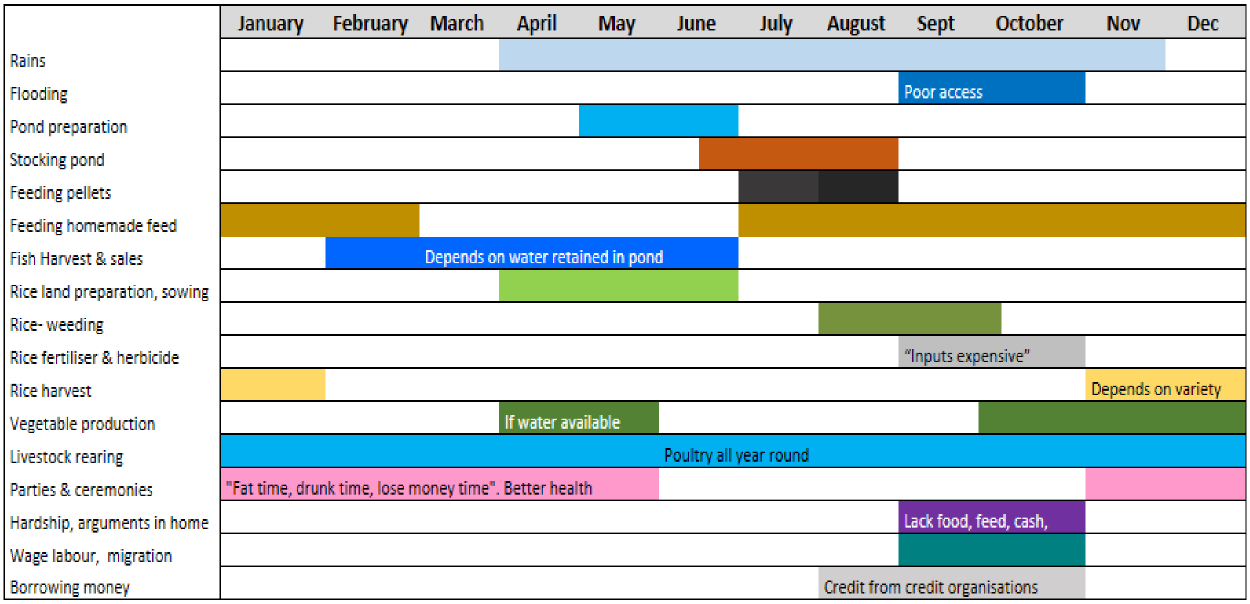


FIGURE 4.14. SEASONAL CALENDAR FOR POND PRODUCERS (SOURCE: FGD THMA KOUL, BATTAMBANG SI)

The charts showing food and consumer prices reflect this seasonality, with higher food prices in September and October. The main season for capture fishing is from July to November. Consumption is highest in November and lowest in May and July.

The factors affecting food supply for cage producers are rather different. Seasonality for cage producers on the Great Lake has a different pattern:

> *"The most difficult times of the year are May and June when the water level is low and dry and there are few fish. (FGD Prasat Bakong, Siem Reap, Cage)*

Producers with cages underneath their floating houses move to a different location to accommodate the changing water levels, while producers with separate cages often move the location of the cage. This may occur several times as water levels change, each time incurring considerable costs.

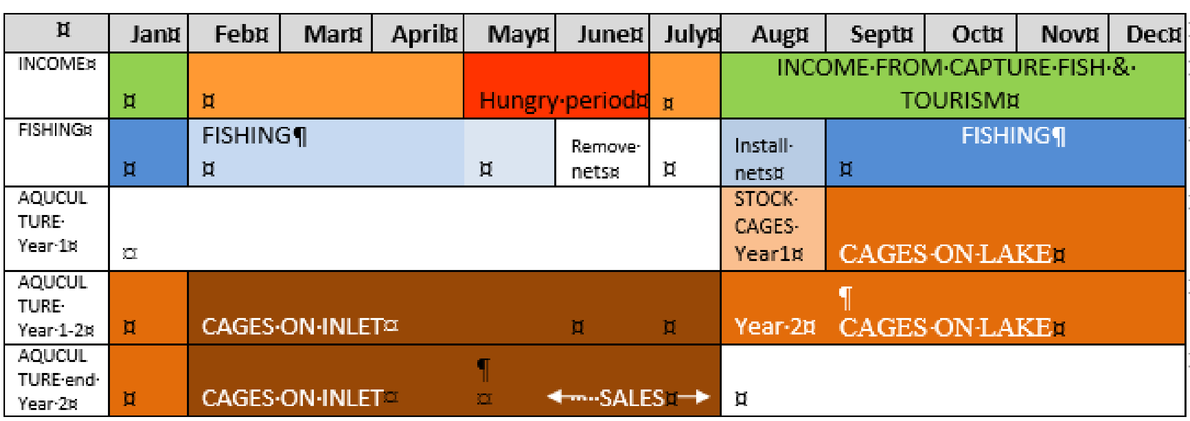


FIGURE 4.15. SEASONAL ACTIVITIES (CAGE PRODUCERS, PRAST BAKONG, SIEM REAP)

Producers emphasised the food security contribution and convenience of aquaculture.

> *"Aquaculture is very important for consumption. If you don't have a pond you face [problems]" (Woman producer, (FGD, Bakan Pursat RF & SI)*
>
> *"if you raise a pig or cow, you cannot cut some meat off it! With fish you can get one any time." (Male producer Bakan Pursat RF & SI)*

4.5 Is Social capital enhanced and equitably distributed throughout the VC?

4.5.1 Strength of producer organisations

There were relatively few groups and farmers' organisations, formal or informal, reported in the communities visited, and most were concerned with agricultural production, savings and credit or community fisheries. Experience with the latter has proved problematic in some areas, with farmers preferring fish culture on an individual basis (Joffre *et al* 2012). Reasons for this included weak social capital linked to the socio-political history of Cambodia (Sheriff *et al* 2010), specifically aversion to collective action resulting from forced collectivisation in the Khmer Rouge era. There were few instances of groups able to negotiate in input and output markets.

In aquaculture production there were informal groups formed around local fingerling producers, mainly for accessing fingerlings and technical information. For marketing, there were no formal groups encountered, but informal arrangements among a group of 10 intensive producers in Siem Reap helped individuals to share transport and access imported fingerlings and fish feed from Vietnam. They also collaborated on planning their stocking and harvesting times. Marketing itself is individual. There is a crocodile producers' association.

For processors, there were no formal groups reported and 'cooperatives and collectives are not a common form of enterprise among women fish processors' (Kusakabe, 2016). Past efforts at collective production and marketing by prahok processors (6 women and 2 men) in Battambang supported by FIA were not successful (Interview with processors in Battambang and Kukasabe, 2016). A number of factors account for this; individuals with successful processing businesses have developed relationships with customers based on a long history of personal relationship and trust. There is often continuity within families as the business passes from mother to daughter. Individual processors rely on their own customers and negotiate based on this relationship. Customers also want to deal with individuals they know. Therefore they perceive limited benefit from collaboration.

Similarly, small scale fish traders operate on an individual basis, selling to a number of buyers within whom they have established relationships (Kusakabe *et al* 2008). Women small scale traders have limited capital and negotiating power in relation to large scale traders who are mostly male, but have not organised to overcome this. Market instability and unpredictability contribute to the perceived risk and reluctance to engage in collective enterprise.

The situation of cage producers, who at certain times of the year are in locations more difficult to access, is more challenging. Women cage producers in Pursat reported that they generally cannot negotiate on prices. If they try to bargain, the buyer can refuse to buy. The supplier of inputs and feed and the collector are the same person. He requires immediate cash payment from them, although they may wait for up to one month for payment from him. Volumes from individual producers were said to be insufficient to attract more buyers and expand the competition.

Regarding inclusivity of group/cooperative membership, most groups at community level are based on common interest and hence are selective of those who have the necessary resources to participate (e.g. rice fields, aquaculture ponds, livestock etc.) or to develop the resources (e.g. by enlarging a small pond). Participation in savings and credit groups requires the ability to make the required regular contributions. Thus it is likely that group membership in practice excludes the poorest members of communities. Landless ethnic minorities may also tend to be excluded. In Siem Reap there is a membership association for people from Vietnam, but it is not for production, more a social support system in case of problems around protection or security. A group of intensive producers are currently discussing with fisheries personnel the formation of an association for aquaculture under the local administration/Ministry of Interior.

There are many instances reported where groups faced difficulties associated with limited leadership capacity. NGOs and projects increasingly recognise the need for investment in leadership skill development to ensure representative and accountable leadership. Community Fisheries are formally constituted bodies with registered members and an elected management committee. However, there is variation in the extent to which the leadership is regarded as having legitimacy and representation, particularly of poorer community members.

4.5.2 Information and confidence

Aquaculture pond producers reported having access to technical advice and training from FIA. In locations where there is a local seed producer trained by FIA or an agriculture focal point, they also provide technical information and advice. Where projects have operated, producers have received technical training. The village head and commune head provide information on policy. Cage producers, particularly women, were less positive about their access to information, relying on each other for advice, and some expressing reluctance to attend training courses as they are *'very busy with fishing and looking after the home'*. Reaching women cage producers with information requires tailored approaches to overcome obstacles of women's work load and lower levels of literacy and confidence. Information on market prices depends on producers and processors own networks. Contacts are made by mobile phone to inquire about and negotiate market prices.

The issue of trust between value chain actors was discussed in the focus groups and was included in the questionnaires. Informants were asked to rate the level of trust they have in their buyers, from one (least trust) to five (most trust). The figure below shows the results from the producer questionnaire. Over 50% of producers in all groups rated the level of trust with their buyers at the maximum score, but levels of trust were highest among intensive producers.

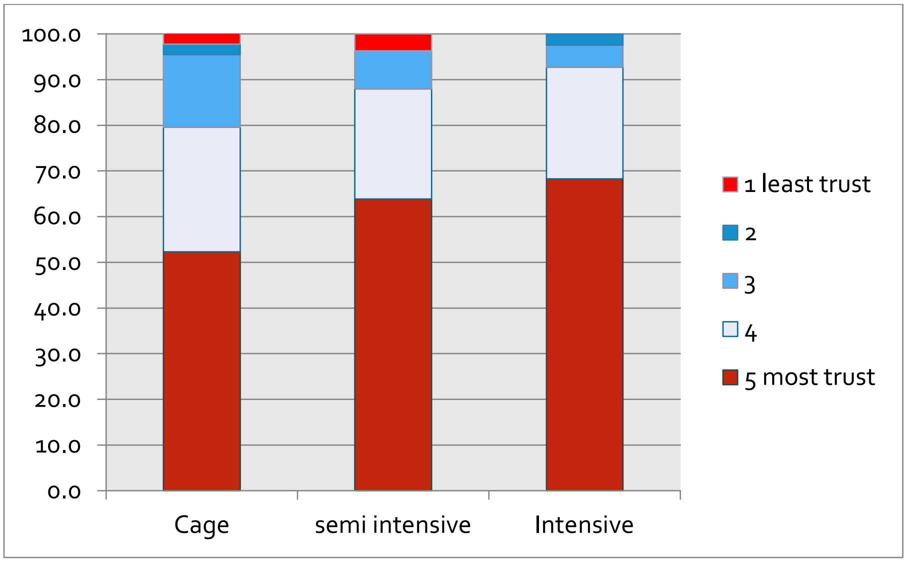


FIGURE 4.16. LEVELS OF TRUST PRODUCERS HAVE IN THEIR BUYERS (% OF TRANSACTIONS RANKED IN EACH CATEGORY BY PRODUCER TYPE). (CAGE 44 TRANSACTIONS, SEMI INTENSIVE 108 AND INTENSIVE 41)

49% of processors ranked the level of trust with their buyers as 4 and 49% as 5. For intermediaries, 61% rated their level of trust in their buyers at the highest level (5), 34% at the next level (4) and 5% at the next (3).

Overall 61% of aquaculture producers sell to people with whom they have a regular relationship, but the proportion is highest for intensive producers at 78%.

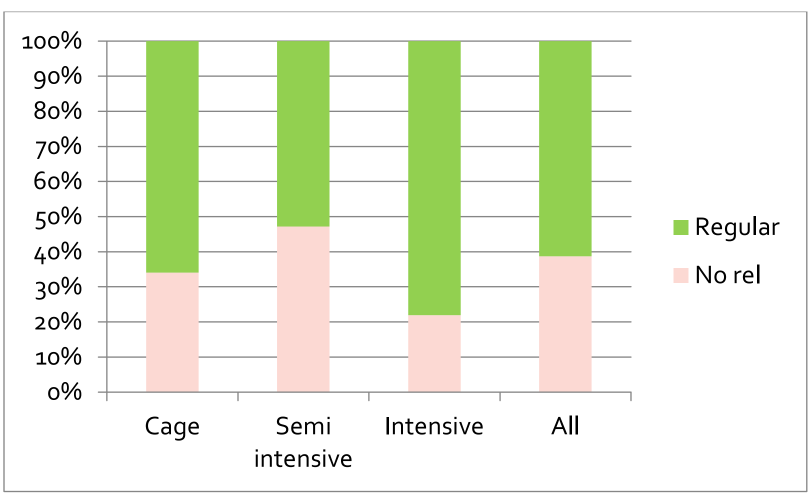


FIGURE 4.17. PROPORTION OF PRODUCERS SELLING TO REGULAR AND IRREGULAR CLIENTS

Focus groups of aquaculture producers were asked more generally about the perceived level of trust within their community and in their relationships with outsiders, whether high, medium or low. Most ranked trust within their community at a medium level (7 out of 9 FGDs), two groups putting it at high to medium. There was somewhat lower trust of outsiders, particularly traders and fish feed sellers, which was put at low, or medium to low by five groups and medium by four others. Trust is lower when the relationship involves money. It depends on observation and individual characteristics, a person's history and reputation and behaviour over time. "*There is no trust of outsiders when we don't know where they are from or their origin" (*FGD, Thmar Koul, Battambang SI*).* The length of the relationship is important. *"Over the last 10 years people have lost money to outsiders. Now they are more cautious*" (FGD Krakor, Pursat, cage).

4.5.3 Social involvement

Focus groups explored whether communities participate in decisions that impact their livelihood. Producers reported that issues relating to aquaculture and aquaculture policy, fishery law and related topics including policy, are raised in meetings convened by local government and NGOs. It is difficult to assess the extent to which feedback and discussion is solicited at these meetings and subsequently acted upon. One woman in the focus group with cage producer in Krakor, Pursat commented:

> *"Two and a half months ago a loud speaker announced a meeting .... I don't care much ..... high ranking government officials talk and talk until you are asleep."*

There appears to be little consultation on the establishment of new enterprises within a community which might impact on local livelihoods.

The CAMCODE recommends that decisions should be evidence based taking into account traditional knowledge of the resources and aquatic habitats, as well as relevant environmental, cultural, economic and social factors. Actions around community fisheries draw on local knowledge of the environment and seasonality. It is less clear the extent to which local knowledge is integrated into the technical recommendations and training content for aquaculture.

Concerning participation in voluntary communal activities for benefit of the community, the main contributions are to communal labour or financial contribution for the upkeep of roads, maintenance of pagodas and fencing. This is organized by the village head. In some locations, people assist each other in field operations for rice cultivation. Community members also contribute to the cost of traditional ceremonies.

An issue that was widely discussed within the focus groups relates to social expenditures; an indication of investment in social relationships. "*The major part of our income we spend on social relations*". The level depends on the family, but in one group people estimated expenditure on ceremonies and weddings of between $500 (equal to two tons of rice) and more than $1000 per year. In areas closer to Phnom Penh, contributions are higher – 20$ per wedding, 10$ for ceremonies, with some estimating expenditure at over 2000$ per year. The frequency of invitations depends on your position in the village/ commune (local leaders, policeman and teachers receive more). There can be from 30 to 50 per year. It is important to attend to sustain communication and traditional relationships as well as current relationships. Those holding weddings are expected to provide food and drinks (soft and alcoholic) and traditional music. Guests take money as a wedding present, around 10$. If they do not attend, they are still expected to send money if they receive and invitation. It is some kind of mutual support and tradition. At funeral ceremonies they take rice and money. At traditional ceremonies on Buddhist days (4 per month) they take cash and food for the monks who say prayers for the ancestors, although this involves fewer families. There are village ceremonies after harvesting for the 'harmonisation' of the village and to ensure good luck and health for which people provide milled rice and money (2 - 5$).

4.6 What are the standards of Health, education and training infrastructure and services and do the VC operations contribute to improving them?

4.6.1 Health services

Focus group discussions explored the level of households' access to health facilities and services, and their affordability. Health facilities are accessible in the areas of the country visited during fieldwork. There is a combination of public and private health care provision and traditional medicine. All communities visited said there was a clinic or health centre within 10km distance. In addition to the health services in public and private clinics there are private individuals who offer health services. These people are medically trained, but there is no system of licensing, so quality of service could be an issue. Other health services include nutritional supplements for mothers and babies, immunization etc.

The health care system is not free. Fees are charged for attendance at private facilities. Public facilities such as community health centres make a small charge (less than 1$) unless households have a social welfare ID card, but medicine is free. An overnight stay costs 10$ per night. Costs are covered from household income, savings, or borrowing from friends and relatives (CSES 2014). There is no general system of health insurance.

Income from aquaculture can contribute to household savings and security in case of illness of a family member.

4.6.2 Housing

Housing quality in rural areas of Cambodia is of relatively good quality. In rural areas 93% of households have roofs made of permanent materials and 77.1% use hard permanent wall materials. Flooring in rural areas is mainly of wooden planks, although 13% are tiled or cement (CSES 2014). House ownership is higher in rural areas (95.7%) than urban (94%). Access to mains electricity is 58% in urban and 47% in rural areas where many people use battery power and increasingly, solar as well as traditional lamps. The majority use woodfuel for cooking. Floating houses need regular expenditure on maintenance and major structural repairs every few years. The contribution of aquaculture in addition to fishing is important to cover these expenses.

Households access to good quality water and sanitation facilities was explored both in focus groups and with reference to the Cambodia Socio economic survey 2014.

The growth of aquaculture has benefited from the existence of many small ponds owned by rural households, maintained principally as a source of water for the household, vegetable cultivation and for livestock.

Access to safe drinking water varies according to season. Overall, 51% of households have access to improved water sources in the wet season and 58% in the dry season. The respective figures for rural areas are lower, at 43% and 51%. There is greater use of unprotected sources in the wet season. Improvements in rural areas have been slow. 67% of rural households said they treated their drinking water.

Focus group discussions reflected the CSES 2014 results. Households reported using underground wells, ponds and rainwater for drinking. Some purchased water for drinking, particularly in the dry season, using pond and lake water for washing clothes and dishes. Some households filter or boil the water before drinking.

With respect to sanitation, overall 56% of households have access to improved toilet facilities, with 46% in rural areas. 47% of households use open land in rural areas (CSES 2014). There has been an improvement over the 2009 rate of 20%, but the poor state of sanitation remains an issue in disease transmission and poor hygiene.

Participants in villages commented that the presence or otherwise of latrines depends on whether the village has had NGO involvement, in which case households generally have latrines. Across the locations visited, 50-80% of households were said to have a latrine, with the lower rates in poorer areas. However, among the cage producers living in floating villages or houses by the lake, the rates were much lower. For example, in Prasat Bakong, Siem Reap, the group reported around 2% having latrines. They said they used to be contacted about this, but now there is no programme. During the flood season they can take a boat out to the forest, in the dry season, they use nearby fields or plastic bags at night. A latrine costs about 500$.

4.6.3 Education and training

There is free public education in Cambodia, although private schools also exist. There are additional costs involved in schooling, such as materials, transport, snacks etc. Generally speaking, primary education is accessible to households; access to education is easier at the earlier stages and increases in difficulty in terms of distance and cost, at secondary and post-secondary levels. Most communes have a primary school, some providing for the first six years of education and others covering up to nine years (ages 6 to 14). All the focus group discussions said that nearly all children of primary school age were in school.

Secondary and/or vocational education is less accessible to households. Some communes also have a secondary school, which also serves adjacent communes. Attendance is influenced by the distance pupils have to travel. A group of aquaculture producers from a floating village visited in Pursat explained that children attend a floating school for the first 6 years (6-12 years). They must learn to swim before they can go to school as the travel in small boats If they can't swim they may delay going to school until they are 7 years old. Children over 12 go to school on the mainland. They attend 4 days a week for a whole day and 2 days per week for ½ day. This distance is around 6-7km. They take a boat to the jetty (which moves according to the water level) and they then travel by bicycle. The costs of sending children to school increase with age as they have to travel longer distances. There is a high dropout rate at this transition point, around 50%, linked to cost. Around 1.25$ per day are needed, for transport and food. A 50% attendance rate at secondary school was reported in other districts of Siem Reap.

The existence and quality of in-service vocational training provided by investors in the value chain was explored. For producers, investment in training by FIA, donor funded projects and NGO initiatives, has had useful results. Particularly important examples in aquaculture are the training of local seed producers and the development of their network; training for individuals in freshwater prawn production and training in the rice/fish system. Small scale processors do not appear to have benefited from training, although there are information products designed to address issues of hygiene in fish processing. The Post Harvest Technology and Quality department of FIA provide training for fish processors. They have conducted training for the last 5 years with EU and government funds, covering hygiene practices at processing facilities (stakeholder interview FIA).

4.6.4 Mobility

As indicated above young people move to take up opportunities in non-agricultural work. Thus labour mobility and migration provide positive economic opportunities. In areas near Phnom Penh, factory work is available but people looking for work may go further afield, for example, to Thailand or South Korea, where, it was reported, they can get contract work paid up to 1000$ per month and an end of contract bonus of 2000$. Some also work in cassava plantations in Pailin Province. Rural to urban migration is 57% of the total, rural to rural 13% and emigration 30%.

Women constitute a larger proportion of migrants. Women in all occupational categories except in the garment industry receive lower wages than men, but remit larger amounts to their families, on average 20% more (Kheam and Treleaven 2013). Women are more likely to move to urban areas. They are especially vulnerable when employed in domestic work. Employment in the fishing sector in

Thailand is male dominated and employs significant numbers of Cambodian migrant men. Accurate overall figures are hard to come by. 700,000 Cambodian migrants with irregular status registered with the Thai authorities from July to October 2014. Migration by a household member or members is part of household livelihood strategies. Those interviewed felt that more supportive policies and procedures could help.

The objective of the government's policy on labour migration is to develop a comprehensive and effective labour migration governance framework that protects and empowers women and men throughout the migration cycle, ensures that migration is an informed choice, and enables a positive and profitable experience for individual workers, their families and communities, that also contributes to the development of Cambodia. It articulates 17 policy goals. The *National Policy of Cambodian Youth Development* in association with the *National Youth Action Plan 2014–2018*, seeks to provide alternatives to migration, while the Millennium Development Goals Acceleration Process includes providing employment and training services as alternatives to migration and options for returning migrants. Positive outcomes of migration include increasing remittances, skills acquisition, lower unemployment, and poverty reduction. However, in some areas it may result in a reduction of food production and shortage of labour at critical times.

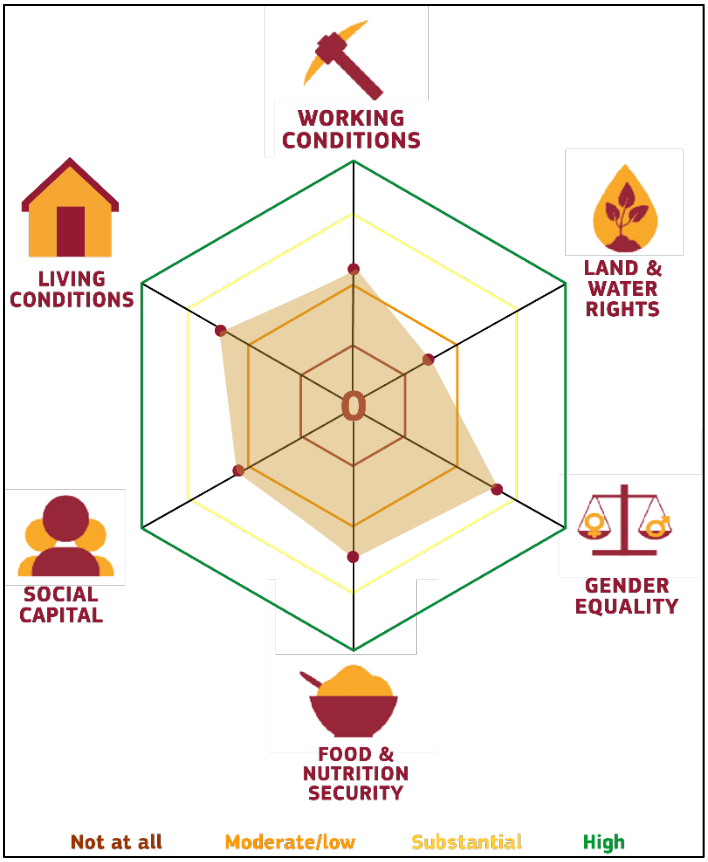
Conclusions of social analysis

This section summarises the main findings and associated recommendations presented above.

4.6.5 Assessment of the social domains.

A score for each of the six domains was calculated from the average scores of the component questions, in each sub domain, according to the degree that the response was realised, whether high, substantial, moderate/low, or not at all. A high score indicates positive social conditions, while a low score indicates potential risks.

The diagram shows the consolidated score for the overall aquaculture sector.



With respect to **working conditions**, ILO labour standards are included in Cambodian labour law 1997. However, aquaculture mainly operates outside formal labour law and without formal contracts. The Cambodian Code of Conduct for Responsible Fisheries, CAMCODE sets out guidelines and good practices, but levels of awareness on its content are limited. The broader context of labour relations and freedom of association is somewhat contentious.

There was no evidence found of forced labour in the aquaculture value chain and no obvious discrimination. In case of expansion of large-scale higher capital intensive commercial aquaculture production, employment opportunities are likely to favour men while processing offers more opportunities for women. Aquaculture provides comparatively good wages for workers. However, working hours in aquaculture production and trading enterprises are unregulated. Aquaculture can be an attractive proposition for young people if they have access to capital and good technical advice. For those without such access, other forms of employment are more attractive.

Children who contribute to aquaculture work on average less than one hour per day. Primary school attendance is over 80% for boys and girls, but there is a high dropout rate from education at the age of fifteen. Children mainly do lighter tasks in aquaculture, but in some cases they may be at risk from liming ponds.

The main health risks arise in processing - particularly the handling of fish waste and waste water. Most processing enterprises have toilet and washing facilities and provide gloves but not other protective clothing. Pollution of water from poor sanitation and industrial effluent are further risks in some locations.

- Further development of large scale aquaculture enterprises risks negatively impacting vulnerable groups unless working conditions are improved. There is a need to increase awareness of the content of the CAMCODE among fisheries personnel, local government, NGOs etc. it is important that the conditions of labour employed are monitored, particularly issues around health and safety, hygiene and working hours and hazards of chemical use for producers.

Regarding **land and water rights**, the available information on tenure issues in Cambodia makes no reference to Voluntary Guidelines on tenure (VGGT) or the Guide to due diligence, although Cambodian land law reflects many of the principles. The granting of economic land concessions to investors has not necessarily followed the principles; in particular, levels of prior disclosure, participation and consultation are highly variable and the payment of compensation and provision of alternative livelihoods, infrastructure and services are not always adequate. In floating villages and recent settlements around the lake, people do not own land and were not beneficiaries of 1980s land distributions. Local governance structures function as conflict resolution mechanisms, but there is no independent dispute resolution body. The environmental impacts of enterprises are also difficult for smallholders to deal with. Weak land and water governance in relation to further investment in and expansion of aquaculture could have detrimental effects on local communities, who generally have a low level of awareness of tenure rights and reluctance to seek remedy in case of environmental impacts.

- Further investment in large scale aquaculture should be conditional on investors following the provisions of Cambodian land law with regard to identification of locations, respect for tenure rights, local consultation and consent, social and environmental impact assessment and compensation and mitigation of livelihood impacts. This could be supported by awareness raising among district and commune leaders and encouraging local reporting of infringements.

Gender equality was a relatively high scoring domain. Women are active in aquaculture production, processing, trade and retail. However, poverty is a factor as value chain participation depends on access to land, labour and capital to invest. Poorer rural households tend to concentrate on rice production and wage labour. Compared to men, women's operations in aquaculture production are smaller. Women are proportionately more represented in semi intensive systems and small cage production than intensive ponds and large-scale cage production. The development of rice-fish farming and local seed producer networks, were reported to have made a positive difference to women and poorer participating households.

Women's property and inheritance rights are supported in law, but there is limited awareness of rights among women and poor access to legal advice in case of disputes. Women have varying degrees of autonomy in organisation of their work. In agriculture and aquaculture production, men and women generally describe their practice as joint decision making. For decisions on market trading, women are more influential. Women have quite a high degree of control over family income, often managing the pooled household income to cover daily living expenses. However, major decisions on expenditure are discussed and negotiated among family members. When money is scarce, domestic conflicts can arise.

An important distinction is drawn between the hours of work - which are longer for women - and the physical intensity of work, which is greater for men. While women have taken up opportunities for earning income, there has been a lack of transformation in gender roles, in particular the domestic burdens on women. Women are not commonly found in leadership positions, although recently there have been steps to increase women's representation in public life.

Lack of women's participation in consultation and decision making processes may risk women's interests being underrepresented. Recognition of women's role in aquaculture production as well as processing and trading is supported by the FIA's National action plan on Gender Mainstreaming and Elimination of worst forms of child labour.

- Gender strategies and action plans need active promotion among both fisheries personnel and value chain actors, with more emphasis on training, practical implementation and monitoring, together with the resources to support this.

Concerning **food and nutrition**, food supplies are generally increasing, with improving rice yields, stable prices and ready availability of fish on local markets. The large volumes of relatively cheap imported fish are an advantage for consumers, but fish producers complained about the negative impact on prices. Despite the high rates of fish consumption, the levels of child and maternal malnutrition are high. Levels of child malnutrition have shown only modest improvements over the last 10 years. Mortality rates are much higher among children of uneducated mothers, those from the poorest households and in rural areas. Micro nutrient deficiencies are important, and dietary diversity is limited. Food preparation practices also influence nutritional content. Poor water and sanitation provision contribute to poor nutrition. The nutritional status of children is affected by waterborne diseases and parasites linked to the absence of latrines.

- A sustained programme of improvements in sanitation and latrine construction is needed to reduce infections and improve water quality.
- Efforts to integrate nutritionally valuable small fish species into some semi intensive systems could be considered.

The **social capital** scores were moderate to low. There are relatively few groups and farmers' organisations at community level. In aquaculture there were informal groups formed around local fingerling producers. The poorest members of communities tend to be excluded as they lack the resources (land, financial contributions etc) to participate. Market instability and unpredictability contribute to the perceived risk and reluctance to engage in collective enterprise. Where NGOs have formed groups, there is a recognised need for investment in leadership skill development.

Levels of trust between actors in the value chain were reported to be quite high, particularly among processors, intermediaries and intensive producers. Processors and traders have developed relationships based on a long history of personal relationship and trust and hence perceive limited benefit from group collaboration. Within communities, social relationships can bring positive and negative impacts; the social norms requiring financial contributions to ceremonies and weddings result in extremely high levels of expenditure for many households.

The lack of farmer-based organisations which relates to the complex social and political history of Cambodia, limits the bargaining power of producers in the value chain and arrangements which could benefit both farmers and production conditions. It also inhibits cost effective access to information and training and input markets. There are examples of farmers who are organised mainly in relation to seed supply, which directly benefits the connected farmers. The arrangements are however mainly project and donor based, which tend to be of a temporary character.

- A strategy to strengthen groups with common interests to access technical information and cooperate in input access could be supported by actions to strengthen group governance capacity.
- Expansion of seed producer training and networks in areas where there is market demand, to improve access to seed, information and improve productivity.

Living conditions varied considerably across different types of provision, but were overall moderate to low. Infrastructure provisions in health, education and housing are generally good. Payment for health care can create stresses on households as health insurance is not widely available. Water and sanitation are important areas requiring improvement. Attendance at secondary school is influenced by the distance pupils have to travel as this influences costs.

There is limited extension provision outside specific programmes. Advice and training are mainly from Fisheries Administration personnel (production and post harvest), local seed producers, fish feed retailers, radio and TV. Access to services is harder for cage producers, partly as a result of their location. People are informed on issues relating to aquaculture policy by local government and NGOs, but there appears to be little systematic feedback and discussion solicited and subsequently acted upon.

- Extend training and support to ensure greater coverage of cage producers.

Migration by household member/s is part of rural household livelihood strategies, particularly where resources are limited. Young people move to work in Phnom Penh, Thailand or South Korea. Men constitute a larger proportion of migrants than women. The government is seeking to develop a comprehensive and effective labour migration governance framework to facilitate the process. Positive outcomes of migration include increasing remittances, skills acquisition, lower unemployment, and poverty reduction. However, in some areas it may result in a reduction of food production and shortage of labour at critical times.

4.6.6 Social sustainability of aquaculture value chains

In considering the social sustainability of aquaculture value chains it is important to understand the different roles of aquaculture in livelihoods. These vary according to system and location (Joffre *et al* 2010) and influence the relevance of interventions in support of aquaculture systems. The analysis presented above discusses the differences between extensive ponds, rice-fish systems, semi intensive, cage aquaculture and intensive pond production. However, within these categories, particularly rice fish systems, semi intensive and cage aquaculture, there is a range of investment levels across different farmers and for an individual farmer in different seasons or years.

4.6.6.1 Extensive pond systems and rice fish systems:

In the lowland areas such as Takeo province, aquaculture is important as part of a diversified portfolio of household income-raising activities which include rice and vegetable production, animal rearing, local trade, wage labour, home processing of fish, catching wild fish in rice fields and work in the garment industry or other urban occupations. Aquaculture is important and highly valued as a source of food, especially for communities with no access to capture fisheries. It helps save money by substituting for expenditure on purchased fish and meat. Fish are harvested mainly for food and local sale through personal networks or in the local market. Patterns are similar in Battambang province where people have access to agricultural land but also some labour opportunities in fish processing. Poorer people can supplement their income by collecting freshwater clams and other aquatic species.

The rice fish systems were reported to have benefits not only for aquaculture, but also for improving rice yields and lowering costs of weed control. Although some farmers received assistance for pond enlargement, channel construction and initial stocking, the systems appeared to be sustainable after project support was ended. The advantage of these systems, as articulated by producers, is that they are flexible with regard to capital requirement, relying almost entirely on feed resources from their own farm land. Some farmers purchase small quantities of feeds from the market when cash availability allows.

These systems are resilient but have low productivity, although rice–fish systems with improved management are showing yield benefits and there is enthusiasm for their expansion.

<u>Semi intensive pond producers</u>

Semi intensive production was found in all provinces visited, with men and women operators, although women were generally operating at a smaller scale. This category spans the space between extensive and intensive, with some farmers reverting to extensive production if they suffer from lack of financial resources and poor returns, while others have some of the characteristics of intensive production. The combination of livelihood activities was similar to the extensive and rice fish farmers, the difference being the higher rate of use of purchased pelleted feed and other inputs. Semi intensive producers in Battambang benefitted from the availability of affordable waste from fish processing. Aquaculture contributes to household consumption as well as sales.

There is a large financial and skill related 'gap' between semi intensive and intensive production. Many smallholders have found it hard to sustain higher level semi intensive production without continued project support or subsidy. Not only is the capital requirement for feed purchase a challenge as the early growth period coincides with the months of hardship, but the required level of management and marketing skills and networking can make the difference between success and failure. FIA and various projects' support to seed producer networks and seed supply systems have had a positive effect. The seed producer networks and the seed supply systems set up by trained individuals in their communities have improved the availability, quality and survival of fingerlings and helped to support semi intensive production. The seed producer networks and supplier nodes are also effective convening points for training and informal learning. As with the rice fish systems, there is interest in other provinces in establishing seed producer networks building on this experience.

Intensive pond systems

These are operated as specialist enterprises employing wage labour (mainly men). Interestingly, the amount of home consumed, home grown fish per household and per capita was highest for this category. Intensive ponds incur higher feed and input costs and require more diversified linkages to input and market channels. Intensive systems are higher in productivity with the capacity to generate large incomes, but they are also higher risk, being vulnerable to market price fluctuation, which producers attributed to large volumes of cheap imported low quality fish from Vietnam which outcompete local aquaculture. This is despite higher levels of trust reported in relationships with buyers and input suppliers. Market price was the most frequent problem expressed in interviews with intensive producers, who wanted to see policy intervention to control the quality and quantity of imports in order for their businesses to survive.

Businesses such hatcheries combined with intensive production could be attractive for young people if access to capital was facilitated. If large scale aquaculture enterprises are further expanded it is important that the conditions of labour employed are reviewed, particularly issues around health and safety, hygiene and working hours. Environmental impacts of such enterprises and the environmental impacts of industry on aquaculture of all types need to be addressed. Further investment in large scale aquaculture should be conditional on following the provisions of Cambodian land law with regard to tenure rights, local consultation, social and environmental impact assessment and compensation.

4.6.6.2 Cage production

Cage aquaculture is also practiced at varying degrees of intensity, from small producers relying on waste from processing or small capture fish, to those utilising high levels of purchased pelleted feeds and producing multiple cycles per year. Cage producers from landless floating communities in Pursat and Siem Riep Province reported that most of their income comes from capture fisheries (70-80% of income) and cage aquaculture (20-30%). There were opportunities for tourist related income around Siem Reap where people can earn up to 500 to 1000$ in the main 6-7 month season taking tourists in boats. This is organised through the community fisheries group. Trade and wage labour were also important.

Cage producers, particularly in the north of the Great Lake, had less access to training and support than those around Phnom Penh. They also appeared to be at a disadvantage in locally accessing seed and selling to markets. Remoteness of location increases costs and reduces competition. Levels of trust in other value chain actors were lowest in this group. The ethnic origin of many small scale cage producers (those originally from Vietnam) may be a further factor in their comparative marginality. However, larger scale producers from the same ethnic group have combined to use their networks successfully to access inputs from Vietnam. Problems of sanitation and water pollution particularly apply to locations with high concentrations of floating homes, many with aquaculture cages beneath. An important social requirement in aquaculture development is to ensure that development efforts recognise these different livelihood patterns, economic capacities and circumstances, tailoring interventions to extensive and rice fish systems, semi intensive pond production, landless cage producers and intensive producers. There should be compatibility between the objectives and capacities of producers, and the scale of their operation and investment. Past experience with intensification has indicated that even with training and business skill development, it is difficult for small producers to sustain investment in feed purchases after project assistance is withdrawn and many revert to their former extensive or semi intensive production. Reasons relate to high feed costs, lower productivity than anticipated and poor market prices.

In terms of social inclusiveness, attention to rice fish and semi intensive systems and small cage production will help to benefit women producers. Similarly, interventions relating to credit and finance for aquaculture need to be tailored to different scales of operation and accessibility improved for women producers. Given the important nutritional contribution of small fish species, efforts to integrate these into some semi intensive systems could be considered. Efforts should be increased to reach small scale cage producers with information and support. The use of mobile phones with information and training applications could be a cost effective way to reach many small producers. Issues relating to sanitation and water pollution which affect both aquaculture production and health and nutrition, need further action at commune level, particularly around the Great Lake.

5. Environmental analysis

5.1 Introduction

The environmental analysis of the aquaculture value chain is based on the Life Cycle Assessment methodology described in two ISO standards / norms (ISO 14040 and 14044). LCA is a comprehensive environmental accounting tool with well-established procedures and international standards (ISO).
The procedure for LCA requires four steps in LCA, which include (Figure 4.1);

1) Defining the goal and scope definition,
2) Life cycle inventory (LCI) analysis,
3) Life cycle impact assessment (LCIA), and
4) Interpretation.

LCA has been previously used to evaluate environmental performance of fishery and seafood products.

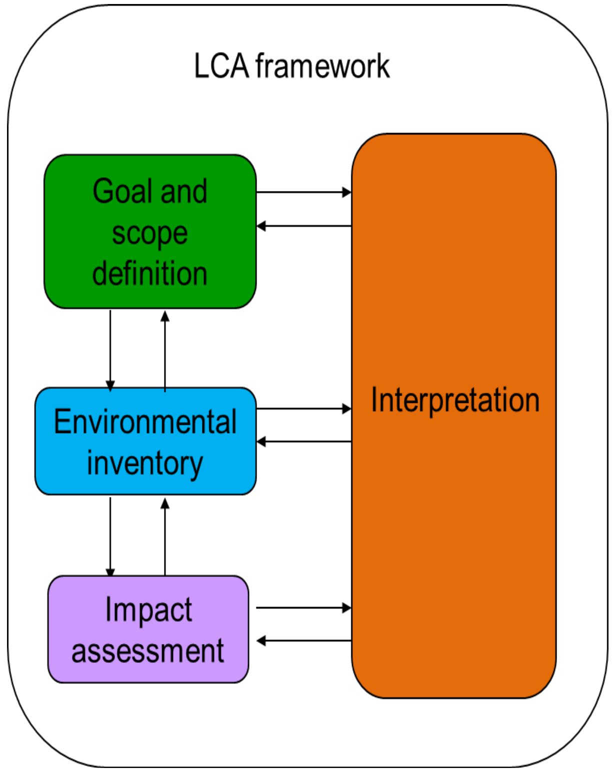


FIGURE 5.1. THE FOUR STEPS OF THE LCA FRAMEWORK

This methodology includes 4 steps, which represent the 4 parts of this analysis. Although the relevance of this framework for evaluating the environmental impacts of agricultural and food products has been demonstrated, its application to aquaculture in South East Asia has mainly occurred over the last decade. The life cycle assessment for the Cambodian aquaculture case represents some challenges, which are mainly related to the diversity of the sector; including multiple species production, variety of production systems, locations and local conditions, and a variety of end products. Therefore the current study required a specific focus on the value chains subject to analysis.

5.2 Goal and scope definition

5.2.1 Objectives

In view of the different challenges identified by the different stakeholders interviewed, the key objectives of this LCA study were:

- To evaluate the impacts of the 3 main production system types identified, according with the 3 areas of protection in LCA:
    - Human Health
    - Ecosystem quality
    - Resource Depletion

- To evaluate the impacts of one additional processing chain
- To identify their respective hot-spots and margins for improvement
    - The hot spot analysis is based on the LC assessment, in addition to expert judgement.

5.2.2 Goal and scope

The LCA for this study has been carried out to assess the environmental impact of aquaculture practices in Cambodia. For this study a selection of aquaculture practices was made, and therefore it does not cover the full diversity and volume of the aquaculture sector in Cambodia. Data in this study are derived from field surveys (n= +10), and existing data from previous studies, which are not primarily targeting LCA (Nhu, Phang, Bosma, Henriksson, SEAT project).

The intended application of the study is to perform an analysis of the state-of-the-art of Cambodian aquaculture within the defined aquaculture systems. This may be used to evaluate future changes in the industry (according to proposed development plans) and to identify current hotspots of environmental impacts.
The audience of the impact assessment results are the governmental bodies involved with aquaculture sustainability and development.
Different aquaculture systems are not directly compared, however the differences in impacts and differences in value chains are described as a background to understand future potential management decisions. Analyses are performed according to similar functional units, and similar system boundaries using defined Cambodian production and value chains.

The scope of the LCA was defined as described below.

5.2.3 System boundaries

The gate-to-gate production chain, including foreground systems, including feed production and fish farming at the farm-level. Impacts through nutrients (i.e., total nitrogenous (TN) and phosphorus (TP)) released via sediment (and wastewater) are modelled using digestion models to calculate the fate of input nutrients. Specific residues released through wastewater are calculated based on average application data, due to an absence of specific quantitative data on application of medicines.

Inputs such as feed are included in the inventory. Homemade feed is quantified based on interviews, whereas the composition of commercial feed from Vietnam is derived from previous LC Assessment studies. Where data is lacking on specific inputs and processes, data is derived from previous studies in a neighbouring country, Vietnam i.e. Bosma et al. (2011), Henriksson et al. (2015) and Nhu et al. (2016). Bosma et al. (2011). These assessments were all part of studies of pangasius (intensive) production systems. Data on inputs is in many cases directly applicable to the Cambodian case studies, since inputs such as feed are from similar sources (Vietnamese feed factories). For crop inputs, such as rice, these studies use generic rice production models, from South East Asian inputs, which make them an adequate replacement for Cambodian foreground data. Since a substantial part of the inputs, such as fingerlings, is imported from Vietnam, and Cambodia produces under similar production conditions, the results are an adequate data source. These indicators are used to identify hotspots in the environmental impact. For reasons of simplification, as well as a known relative low contribution to environmental impacts, the impacts of hatchery are derived from the Vietnamese LCA carried out by Henriksson in the frame of the EU FP7 SEAT project. Impacts through nutrients (i.e., total nitrogenous (TN) and phosphorus (TP)) released via sediment (and wastewater) were modelled using digestion models to calculate the fate of input nutrients.

The background system, defined as the part of the production chain outside the gate-to-gate boundary, includes industrial processes (agricultural cultivation, chemical production, transport, etc.) necessary to produce and deliver the inputs to the foreground system. Infrastructure (e.g. roads and harbours) is excluded due to its limited contribution towards overall impacts (Ayer and Tyedmers, 2009) and to be consistent with the data sourced e.g., production of fishmeal, fish oil or wheat farming (Henriksson et al., 2015b). Further infrastructures are included in background and foreground data.

5.2.4 Allocation rules

Pangasius and Snakehead can be sorted by means of quality indicators, in relation to consumers/traders demands, which will have different prices. However, we could not allocate the results on an economic basis due to data gaps on prices, local and seasonal variability for each farm system type. Economic allocation would have increased the variability in the assessment. Therefore our allocation corresponds to a mass allocation for which we allocated based on the weight of target species produced, and the additional production of non-target species. The environmental analysis follows a Life Cycle Assessment approach, for which a selection of aquaculture practices was needed, and it therefore does not include the entire aquaculture value chain.

One ton live weight of mixed fish (semi-intensive culture) or pangasius (intensive and semi-intensive pond culture) or Snakehead (cage and pond culture) delivered at the farm gate was selected as the overall functional unit (FU). The gate-to-gate production chain included foreground systems, including feed production and fish farming at the farm scale (see additional tables for supporting information).

5.2.5 Life cycle inventory (LCI)

In this study, data derived from fish farms were collected by a team of 5 interviewers. The interviewers received training on data collection, using a fixed format, which was designed to collect data on Economic, Social and Environmental parameters. The farms were visited during February and March 2017. The primary data in the groups are variable in; (i) the timing of the survey; and (ii) the data characteristics of some important flows, e.g., feed types, water input and nutrient emissions..

Data collected from the field surveys were aggregated in an Excel data base, followed by data cleaning, processing and calculation. The means of all inputs and outputs, were calculated per production system, and associated species. A sensitivity analysis was not performed on the data, due to the available time to process all data, and the explorative nature of this study. Data on variability is available for follow up analysis. Identified flows of the foreground systems (including fish farming and feed production). It was decided not to quantify the overall uncertainty (as foreseen in the protocol by Henriksson et al. 2014a) due to time constraints. The LCI sources for production and processing of feed ingredients (i.e., agricultural farming practices and capture fisheries) that accounted for most of the upstream emissions were mainly modelled using region-specific secondary data retrieved from other research, as included in the ILCD methodology. Average feed compositions were used to calculate the inputs of commercial feed sources. Additional inputs, such as lime production were quantified by LCI data derived from Ecoinvent v.3, LCA DK, USDI, etc.. For the additional inputs (e.g., vitamins, probiotics) used for pond preparation and farming, which were not available in the database, two more generic processes are used as defaults (‘chemicals organic, at plant/GLO’ and ‘chemicals inorganic, at plant/GLO’). CO2 emissions due the application of Lime stone (pond preparation) were modelled, based on Henriksson (2015). Models on emissions of aquaculture processes were performed according to Henriksson (2015) using foreground data on feed conversion and feed composition.

Allocation of the environmental impact among coproducts can be conducted based on different properties (ISO, 2006). Mass allocation was applied to the foreground system and the production/processing of feed ingredients whenever practical. Mass allocation was decided for due the potential to compare different life cycles assessments performed in the VC4D project, and to compare the data with studies performed in Vietnam. The influence of different allocation approaches based on mass or economic value on results was not assessed, although this may have a strong influence on the final results.

Processes inventoried in the Ecoinvent database (version 3) available in the SIMAPRO software (version 8.3), were used as background data for energy production (Dones et al., 2007), fertilizer production (Nemecek and Kägi, 2007) and pesticide production (Sutter, 2010). Due to the lack of LCA data specific for South East Asia, and Cambodia in particular, the transportation stages from the Ecoinvent processes were adapted to Cambodian data. All used parameters, inputs and results used in the inventory are described in a separate document: 20170616 VCA Cambodia Foreground and background data.xlsx. Fishmeal and fish oil data was derived from LCA DK database. Due to time constraints and timing recent documentation on the Peruvian fishmeal production could not be included (available after the primary LCA work) (e.g. Fréon et al. 2017).

Data was collected by two field studies of the international VCA team, which was used to make an inventory and overview of the entire value chain. Based on this inventory a questionnaire was designed, focusing on all inputs and outputs of the Value chain. A team of five interviewers performed a wide variety of interviews, and collected and compiled the data. The data was delivered to the VCA team, and further processed.

	Samples (n)
Mixed fish Pond production	14
Pangasius Semi-Intensive Pond Production	22
Pangasius Intensive Pond production	7
Snakehead Pond production	16
Snakehead Cage production	13

Table 5-1. Quantity of samples derived from fields surveys per production system/species combination. Values may vary from table 8 due to the separation of specific pangasius, and snakehead productions.

5.3 Environmental Impact Assessment

5.3.1 Assessment methods

The methods which were used are in accordance with the: "VCA4D Methodological Brief: Frames and Tools" for the VCA4D project. The environmental impact of the three different production types of mixed fish, pangasius and Snakehead production systems will be assessed and compared at the midpoint, including both resource- and emissions-related categories. The results represent the extent of impacts at an early stage of the cause-and-effect chain and act as straightforward standards for decision making.

Regarding emissions-related categories, following the work of Bosma et al. (2011) and Pelletier et al. (2007), the impacts on global warming (GW), acidification (AC), freshwater (FE) and marine eutrophication (ME) are calculated using the ILCD Midpoint 2011+method. The ILCD 2011 Midpoint method was released by the European Commission, Joint Research Centre in 2012. It supports the correct use of the characterization factors for impact assessment as recommended in the ILCD guidance document "Recommendations for Life Cycle Impact Assessment in the European context - based on existing environmental impact assessment models and factors? (EC-JRC, 2011)". The RECIPE 2.2 Endpoint World H/A (Hierarchical/Average) method is used as a holistic LCIA methodology that includes impact at endpoint level. The impact assessment was performed following the recommendations from the ENVIFOOD Protocol which also corresponds to the recommendations from the ILCD Handbook (2011). The indicators included are presented in the table below.

Field emissions	Recommended models	Comments
Ammonia (NH3)	EMEP (EEA 2013) Tier 2	For crops: emissions depend on the type and amount of fertilizer applied and the soil pH (EEA 2013, 3D, Tab. 3.2) For livestock: emissions depend on the housing period, the duration of grazing, N excreted, the liquid or solid manure storage and the manure spreading (EEA 2013, 3B, Tab. 3.7)
Nitrous oxide (N2O)	IPCC (2006) Tier 1 for crops Tier 2 for livestock x EEA 2013 IPCC (2013) for emissions due to drainage of peatland area	For crops: emissions consist of both direct and indirect field emissions. Direct field emissions are related to the total amount of N applied (synthetic or organic fertilizers, crop residues, animal grazing excrement…) (IPCC 2006, Eq./Tab. 11.1). Indirect field emissions are calculated as a fraction of previous direct field emissions of NH3, NOx and NO3- (IPCC 2006, Eq. 11.9-10, Tab.11.3). For livestock: emissions are calculated for both manure (depend on types and storage) and grazing (EEA 2013, 3D, Tab. 3.6). Indirect field emissions are calculated the same way as for crop-related indirect emissions.
Nitrogen oxides (NOx)	EMEP (EEA 2013)	For crops: emissions are related to the total N applied (EEA 2013, 3D, Tab. 3.1) For livestock: emissions are calculated after NH3 volatilization is deduced and depend on whether the manure is spread as liquid or solid (EEA 2013, 3D, Tab. 3.8)
Nitrate (NO3-)	SQCB (Faist Emmenegger et al. 2009)	Gaseous emissions of NH3, NOx et direct N2O are subtracted from the total available N before calculating nitrate leaching.
Methane (CH4)	IPCC (2006) Tier 2	For rice: the default emission factor for non-flooded rice fields is adjusted according to the water regime before and during rice cultivation, and to organic amendments (IPCC 2006, Tab. 5.11, 5.12, 5.13) For livestock: emissions are calculated for both the enteric fermentation (depend on feed and production levels) and manure management and grazing (IPCC 2006, Tab. 10.12, 10.17)
Phosphorus (P, PO43-)	SALCA-P (Prasuhn 2006)	SALCA-P includes formulae to calculate phosphate leaching to ground water and run-off to surface water, and phosphorus losses into surface water through erosion. It accounts for the land use type, soil type, distance to the next river and drainage, the type and quantity of P fertilizer and the impact of soil cover on erosion.
Heavy metals	SALCA-SM (Freiermuth 2006)	Heavy metals are found in soils, seeds, fertilizers, pesticides and also come from air deposition. Heavy metals may be leached to the ground water or lost into surface water through erosion. Emissions of heavy metals to the soil consist in the balance between total inputs minus total losses to water bodies.

Field emissions	Recommended models	Comments
		Default factors on heavy metals contents of crops and products are provided in the model documentation. When the studied crop or used product is not available in the reference publication an average of all relevant factors should be taken.
Carbon dioxide (CO2), fossil	IPCC (2006) Tier 1 for urea and lime application	IPCC 2006 Eq. 11.12, 11.13
Carbon dioxide (CO2), biogenic	IPCC (2006) for LULUC IPCC (2013) for emissions due to drainage of peatland area	See sheet LUC
Pesticides	Ecoinvent® v2 (Nemecek and Kägi, 2007)	An international working group in charge of building a consensus for pesticide emissions (Rosenbaum et al., 2015) is elaborating default emission fractions which should be available by the end of 2015. It is strongly advised to use them as soon as they are released in preference to the Ecoinvent® v2 method.
Water fluxes	For herbaceous crops : AQUACROP Model (Allen et al., 1998) For non-herbaceous crops: CROPWAT model using actual water withdrawn by farmers (Steduto et al., 2012)	CROPWAT suffers from scientific and conceptual limitations (see limitations due to the use of Ky and Kc) and is progressively replaced by the AQUACROP Model. AQUACROP is more relevant but is only available for herbaceous crops. Future versions of AQUACROP should include perennials. CROPWAT : http://www.fao.org/nr/water/infores_databases_cropwat.html AQUACROP : http://www.fao.org/nr/water/infores_databases_aquacrop.html

TABLE 5-2. RECOMMENDED MODELS FOR ESTIMATING FIELD EMISSIONS

The set of impacts and associated indicators presented in Table 5-2 is recommended by the European food sustainable consumption & production round table in the ENVIFOOD Protocol report version 1.0. The assessment methods (second column) represent the latest scientific consensus[10]. Although alternative methods for aquaculture specific LCA have been advised (Henriksson, 2015), it was decided to use the recommended methods in the VC4D approach.

[10]More information on these methods is available in the "Recommendations for Life Cycle Impact Assessment in the European context (EC, 2011)" from the ILCD Handbook (2011), presented in Step 1 of the project.

Global Warming Potential (GWP) is an indicator mapping all inputs or outputs that result in greenhouse gas emissions. The greatest contributor is generally the combustion of fossil fuels such as coal, oil and natural gas. The consequences include increased average global temperatures and sudden regional climatic changes. Climate change is an impact affecting the environment on a global scale. Unit of measurement: Kilogram of Carbon Dioxide equivalent (kg CO2 eq). During the calculations, the global warming potential of all greenhouse gas emissions are compared to the amount/equivalent of the global warming potential of 1 kg of CO2. Different emitted gasses have a different CO2 equivalence, e.g. CO2 (1 CO2 Eq), Methane (21 CO2 Eq), and Nitrous oxide (298 CO2 Eq).

The stratospheric Ozone (O3) layer protects us from hazardous ultraviolet radiation (UV-B). Its depletion can have dangerous consequences in the form of increased skin cancer cases in humans and damage to plants. The stratospheric ozone depletion is an impact which affects the environment on a global scale. Unit of measurement: kilogram of CFC-11 equivalent (kg CFC-11 eq). During the calculations, the potential impacts of all relevant substances for ozone depletion are converted to their equivalent of kilograms of Trichlorofluoromethane (also called Freon-11 and R-11).

Potential impacts on human health caused by absorbing substances through the air, water and soil. Direct effects of products on humans are currently not measured. Cancer in humans is an impact which predominantly affects people at local and regional scale. Unit of measurement: Comparative Toxic Unit for humans (CTUh). This is based on a model called USEtox.

Potential impacts on human health caused by absorbing substances from the air, water and soil. Direct effects of products on humans are currently not measured. Human toxicity is an impact which predominantly affects people at local and regional scale. Unit of measurement: Comparative Toxic Unit for humans (CTUh). This is based on a model called USEtox.

Potential toxic impacts on an ecosystem, which may damage individual species as well as the functioning of the ecosystem. Some substances have a tendency to accumulate in living organisms. Eco-toxicity is an impact which predominantly affects the environment at local and regional scale. Unit of measurement: Comparative Toxic Unit for ecosystems (CTUe). This is based on a model called USEtox.

The adverse impacts on human health caused by emissions of Particulate Matter (PM) and its precursors (e.g. NOx, SO2). Usually, the smaller the particles are, the more dangerous they are, as they can go deeper into the lungs. Unit of measurement: kilogram of Particulate Matter 2.5 equivalent (kg PM 2.5 eq). The potential impact of respiratory inorganics is converted into the equivalent of a kilogram of particulate matter of a diameter of 2.5 micrometres or less.

The exposure to ionising radiation (radioactivity) can have impacts on human health. The Environmental Assessment only considers emissions under normal operating conditions (no accidents in nuclear plants are considered). Unit of measurement: Kilogram of Uranium 235 equivalent (kg U235 eq). The potential impact on human health of different ionising radiations is converted to the equivalent of kilobequerels of Uranium 235.

While stratospheric ozone protects us, ozone on the ground (in the troposphere) is harmful: it negatively affects organic compounds in animals and plants and it increases the frequency of respiratory problems when photochemical smog ("summer smog") is present in cities. Photochemical ozone formation is an impact which affects the environment at local and regional scale. Unit of measurement: kilogram of Non-Methane Volatile Organic Compound equivalent (kg NMVOC eq). The potential impact of substances contributing to photochemical ozone formation are converted into the equivalent of kilograms of Non-Methane Volatile Organic Compounds (e.g. alcohols, aromatics, etc.).

Acidification has contributed to a decline of coniferous forests and an increase in fish mortality. Acidification can be caused by emissions getting into the air, water and soil. The most significant sources are combustion processes in electricity, heating production and transport. The contribution to acidification is greatest when the fuels contain a high level of Sulphur. Acidification is an impact which mainly affects the environment on a regional scale. Unit of measurement: Mole of Hydron equivalent (mol H+ eq). Hydron is general name for a cationic form of atomic Hydrogen. Mole is a common unit of measurement used in chemistry, expressing amount of substance. The potential impact of substances contributing to acidification is converted to the equivalent of moles of Hydron.

Eutrophication impacts ecosystems due to substances containing nitrogen (N) or phosphorus (P). These nutrients cause a growth of algae or specific plants and limit growth in the original ecosystem. Eutrophication is an impact which affects the environment at local and regional scale.
Unit of measurement: Mole of Nitrogen equivalent (mol N eq). The potential impact of substances contributing to terrestrial eutrophication is converted to the equivalent of moles of Nitrogen.

Eutrophication impacts ecosystems due to substances containing nitrogen (N) or phosphorus (P). If algae grow too rapidly, it can leave water without enough oxygen for fish to survive. Nitrogen emissions into the aquatic environment are caused largely by fertilisers used in agriculture, but also by combustion processes. The most significant sources of Phosphorus emissions are sewage treatment plants for urban and industrial effluents and leaching from agricultural land. Eutrophication is an impact which affects the environment at local and regional scale. Unit of measurement: kilograms of Phosphorus equivalent (kg P eq). The potential impact of substances contributing to freshwater eutrophication is converted to the equivalent of Kilograms of Phosphorus.

Use and transformation of land for agriculture, roads, housing, mining or other purposes. The impacts can vary and include loss of species, of the organic matter content of soil, or loss of the soil itself (erosion). Unit of measurement: kilograms of carbon deficit (Kg C deficit). This is an indicator of loss of soil organic matter content, expressed in kilograms of carbon deficit.

The withdrawal of water from lakes, rivers or groundwater can contribute to the ‘depletion’ of available water. The impact category considers the availability or scarcity of water in the regions where the activity takes place, if this information is known. Unit of measurement: cubic meters (m3) of water use related to the local scarcity of water.

The earth contains a finite amount of non-renewable resources, such as metals, minerals and fossil fuels like coal, oil and gas. The basic idea behind this impact category is that extracting a high concentration of resources today will force future generations to extract lower concentration or lower value resources. For example, the depletion of fossil fuels may lead to the non-availability of fossil fuels for future generations. Unit of measurement: kilogram of Antimony equivalent (kg Sb eq). The amount of materials contributing to resource depletion are converted into equivalents of kilograms of Antimony.

Impact Category	Impact Assessment Model	Indicators	Source	Model
Climate Change	Bern model - Global Warming Potentials (GWP) over a 100 year time horizon.	kg CO_2 equivalent	Intergovernmental Panel on Climate Change, 2007	ILCD 2011 Midpoint+
Ozone Depletion	EDIP model based on the ODPs of the World Meteorological Organization (WMO) over an infinite time horizon.	kg CFC-11 equivalent	WMO, 1999	ILCD 2011 Midpoint+
Ecotoxicity for aquatic fresh water	USEtox model	CTUe (Comparative Toxic Unit for ecosystems)	Rosenbaum et al., 2008	ILCD 2011 Midpoint+
Human Toxicity - cancer effects[11]	USEtox model	CTUh (Comparative Toxic Unit for humans)	Rosenbaum et al., 2008	ILCD 2011 Midpoint+
Human Toxicity – non-cancer effects[2]	USEtox model	CTUh (Comparative Toxic Unit for humans)	Rosenbaum et al., 2008	ILCD 2011 Midpoint+
Particulate Matter/Respiratory Inorganics	RiskPoll model	kg $PM_{2.5}$ equivalent	Humbert, 2009[12]	ILCD 2011 Midpoint+

[11] Human toxicity assessment models in LCA do not capture food safety issues, which are addressed by Regulation (EC) No 178/2002.

[12] Mainly based on Rabl and Spataro (2004) and Greco et al. (2007).

Impact Category	Impact Assessment Model	Indicators	Source	Model
Ionising Radiation – human health effects	Human Health effect model	kg U^{235} equivalent (to air)	Dreicer et al., 1995	ILCD 2011 Midpoint+
Photochemical Ozone Formation	LOTOS-EUROS model	kg NMVOC equivalent	Van Zelm et al., 2008 as applied in ReCiPe	ILCD 2011 Midpoint+
Acidification	Accumulated Exceedance Model	mol H+ eq	Seppälä et al.,2006; Posch et al., 2008	ILCD 2011 Midpoint+
Eutrophication – terrestrial	Accumulated Exceedance Model	mol N eq	Seppälä et al.,2006; Posch et al., 2008	ILCD 2011 Midpoint+
Eutrophication – fresh water	EUTREND model	fresh water: kg P equivalent marine: kg N equivalent	Struijs et al., 2009 as implemented in ReCiPe	ILCD 2011 Midpoint+
Eutrophication – marine water	EUTREND model	fresh water: kg P equivalent marine: kg N equivalent	Struijs et al., 2009 as implemented in ReCiPe	ILCD 2011 Midpoint+
Resource Depletion – water use	Water stress index model	m^3 water use related to local scarcity of water	Ridoutt, B.G. and Pfister, S., 2010[13] Swissecoscarcity, 2006	MidPoint
Resource Depletion – mineral, fossil	CML2002 model	kg antimony (Sb) equivalent	van Oers et al., 2002	Midpoint
Land use[14]	Soil Organic Matter (SOM) Model	Kg C (deficit)	Milà i Canals et al., 2007	Midpoint

Table 5-3. Environmental impacts, assessment models and indicators for the Cambodian LCA. (Source: Envifood Protocol V1.0, as summarized for VCA4D)

Characterization factors for all impact assessment models can be downloaded from the European Reference in the repositories. Long term effects were calculated using ReCiPE Endpoint World H/A.

[13] In this context, the scope of this method is limited to blue water only.

[14] Land Use reflects the damage to ecosystems due to the effects of occupation and transformation of land according to the ILCD definition.

Impact Category	Source of characterization factors	repository
All categories except water use	ILCD 2011	http://eplca.jrc.ec.europa.eu/ELCD3/LCIAMethodList.xhtml
Water Use	EI99+ water use	http://www.ifu.ethz.ch/ESD/downloads/EI99plus

TABLE 5-4. LINKS TO CHARACTERIZATION FACTORS FOR ALL IMPACT ASSESSMENT METHOD, AS PRESCRIBED BY THE VCA4D METHODOLOGICAL BRIEF.

Although the method for the land use impact category from Mila i Canals et al. (2007) is disputed, it was decided to include this as an impact category.

Regarding emissions-related categories, following the work of Bosma et al. (2011) and Pelletier et al. (2007), the impacts on global warming (GW), acidification (AC), freshwater (FE; linked with phosphorous emissions) and marine eutrophication (ME; linked with nitrogenous emissions) were considered using RECIPE midpoint (M) v.1.12). The RECIPE method is a recent holistic LCIA methodology that includes impact assessment methods for many impact categories and comprises a harmonized category at both midpoint and endpoint levels. The hierarchical (H) perspective was chosen because it is based on the most common policy principles with regards to time frame and other issues and is thus often encountered in scientific models (Goedkoop et al., 2013b).

5.3.2 LCI Results

The Life Cycle Inventory for Cambodian Aquaculture is summarised in Figure 5.2. In different aquaculture value chains, a different set of primary and secondary data needs to be acquired.

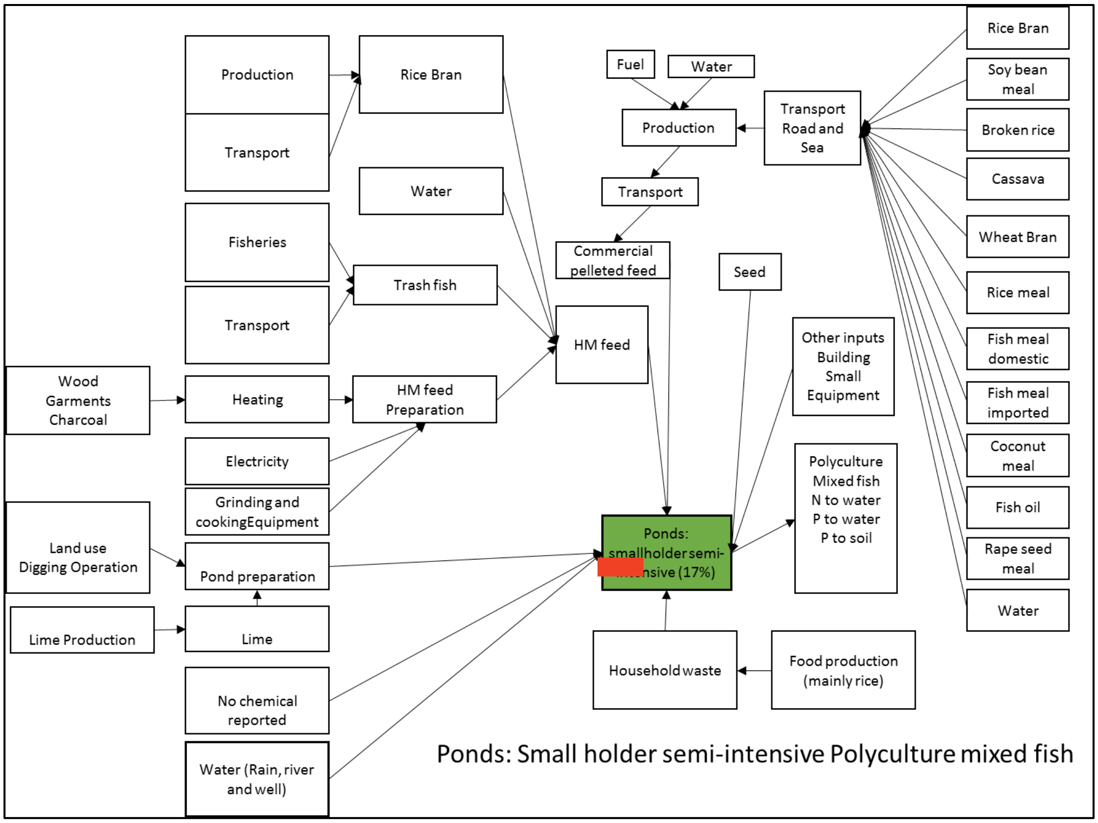


FIGURE 5.2. OVERVIEW OF THE LCI FOR CAMBODIAN MIXED FISH PRODUCTION IN POND SYSTEMS.

Arrows are used to indicate the flows of materials, other inputs and processes in the production processes. The boxes indicate the resources, or processes which are involved in the production process. Background processes for production of agricultural resources (eg. feed inputs) are not shown for reasons of simplification. System boundaries are inclusive, with the exception of seed and infrastructure (buildings).

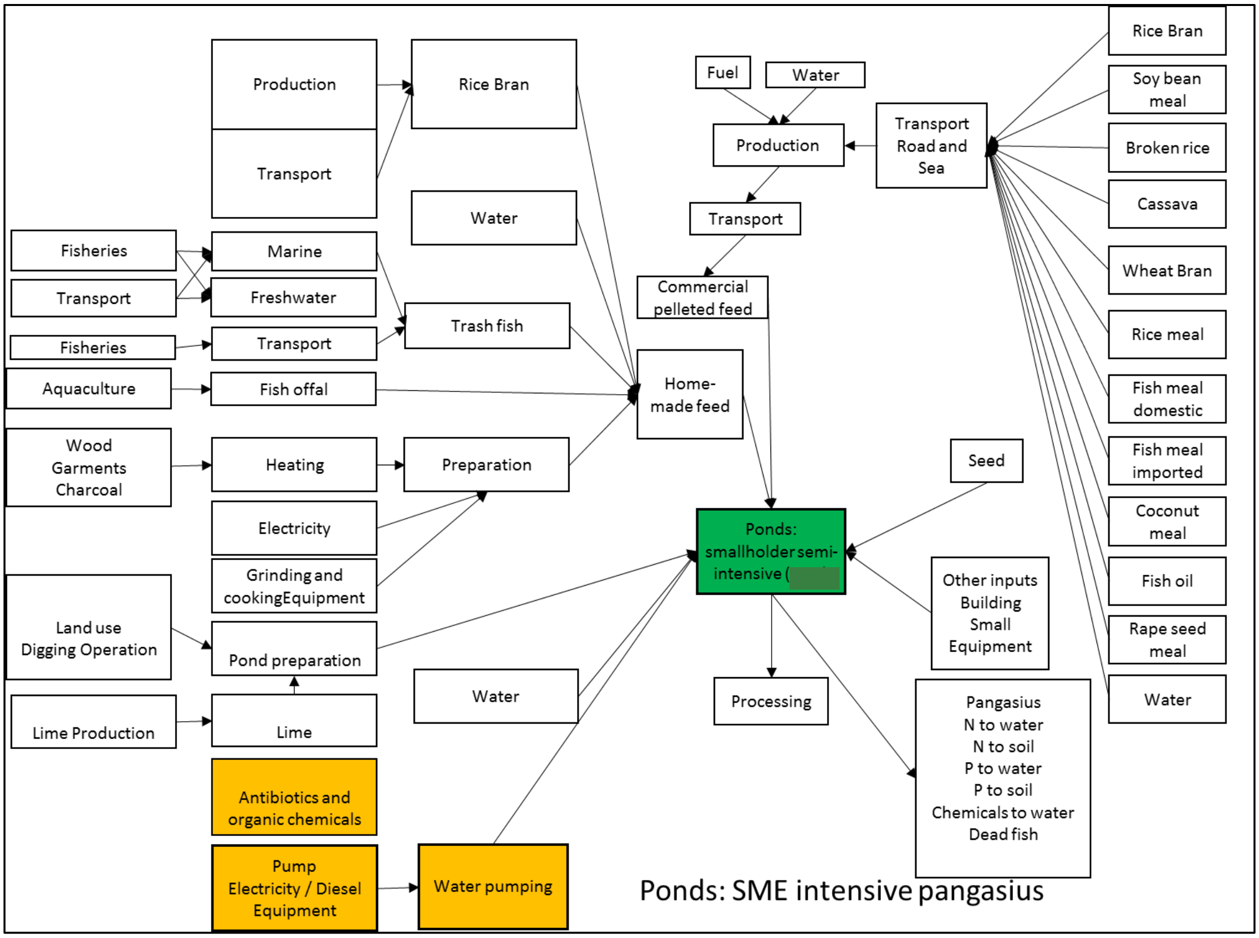


Figure 5.3. Overview of the LCI for Cambodian Pangasius (semi-intensive and intensive) production systems.

Arrows are used to indicate the flows of materials, other inputs and processes in the production processes. The boxes indicate the resources, or processes which are involved in the production process. Background processes for production of agricultural resources (eg. feed inputs) are not shown for reasons of simplification. System boundaries are inclusive, with the exception of seed and infrastructure (buildings).

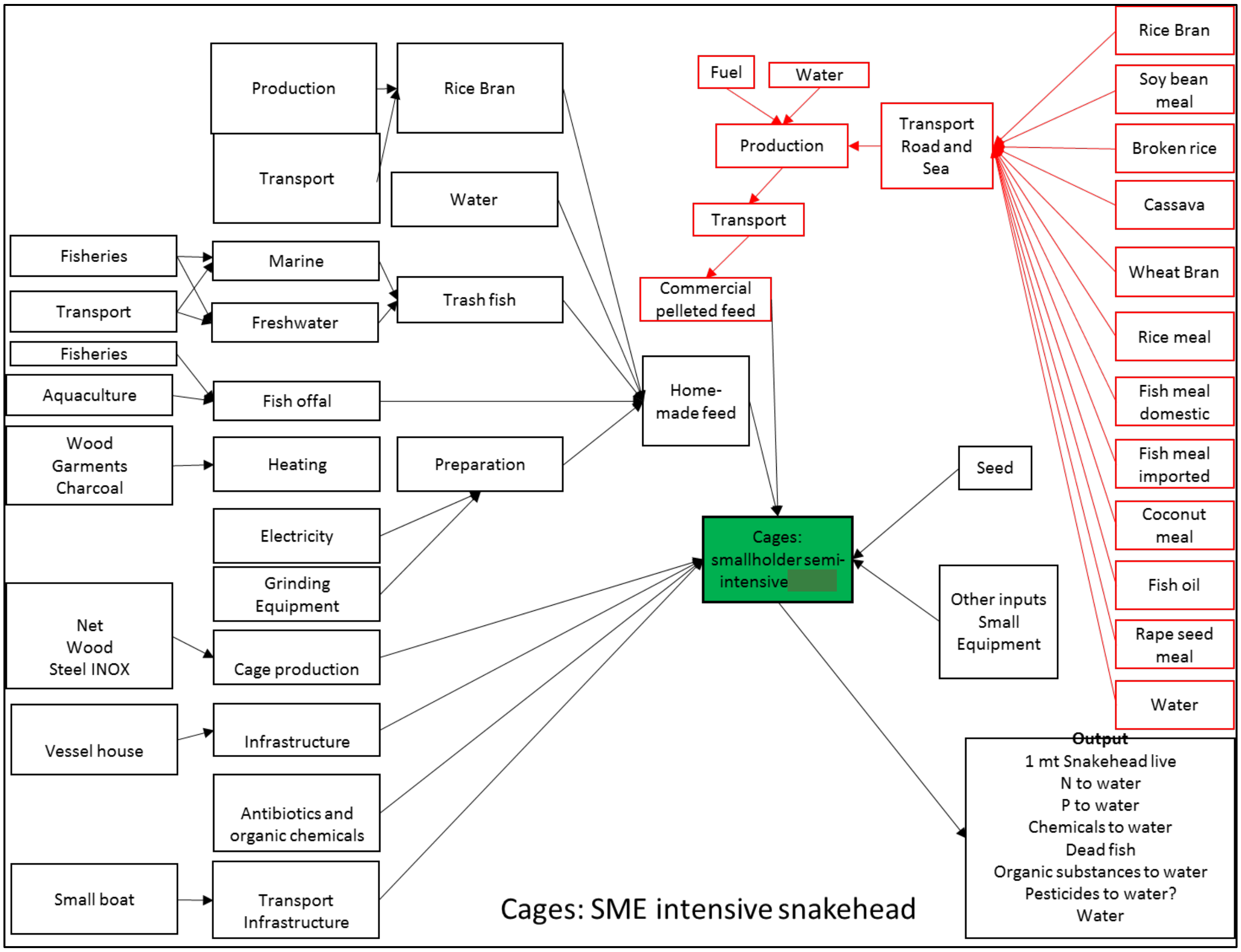


FIGURE 5.4. OVERVIEW OF THE LCI FOR CAMBODIAN SNAKEHEAD PRODUCTION IN CAGE SYSTEMS.

The boxes indicate the resources, or processes which are involved in the production process. The red boxes indicate the data derived from back ground processes. Background processes for production of agricultural resources (e.g. feed inputs) are not shown for reasons of simplification. System boundaries are inclusive, with the exception of seed and infrastructure (buildings).

5.3.3 Impact Assessment

The assessment of the impact of all aquaculture processes is calculated using SimaPro 8.3. This enables comparisons and data assessment. All relevant data used, and results of analysis are projected in separate Excel sheets, covering all calculations, assumptions, summarized data, as well as foreground data of all relevant parameters, and back ground information on results obtained in this study (20170616 VCA Cambodia Foreground and background data.xlsx).

The analyses are performed in accordance to a specific set of methods. Table 5-5 shows the end results derived from the ILCD MidPoint 2011+ analyses, with the relevant effect categories. All relevant (ILCD 2011) effect categories are assessed. However, in the further document, the impact categories, particle matter, ionizing radiation and photochemical ozone formation are not further elucidated. This is done to improve ease of understanding of the results for policy application.

Effect category	Unit	Mixed fish at farm gate Semi-intensive	Pangasius at farm gate I Pond	Pangasius at farm gate SI Pond	Snakehead at farm gate Cage	Snakehead at farm gate Pond
Climate change	kg CO2 eq	7.10	6.21	6.00	3.34	3.50
Ozone depletion	kg CFC-11 eq	1.09E-06	8.04E-06	1.29E-06	6.54E-06	4.7E-06
Human toxicity, cancer effects	CTUh	8.6E-08	1.44E-07	9.71E-08	1.17E-07	1.07E-07
Human toxicity, non-cancer effects	CTUh	4.62E-08	3.77E-08	4.62E-08	2.73E-08	2.27E-08
Particulate matter	kg PM2.5 eq	0.001447	0.001121	0.001309	0.000702	0.000722
Ionizing radiation HH	kBq U235 eq	0.095298	0.199488	0.097178	0.158024	0.118181
Ionizing radiation E (interim)	CTUe	2.72E-07	4.28E-07	2.75E-07	3.36E-07	2.59E-07
Photochemical ozone formation	kg NMVOC eq	0.038	0.048	0.030	0.032	0.031
Acidification	molc H+ eq	0.049	0.040	0.044	0.021	0.024
Terrestrial eutrophication	molc N eq	0.224	0.187	0.201	0.096	0.114
Freshwater eutrophication	kg P eq	0.015	0.015	0.015	0.008	0.009
Marine eutrophication	kg N eq	0.197	0.185	0.232	0.136	0.128
Freshwater ecotoxicity	CTUe	983	908	2400	1968	4250
Land use	kg C deficit	2.911	1.005	3.242	0.898	0.919
Water resource depletion	m3 water eq	0.0041	0.4862	0.1875	0.0031	0.1589
Mineral, fossil & ren resource depletion	kg Sb eq	1.14E-07	3.03E-08	1.16E-07	6.93E-09	2.6E-08

Table 5-5. Results of the LCA of Cambodian Aquaculture products (mass allocation). The results are based on 1 kg of end product fish, gate-to-gate, using SimaPro8.3, and ILCD MidPoint 2011+ analyses.

The main impacts in terms of Global Warming potential (GWP) Climate change are resulting from the production chains which include homemade feed, including rice products as dominant feed source. Methane (CH4) is released in the production of rice, resulting in a relatively high contribution to the GWP of the produced product. Although this contribution is a result of the production of rice, the chosen methodology requires the inclusion of this as an input, even though the input is a by-product of rice production for human consumption. In the LCA calculations the contribution of rice bran (34%) and broken rice and white rice (66% total) is accounted for in the allocations.

The allocation method used is a mass allocation; this approach does not allow the ruling out of any inputs and time restrictions did not allow the analysis to be carried out with different allocation types. To determine the relevant impact of the rice contribution, the analysis was performed with an allocation of 100% to broken rice and white rice (Table 5-6), and thus neglected rice bran contributions (allocated for 0%). The analyses show that roughly half to 2/3 of the greenhouse emissions is a result of rice production (one of the main inputs) in mixed fish and pangasius production. For snakehead production, which includes 4x less rice bran, the contribution is also 25% lower when excluding rice bran production. Other effect categories, such as ozone depletion, human toxicity (cancer and non-cancer effects) are affected by these allocation decisions.

This demonstrates the importance of the effects of allocation rules in an LCA system, and the draw backs of methodological assumptions for decision makers. The impact or effect categories are described in Table 5-3.

Effect category	Unit	Mixed fish at farm gate Semi-intensive	Pangasius at farm gate I Pond	Pangasius at farm gate SI Pond	Snakehead at farm gate Cage	Snakehead at farm gate Pond
Climate change	kg CO2 eq	3.68999315	3.195403828	2.260658815	3.086157234	2.452455577
Ozone depletion	kg CFC-11 eq	9.64996E-07	7.93549E-06	1.15897E-06	6.52881E-06	4.65818E-06
Human toxicity, cancer effects	CTUh	3.08471E-08	2.46686E-08	2.94568E-08	2.61288E-08	1.8091E-08
Human toxicity, non-cancer effects	CTUh	7.6882E-08	1.36168E-07	8.71407E-08	1.16588E-07	1.04471E-07
Particulate matter	kg PM2.5 eq	0.000935266	0.000605911	0.000747614	0.000590874	0.000518938
Ionizing radiation HH	kBq U235 eq	0.085897649	0.191487859	0.086887368	0.157327114	0.115353388
Ionizing radiation E (interim)	CTUe	2.45274E-07	4.05567E-07	2.46425E-07	3.33881E-07	2.50605E-07
Photochemical ozone formation	kg NMVOC eq	0.022239901	0.034415273	0.012958571	0.03036485	0.02666194
Acidification	molc H+ eq	0.024128504	0.019176404	0.017150599	0.019524083	0.016719967
Terrestrial eutrophication	molc N eq	0.105647713	0.085807476	0.071432893	0.087479125	0.078508913
Freshwater eutrophication	kg P eq	0.013466088	0.013291966	0.013355152	0.008137582	0.008171568
Marine eutrophication	kg N eq	0.078547238	0.084185275	0.102797432	0.127152946	0.092222061
Freshwater ecotoxicity	CTUe	970.1038649	896.6810899	2386.073612	1967.755725	4246.098865
Land use	kg C deficit	2.693121768	0.877351544	2.960733737	0.899404087	0.87775145
Water resource depletion	m3 water eq	0.539596301	0.830734239	0.672388348	0.213758338	0.375785937
Mineral, fossil & ren resource depletion	kg Sb eq	4.33539E-08	8.79622E-09	5.69152E-08	3.16944E-09	1.26023E-08

Table 5-6. Results of the LCA of Cambodian Aquaculture products, excluding rice bran production (full allocation of rice production to rice and broken rice). The results are based on 1 kg of end product fish, gate-to-gate, using SimaPro8.3, and ILCD MidPoint 2011+ analyses.

All contributions were reported in exact values, as shown in Table 5-6. The results are graphically reported in Figure 38. The analysis is also conducted on a normalised basis. In this analysis the contributions of the highest impact are considered as the reference (100%). The normalised contributions are depicted in Annex 6.

GWP for SI ponds and all home-made feed is partially a result of rice production, for which the home-made feed sources have a high feed inclusion. For mixed fish production approximate half of the contribution is a result of paddy rice production (and thus rice bran), with a high output of CH_4 in the primary production. Roughly one fourth is a result of excretion of carbon dioxide (and nitrogenous compounds) as a result of undigested feed sources. The other fourth is mainly caused by production of fertilizer (N) and fuel combustion. The main improvements of the production process are therefore found in optimisation of feed (and feed sourcing) and feeding efficiency, in general the feed conversion of 1.6 is improvable only in a combined effort of these parameters.

GWP in the production process of Semi-intensive pangasius production is found to have similar effects, however there are some differences, the differences are mainly found in the digestion capabilities, where the mixed fish population and feeding releases more N2O.

However, for snakehead culture there is a relatively low contribution of rice inclusion in the feed, and thus resulting in less methane excretion. The results of the primary fish production process are more or less similar with the exception that inputs from fishing and gasoline combustion are slightly higher.

Therefore, the main differences of GWP in the primary production of both snake head and pangasius are related to emissions of undigested feed, and therefore found in species differences, feed composition and feed management. Improvement of feed will improve the release of undigested compounds.

Human toxicity (both cancer and non-cancer effects) is mainly a result of all production processes which require combustion of fossil fuels in the production system. These processes combust toxic components in the air, water and soil. The majority of the processes are not taking place in the aquaculture part of the process, however transport and rice production do contribute here. Toxicity through the release of antibiotics and medicine is not considered due to the selected model. The release of these components is considered in freshwater toxicity, which also has a feed back to humans through the use of water. However the models are not developed specifically for application in Asia, and therefore do not directly consider the use of untreated river water prior to consumption.

Fresh water ecotoxicological effects are highest in intensive pangasius and snakehead cultures. The analysis of a comparison of LCA Results of the five different production-species system (Method: ILCD Midpoint 2011+) is shown in Figure 38. Freshwater Ecotoxicity is highest in pangasius semi-intensive and snakehead (both cage and pond) culture. The main reason is found in the release of antibiotics, medicine, and chemicals affecting the ecosystem. These also have a potential feedback to human health. Intensive pangasius culture, and intensive snakehead pond cultures have a high impact on freshwater ecotoxicity, the underlying reason is the use of antibiotics and chemical drugs for in these cultures in a more intensive way than in the semi-intensive production systems of pangasius and mixed fish. The snakehead culture in cages has a higher impact on freshwater ecotoxicity, this is also traced back to the application of medicine in the production system.

The production and application of fertilizer mainly contributes in the mixed fish pond production system (1/7 of the contribution), while the impact in the other production chains is at least half (pangasius) or negligible (snakehead).
Marine Eutrophication is similar in all production chains which use rice products as a primary food source - the mixed fish pond culture, and pangasius cultures. Nitrogenous compound emissions in snakehead cultures are appearing lower (~0.13 kg N eq per kg produced fish) in comparison to mixed fish and pangasius culture (0.18-0.23 kg N eq per kg of produced fish). Paddy rice production is the

main contributor of the total N eq output, primary production of rice contributes approximately 2/3 to the total N eq output. This is the case for mixed fish and pangasius cultures.

Other contributions are mainly a result of the digestibility of the feed, and release of undigested nutrients (N) via water, and sediment. In snakehead cage cultures the release of N is higher than in pond systems. The reason is the more direct interaction with the surrounding waters, and thus greater direct release to the natural system. In snakehead cultures the contribution of paddy rice production is substantially lower than in pangasius and mixed fish production due to the lower inclusion of rice bran in the feed. Altogether, emissions of N eq are up to 90% higher in the mixed fish and pangasius cultures, mainly due to the feed inclusion. Changes in feed efficiency and sourcing of feed may reduce these numbers.

Freshwater Eutrophication is similar in all production chains which use rice products as a primary food source (mixed fish pond and pangasius cultures). Rice bran has a relatively high phosphorus content, which in turn is not suitable for complete digestion by the fish. This results in emission of P to the environment. In general, P content in fish-based diets is relatively high, however the P content of snakehead feed is relatively low due to the use of trash fish (with a relatively low P content). Therefore even though P is not fully utilised in the snakehead digestion process, the outputs are approximately 50% in comparison to cultures, which use rice bran as an important feed source. Phosphorus release appears higher in (0.015 kg P eq / kg produced fish), where releases of 0.008 kg P eq / kg fish are shown.

Improvement of feed sourcing in snakehead cultures, may lead to higher P releases due to the likely increase of P in the feed. Feed management and feed sourcing may contribute to more efficient feed use and thus a reduction of P emissions.
In mixed fish and pangasius cultures, feed management, sourcing and composition may favour reduction of feed emissions, since rice bran is high in P content in comparison to many other sources.

Water resource depletion is mapped in the analysis, and calculated for the different production systems. Water use in snakehead cage culture is low. This is due to the lack of direct use; there is only extraction of water via the main input processes. The utilization of water does not occur in primary production, since the cages are in the water and no extraction (or only to a small extent) occurs. The drawbacks of water use and contaminations are discussed in other sections of the analysis.

The mixed fish pond production system also utilizes minor volumes of water. The main water source used is rain water. There is usually only a limited use of other water sources, although this may vary per district. Water use in intensive pangasius ponds is higher than in semi-intensive systems (both snakehead and pangasius). In general, water exchange is higher to maintain water quality and production rates.

This analysis does not reveal the local difficulties in water management. Rain patterns are changing, and there is a shortage of water in the dry season in some areas. This creates low availability of fish culture water, and decreases the length of the production season. This co-occurs with less water exchange, lower water quality, and higher disease pressure in the systems. Therefore, water management is an important factor for production in several provinces.

Resource extraction is relatively low in the production processes (and inputs) for the aquaculture value chain. The production procedures are mainly artisanal and low input in many cases. In general, most local resources used, are still (except for electricity, which is recently restructured) based on hard oil, coal, or diesel, garments (and the production thereof), these inputs are in general subject to improvements in replacement by alternative sustainable sources on a long term. However, the analysis does not represent the input of natural resources such as fisheries products, and depletion of fish stocks. This quantitative description is given later in the document.

Fish use can be mapped by using an indicator such as the FIFO (Fish In: fish Out Ratio), which gives an indication on the used amount of fish, including consideration of fishmeal production, which generally requires 4-5 kg of input fish for the production on 1 kg of fishmeal. Oil is not specifically accounted for due to the lack of fish oil use in the Cambodian case studies.

In the FIFO calculations the total fish inputs of the Cambodian processes are compared. For the comparison, the data used by IFFO (International Fishmeal and Fishoil Organisation) is used as a reference point. Fish consumption in the semi-intensive mixed fish pond system is very low, the main inputs are from plant origin (0.13 kg of wild fish per kg of produced fish). The semi intensive pond system used more fish as ingredient and is comparable to world averages (reported by Tacon & Metian) (0.7 kg of wild fish per kg of produced fish). Snakehead requires significantly more fish than the other species (2-3 kg of wild fish per kg of produced fish). This has a direct pressure on the local fish sources (the main source). Furthermore, one could extract that the FIFO from the salmon industry, which is significantly improved over the period 2008-2012 and further, could be seen as an example of reducing fish dependence. It also illustrates that the traditional and artisanal production of snakehead (still in its development infancy), need development in terms of fish reliability.

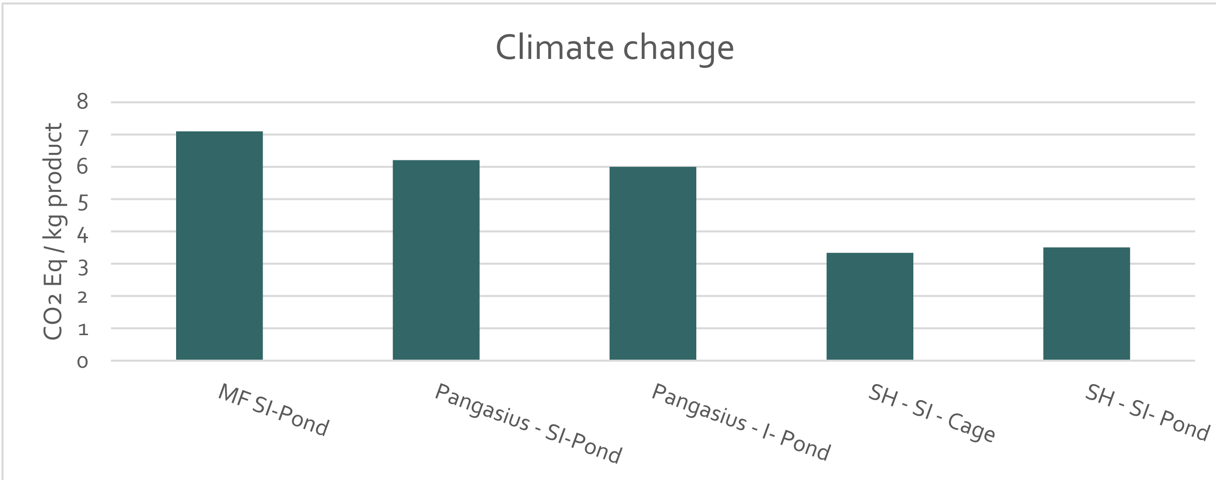
	Salmon 2008	Salmon 2012	Pangasius pellet	weight mixed live fish species from semi-intensive ponds	fresh pangasius from semi-intensive pond	live weight snakehead from ponds	live weight snakehead from freshwater cages
Wt of pelagic fish at start kg 1000	1000	1000	1000	1000	1000	1000	1000
Wt of Fishmeal or trashfish	225	225	225	225	1000	1000	1000
Wt of fish oil	50	50	50	0	0	0	0
Fish oil in the diet %	20	12	1.225	0	0	0	0
Fishmeal in the diet %	30	25	14.83	0.97	0.00	0.00	0.00
Trashfish in diet				5.90	26.26	77.32	96.52
FCR*	**1.25**	**1.25**	**1.5**	**2.09**	**2.70**	**2.55**	**3.14**
FIFO	**2.27**	**1.68**	**0.81**	**0.13**	**0.71**	**1.97**	**3.03**

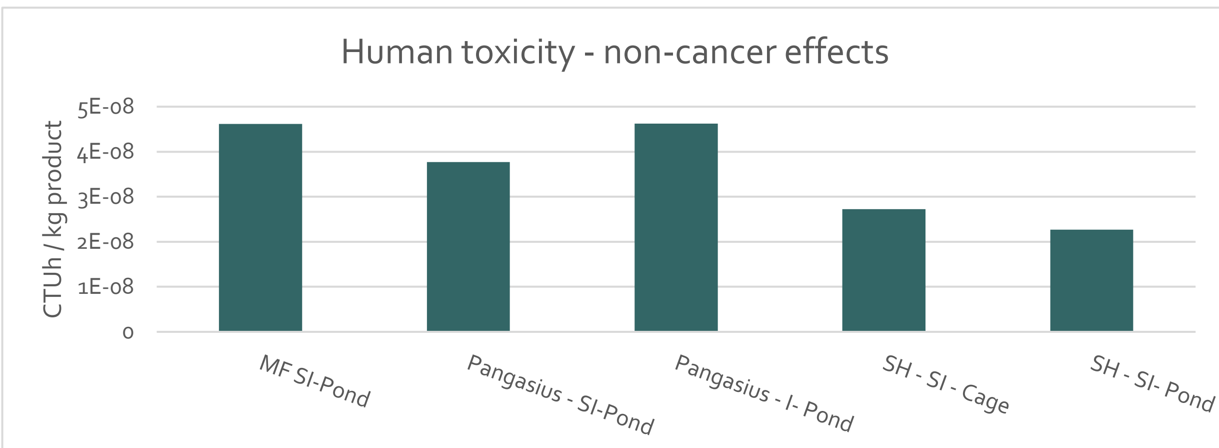
*Table 5-7. Results of the LCA of Cambodian Aquaculture products, excluding rice bran production. *For Cambodia derived from the surveys.*

$$\text{FIFO Ratio} = \frac{\text{Level of fishmeal in the diet + Level of fish oil in the diet}}{\text{Yield of fishmeal from wild fish + Yield of fish oil from wild fish}} \times \text{FCR}$$

Snakehead culture in general has a lower impact on the analysed indicators. The main reason for the low impact is the fact that the higher impact categories for pangasius and mixed fish culture are primarily influenced by indicators which do not influence snakehead production to a large extent. Inputs from fisheries are relatively energy (Fossil) efficient for snakehead cultures, with a limited use of e.g. fossil fuels, and a low inclusion of rice. P and N emissions would however be expected to contribute more in snakehead farming, due to the high inclusion of fish (which is commonly seen with fish meal inclusion). However, the composition of the included trash fish is relatively low in P content, and therefore the emissions of P are also relatively low.

The analysis of a comparison of LCA Results of the five different production-species systems (Method: ILCD Midpoint 2011+) is shown in Figure 38. The analysis is performed based on a single score for each of the impact categories. Freshwater Ecotoxicity is the highest indicated impact category for all five of the production-system combinations. However, there is a difference in total impact for freshwater ecotoxicity. The analysis shows that semi-intensive pangasius culture, and intensive snakehead pond cultures have a high impact on freshwater ecotoxicity, the underlying reason is the use of antibiotics and chemical drugs in these cultures in a more intensive way then the semi-intensive production systems of pangasius and mixed fish. The snakehead culture in cages has a higher impact for freshwater ecotoxicity, this is also traced back to the application of medicine in the production system, given the fact that semi-intensive production systems for pangasius are not fully supported by adequate disease management procedures. For snakehead cultures there is a lack of disease knowledge, and management, potentially resulting in inadequate and excessive medicine use.





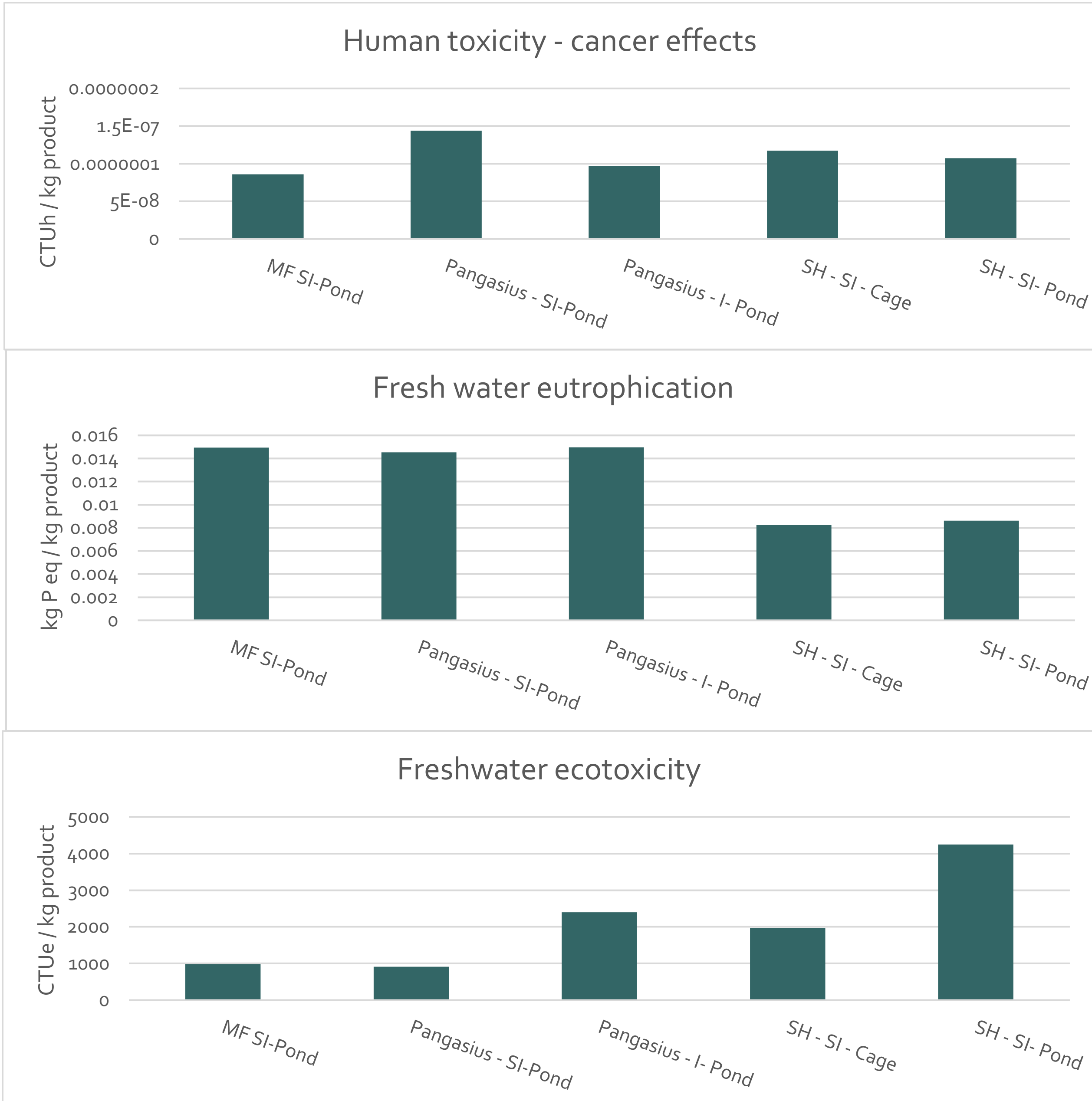


FIGURE 5.5. COMPARISON OF LCA RESULTS OF THE FOUR DIFFERENT PRODUCTION-SPECIES SYSTEM (METHOD: ILCD MIDPOINT 2011+). THE INDIVIDUAL SCORES ARE PRESENTED IN SEPARATE TABLES (TABLES 23-25).

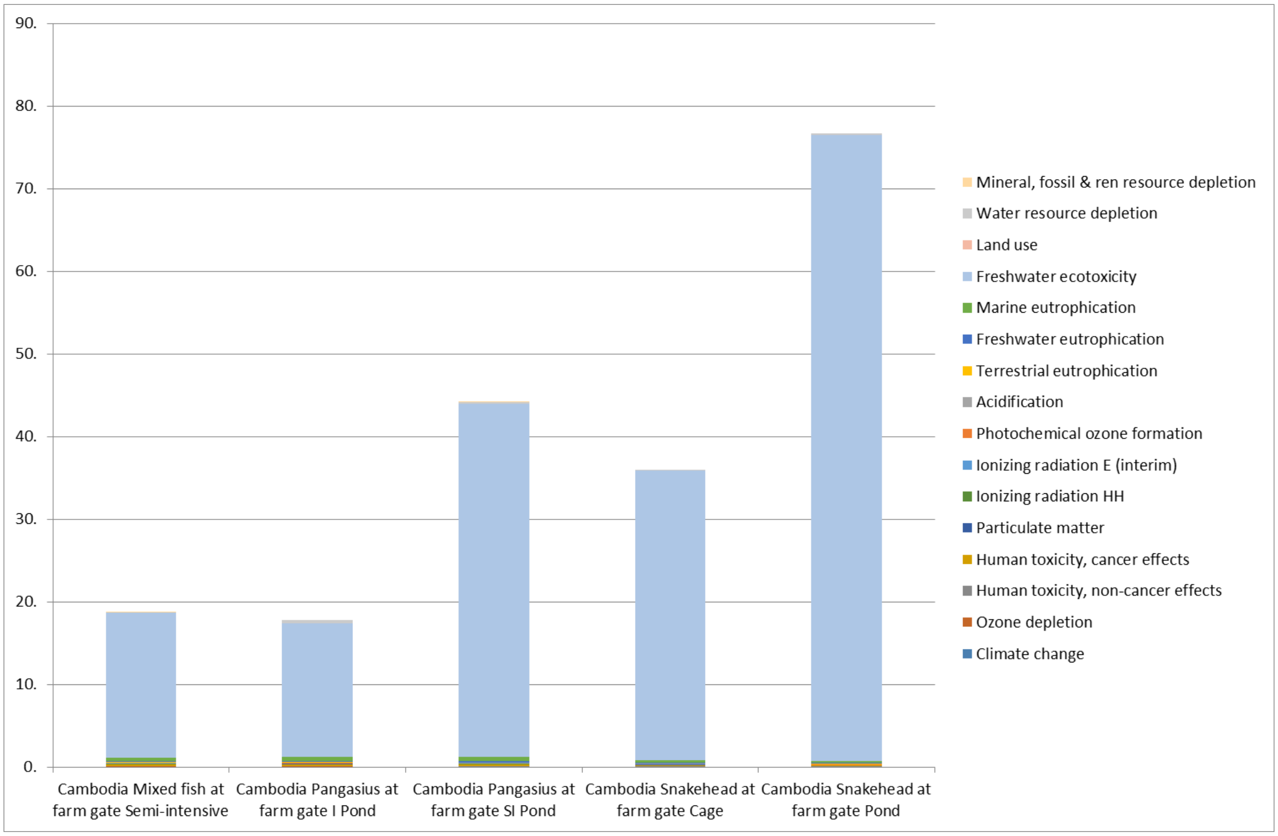


FIGURE 5.6 COMPARISON OF LCA RESULTS OF THE FIVE DIFFERENT PRODUCTION-SPECIES SYSTEM (METHOD: ILCD MIDPOINT 2011+) .

The analyses show the relative impact based on a single score (Midpoint). Freshwater Ecotoxicity is the highest indicated impact category for four production-system combinations. The origin can mainly be traced back to the inputs of medicine (which is lacking in snakehead cages). The y-values are depicted in the unit mPt (milli-Points), 1 Pt is representing one thousand of a yearly of environmental load by one citizen.

For comparison with other production systems the analyses of previous studies performed by Henriksson (2015), and Trang (2015) are used. The data derived in the Cambodian Assessment is compared to a similar method of analysis used in the previous studies. The data is also reported in the attached Excel file (fore and background information), as well as in Figure 39.

The analysis shows that the results fall within similar ranges of outcomes (with a 100% variation, which can be explained to the wide variety of production systems and simplification of the analysis). Human toxicity effects are found to be lower in the Vietnamese case (Bosma, 2011), and that negative production is the result of the inclusion of soy bean and assumptions made in the foreground data (Ecoinvent 3). This effect is not present in the Cambodian cases due to the lack of inclusion of soy beans in homemade feed, and the low inclusion in commercial feed.

Comparing the results for GWP, similar patterns are seen for both Cambodia and Vietnam. The more intensive the farming process is, the less WGWP is reported. A full analysis of the contributions is not performed. However, feed optimisation, feed ingredient sourcing, and feeding practices are a major driver for these observations.

The reported human toxicity presents a 3-5 fold difference between the Vietnamese case studies and the Cambodian. The main reason is found in the lower input system (in terms of industrial processes and different ingredients) due to the higher use of commercial feed in Vietnam. This increases the required inputs of different agricultural and technical processes, and thus also includes associated processing and transport steps, which are considered relevant for human toxicity inputs. The use of different sets of chemical inputs, also affects the results and thus comparison of human toxicity and freshwater ecotoxicity. However, the main difference in both freshwater ecotoxicity and human health is the use of chemical inputs, which in Cambodia is not well organised, and may be excessive.

Marine and freshwater eutrophication are observed to be higher in the Cambodian case. The main process which is influencing this, is the farming process in Cambodia. In this process N is insufficiently taken up by the fish, and thus excreted or unaccounted for. The main input for N in this process is the rice fraction in the feed, which has lower digestibility. For phosphorus similar observations are done, with the difference that P content in rice is relatively high, and uptake lower. The Vietnamese case is (although not always optimal) better addressing nutritional demands. Commercial feed use in Cambodian pangasius cultures including adequate feed management, would potentially alleviate the environmental pressure of unaccounted feed.

Water use results in large differences in the different production scenarios in Cambodia. The results for water use in Vietnam are further not comparable since water use was not reported in other studies (Henriksson). One striking observation is the higher water use in both intensive production of pangasius in Cambodia, and medium sized farming practices (Trang) in Vietnam. Both systems operate with a higher water exchange than the other systems. The sustainability issues in water use are mainly dependent on local depletion, and water availability. In Cambodia water scarcity in the dry season is a relevant risk for producers. GWP is reported in similar ranges for all categories of production and country.

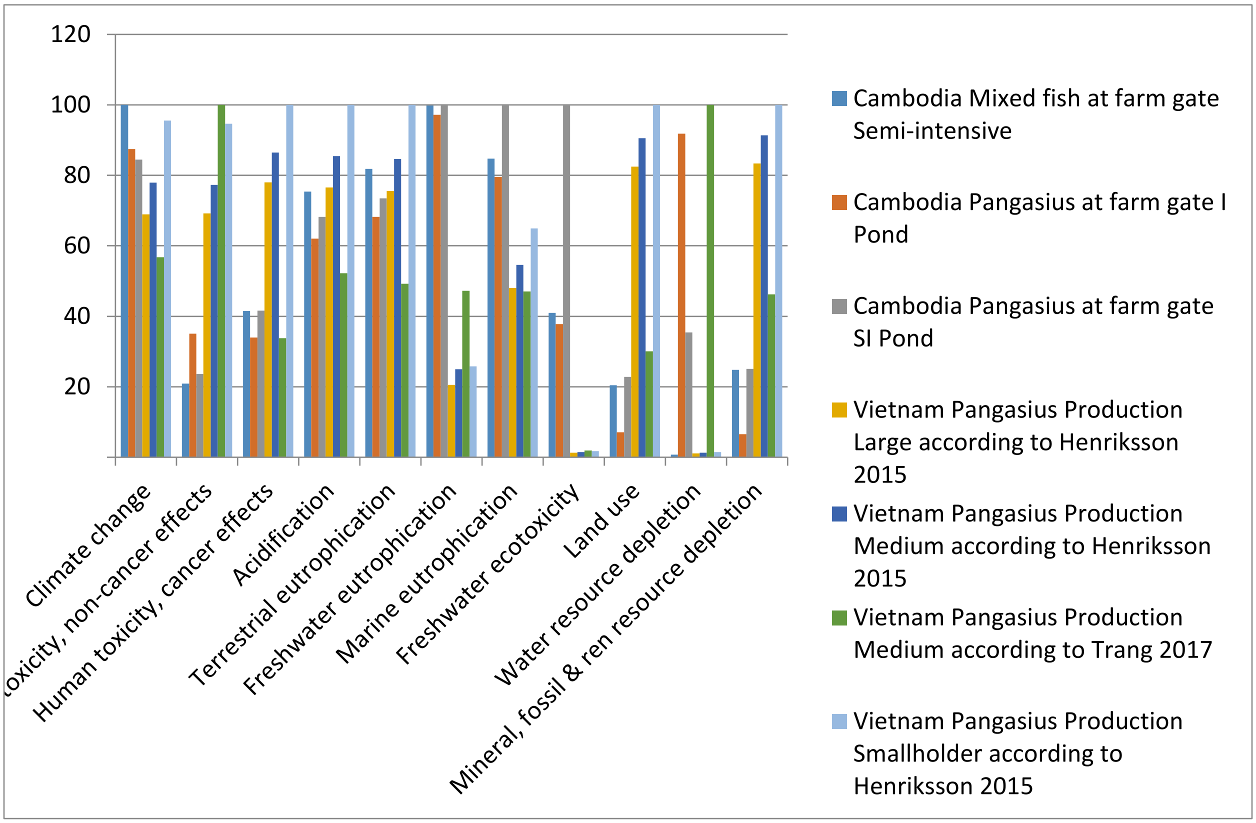


Figure 5.7 Comparison of LCA Results of the seven different production-species system, and five Vietnamese data sects (Henriksson, Trang) (Method: ILCD Midpoint 2011+). The analyses show relative impact based for the different indicators (Midpoint). The y-axes represent the percentage of contribution in relation to the production system with the highest contribution (set at 100%).

The LCA analysis is also performed for the assessment of end point indicators. For this analysis Recipe2.2 H/A is used as an end point impact indicator. The results of the analysis (Figures 40 and 41) indicate that the end point results are more variable for the different cultures. The contribution calculations are considered as less suitable for aquaculture analysis, given the methodological restrictions (mainly dominating factors for terrestrial use). This also results in lower values for snakehead cage cultures, which in turn does not give the possibilities to report relevant indications for improvements, or overall impacts of the culture.

Although the production of mixed fish in pond systems in semi-intensive systems seems to be a low input system, due to the extensive use of own grown or produced products in combination with homemade feed. However, in the assessment the inputs for fish farming are considered to be produced as input for the fish production cycle. Therefore, farm waste is not considered as a waste product from farming (agriculture), but as a primary production input. Therefore, the contributions to produce the products are accounted for. The low FCR in this production cycle directly results in high inputs per kg of fish, translating directly to high end pond (and midpoint) emissions.

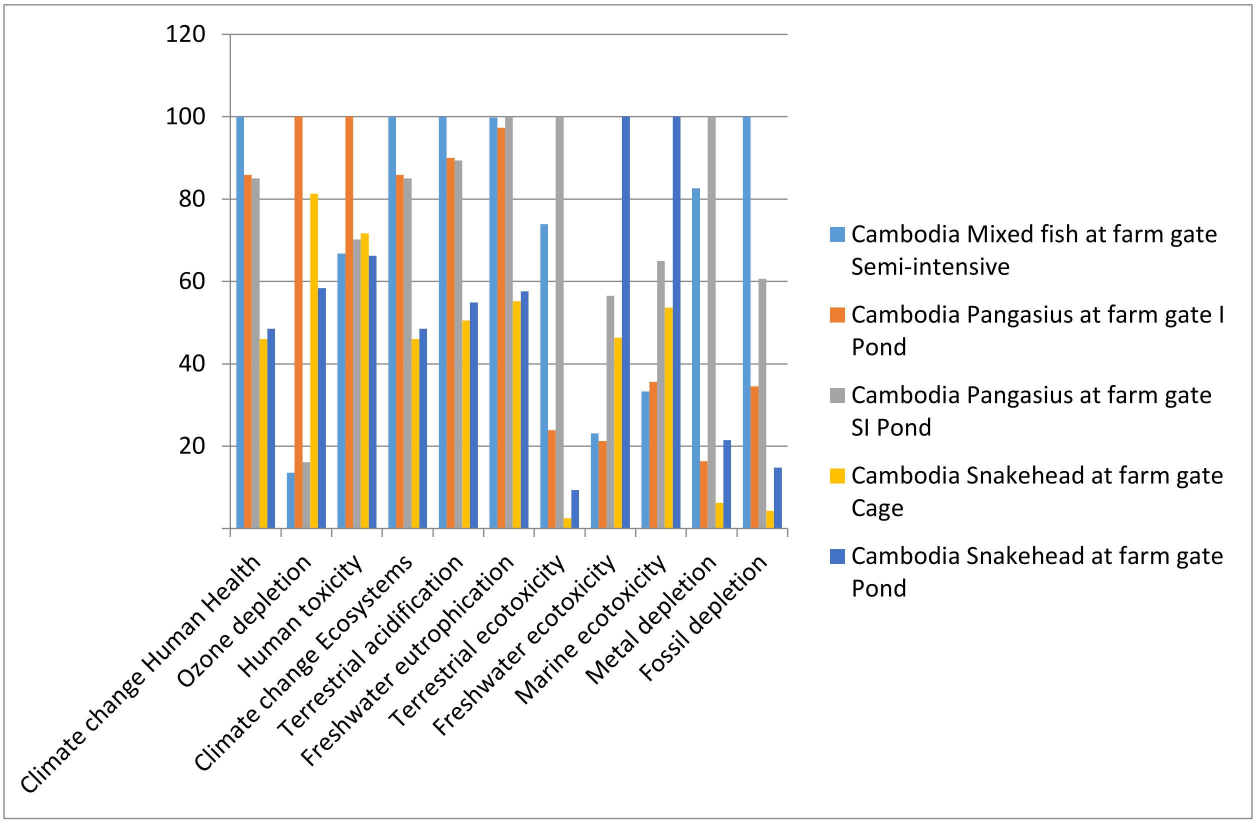


Figure 5.8. Comparison of LCA Results of the five different production-species system (Method: ReCiPe EndPointV1.13), World Recipe H/A). The analyses show the relative impact based (End point). The y-axes represent the percentage of contribution in relation to the production system with the highest contribution (set at 100%).

The results of the end point impact analysis show some interesting aspects, which are highlighted. Freshwater ecotoxicity is larger in the snakehead pond culture, followed by the snakehead cage culture. From the pangasius cultures the intensive pond shows the highest impact. The same observation can be done for marine ecotoxicity. The main reason lies in the use of medicine and chemicals in aquaculture. Possible interventions to overcome these aspects, are a targetted disease management and fish health program, including the knowledge of farmers, and the knoweldge and awareness of specific snakehead pharmaceutical treatment.

The other impacts are already described in the midpoint analysis, and will therefore not be discussed in detail.

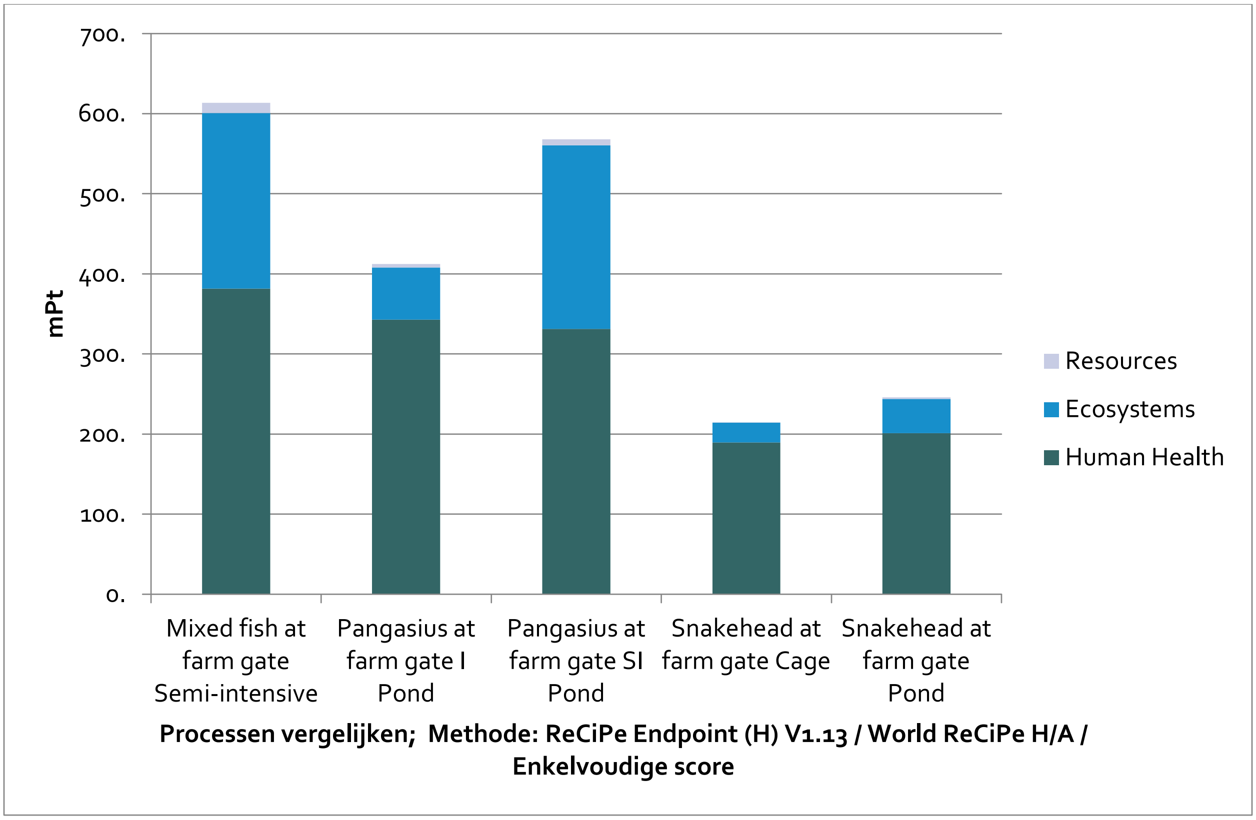


Figure 5.9. Comparison of LCA Results of the five different production-species system (Method: ReCiPe). The analyses show the relative impact based on a single score (End point). The y-values are depicted in the unit %.

An analysis was carried out to identify the hotspots for environmental impact for each value chain, using LCA and midpoint and endpoint analysis as a tool. Since LCA should be considered as a tool to identify certain impacts of the value chains, the use of LCA is not functional to identify the full set of hotspots, since desired indicators are not included in the analyses.

The results of contributions for the three most important indicators (GWP, Marine Eutrophication, and Freshwater Eutrophication and human toxicity) are presented for mixed fish production in semi-intensive pond systems (see Annex 6), pangasius production in semi-intensive pond systems (see Annex 6), pangasius in intensive pond systems (see Annex 6) and snakehead production in a pond system (see Annex 6).

The contributions of the different production steps are covered in Annex 6.

5.4 Impact of Processing dried products

LCIA analysis was not performed on processed fish. The LCI revealed that most of the by-products from processing in the Cambodian Value Chain are used for further processing or further utilization. For the LCA this would mean that the main analysis would give mathematical results on the allocation of by-products versus the product of interest (dried fish), therefore the analysis does not give indications on the sustainability of the processed product. The main results of a LC analysis mainly indicate the contributions of impact categories from the process on the end product of interest. Therefore, a qualitative analysis on the value chain is performed to identify hotspots.

Inputs for processing are quite low in comparison to different other processing scenarios, worldwide. The level of technological / resources inclusion in processing in Cambodia is relatively low. Processing is performed as artisanal processing, including mainly manual stripping, degutting and de-skinning of the fish. This process is followed by sun drying, with addition of artisanal covered drying using mainly an open-oven with coal and wood as a fuel source. Processing waste is mainly sold or re-used in fish culture or household consumption. From a LCA perspective, the analyses would only partially reveal and quantify the issues arising from processing.

Furthermore the LCI gives results on a dried product basis, which also give a by-ass of the comparison of the results. This could be compensated by preparing the calculation based on protein inclusion, however this is not chosen within the used methodology, and would therefore not contribute to comparison with other LCA's performed in aquaculture value chains. The main issues which were revealed in the LCI for processing are described below.

5.4.1 Re-use of fish waste in aquaculture (feed) and disease risk

Fish from processing is directly sold as processing waste to the aquaculture sector. There is no control on potential disease transmissions through the feed chain, and there is no consideration of intra-species (same species) procedures. The lack of control on disease and lack of information on the source of the input product are weak spots in disease transmission to aquaculture facilities and other water bodies. This is mainly the case since processing of feed does not include any heating or sterilization steps.

In addition, the processing waste of Pangasius or snakehead is used in aquaculture from the same species. There are no protocols to prevent intra-species feeding which directly poses disease transmission risks. The interventions which could be performed are mainly prevention of intra-species feeding, and understanding, improvement of protocols, control and best-practice on disease management. Aquaculture fish processors are a linking pin in the intra-species trade and information transmission

5.4.2 Organic waste discarded to the environment

Organic waste from the fish processing facility is directly discharged into the river system. This mainly includes fish blood and processing water. The discharge may result in local eutrophication and impacts on the local environment. In areas which harbour a concentration of processing facilities, local problems may occur; besides this does not benefit the livelihood quality of the processing neighbourhood.

There is a lack of adequate systems (waste treatment) to process the waste on a central basis. It would be beneficial to operate processing facilities in a concentrated region, and invest in processing waste treatment. Examples of concentration of fish processing in Cambodia are present, however process water is discharged untreated. Beside risks on the environment, this also results in an open route for transmission of diseases to the environment. The potential intervention is to invest in processing waste (process water) treatment to avoid disease risks, and to reduce local environmental pressures.

5.4.3 Fossil fuel use

Fish processing is mainly performed using artisanal methods. Sun drying is one of the most energy efficient methods. However, in periods of rain the fish are dried (partially) using semi-open oven systems, which are heated by coal. Coal has a high environmental impact when burned for heat. Therefore, the change to more efficient and less polluting and fossil resource extraction would be recommended. Utilisation of non-fossil fuels (briquette based) could be possible, improving the circular economy and reducing emissions through coal burning. On a long run this will result in phasing out the use of coal as a fuel source.

5.5 Hotspot analysis

Besides the hotspots as identified in the LC analysis for the known and prescribed indicators, some of the indicators do not appear as a hotspot when using LCA and the prescribed methods. The LCA methodology is lacking the right tools to analyse these, therefore the hot spot analyses are quantified.

5.5.1 Disease transmission and medicine

The Cambodian value chain is very dynamic, and a lot of smallholders are involved in the value chain. The trade system is highly informal, and control measures are not in place to the full extent. In both trade as well as production a diversity of smallholders are active. There is knowledge about the risk of diseases in terms of financial and production risks, however an adequate system to prevent, foresee and avoid disease is not yet in place. The transport systems for fish both internally as well as from imports are highly subject to the spreading of diseases, by fish and by the transport water. In most cases, transport of fish and associated water are not regulated, nor is a control and verification process in place. This enables the spread of diseases without any oversight on direction, extent and conditions. Therefore a more robust disease management, mitigation and control system should be in place, at the level of producers, the supplying industry, and regulation.

There is an extensive availability and range of medication, probiotics and chemicals available in Cambodia. This promotes widespread use in aquaculture processes (as also seen in the freshwater ecotoxicity data). Medicine release is one of the main drivers for ecotoxicological impacts; however the analysis does not reveal the implications for human health, due to the method choice. Excessive medicine use, which has ecotoxicological consequences may also harm humans via indirect pathways.

The farmers mostly rely on their own (often insufficient) knowledge, and provision of advice from the government or private suppliers. Many farmers indicated that better quality and more accessible knowledge, and the organisation of control and advice throughout the production chain, would considerably benefit the avoidance of disease, and the mitigation of problems.

In addition, the open trade and technically open transport methods are a risk for disease spread. Therefore these procedures should be revised and potential investments in water treatment methods should be enforced.

5.5.2 Use of trash fish for feed inclusion

The feed for both Snakehead and pangasius culture are mainly composed of rice inputs, and trash fish from local fisheries or imports. The local fisheries are often not well regulated or controlled. The extent to which trash fish is extracted without license is not well known, and should be re-evaluated based on the current regulations. The benefit of trash fish extraction is that the feed sourcing comprises a low CO_2 eq emission, since the fisheries require relatively low amounts of energy. However, there are potentially high local effects on the ecosystem when extracting the small fish, especially when considered for the Tonle Sap basin, when this is done in an uncontrolled and non-organised way (as currently is the case). This, together with a high FCR (Feed Conversion Ratio) in comparison to other feed sources, puts high pressure on Cambodian fresh water resources. In the FIFO calculations the total fish inputs of the Cambodian processes are compared. For the comparison, the data used by IFFO (International Fishmeal and Fishoil Organisation) is used as a reference point. Fish consumption in the semi-intensive mixed fish pond system is very low, the main inputs are from plant origin (0.13 kg of wild fish per kg of produced fish). The semi intensive pond system uses more fish as an ingredient and is comparable to world averages (reported by Tacon & Metian) (0.7 kg of wild fish per kg of produced fish). Snakehead requires significantly more fish than the other species (2-3 kg of wild fish per kg of produced fish). This has a direct pressure on the local fish sources (the main source).

Commercial feed in general yield, if the right formulation is applied, improved feed utilisation in comparison to direct fish feeding. In addition, excessive nutrient emissions can be reduced due to improved digestibility by the fish. However, there are environmental drawbacks to the use of commercial feed as well; this is mainly due to the inclusion of industrial or low value marine fish, and due to the inclusion of less digestible plant based fractions, and high energy requirements for production and transport of feed and ingredients. In general, the inclusion of adapted feed resources, in combination with best practice aquaculture applications, creates beneficial conditions to convert fresh fish based feeding to pelleted feed practices. Worldwide the application of commercial feed is seen as an economical solution for farmers, and if well-developed, more sustainable.

In Cambodia there are major issues with the extraction and application of trash fish, for which the economic factor (free or cheap feed by own extraction), is one of the main bottlenecks, which should be overcome. Programs to develop the accessibility of local commercial feed formulated for the species and conditions available in Cambodia are recommended.

Besides this, evaluation of the impacts of overall fisheries pressure in the Tonle Sap area including extraction patterns of fish for aquaculture (domestic and export market) is recommended. The impact of extraction of young fish prior to reproduction, multi- annual fish in high quantities, and one year fish in high quantities should be evaluated. Methods used could be MSY (Maximum Sustainable Yield) analyses of the entire ecological system and for local ecological impacts. In addition, adequate fisheries management plans, education and enforcement are required to guide this process. In some cases the scarce trash fish resources are exported to Vietnam, and consumption sized snakehead or Pangasius are reimported. This puts high pressure on local resources, without benefitting on an economic scale.

5.5.3 Pesticides from Mekong to product and vice versa: accumulation in fish through fresh water trash fish

During the LC Inventory, data on pesticides fisheries products in fresh water fish in Cambodia have not been generated. Data on commercial farming in Vietnam indicates extensive debates on the pesticide and residue uptake by Mekong fisheries and aquaculture. Several studies have indicated that pesticides are not directly a problem in export samples from aquaculture in Vietnam. However, these studies have analysed for production of filets only, whereas in south east Asia nearly all parts of the fish are consumed by humans or enter the aquaculture chain. Besides this, the production for export markets is not fed with trash fish from the same basin (pellet based feed). There may be a potential risk for the accumulation of residues in feed fish as well as in consumption fish, fed with local Mekong species in Cambodia. The extent to which this may pose a human health risk is not known or documented, and can thus not be quantified.

In particular, the potential concentration of pesticides in the Mekong river basin may pose a risk, since substantial rice production (and associated residues) are a direct influence on fish, and the potential accumulation of residues. It is advisable to analyse the content of residues in both feeding fish as well as end products to ensure that no human health issues are introduced with new aquaculture procedures (or species), especially considering a circular economic cycle in which accumulation in the aquaculture products may occur.

5.5.4 Best aquaculture practices

In general, aquaculture in Cambodia is performed on a traditional and low technology basis. From a sustainability perspective this is not directly considered a risk. However, the lack of efficiency, knowledge (capacity and transfer), level of organisation, and application of best practice farming is considered a risk for sustainable continuation of a large part of the production system. Due to the low level of organisation by farmers, high influence of the supplying industry on the production sourcing materials, and due to high competition in price and quality of imported fish there is a wide range of pressures on the production chain. The pressures are different in the different regions in Cambodia. The lack of farmer based organisations does not allow for representation and access to information and services which could directly benefit the farmers and production conditions. There are examples of farmers who are organised mainly in relation to seed supply which directly benefits the connected farmers. The arrangements are, however, mainly project and donor based, which tend to be of a temporary character. Investment in farmer support and knowledge transfer organisation does have the required impact for sustainable developments.

Other environmental pressures, which are mainly external are the lack of water supply and the potential effects of longer dry seasons and shorter and heavier wet seasons, the pressure on water availability is high. Therefore, zoning plans to better address and guide water availability are advised.

Overall, best practices in feed sourcing and feed management are considered as relevant hot spots. From an environmental eutrophication perspective, the mixed fish and pangasius production is highest in nutrient emissions, for both N and P eq, due to the higher inclusion of indigestible and excessive nutrients. However, from a total feed and fish resource perspective, the snakehead cultures require development to decrease reliance on fish resources. Feed improvement and feed management in this respect are required in all development scenarios, and will benefit by reduction of local impact.

6. **Conclusions and recommendations**

6.1 Framing questions

6.1.1 What is the contribution of the VC to sustainable economic growth?

Where appropriate, two scenarios have been provided; scenario 1 which uses the official aquaculture production statistics and scenario 2 which uses our own estimate of realistic production. Here we provide the summary for scenario 1, the values for scenario 2 are consistently lower. The contribution to economic growth of the Cambodian aquaculture value chain is at present relatively limited. Some farmer types are presently operating at a very small profit, although traders in particular still have significant profits. Total direct and indirect value added of the sector (under the scenario of the official government data) has been estimated at 295.8 million Euro (scenario 1) contributing 1.8% to GDP, 6.8% to agricultural GDP and 30.6% to fisheries GDP. The contribution of the aquaculture value chain to the public funds balance is limited. There is some contribution from quota and licenses for licensed imports of feed and seed. At the same time, the government presently misses out on a large volume of unreported / unlicensed imports of both fish and feeds.

The balance of trade is negative (-131 million Euro under scenario 1), this is due to the high level of imports of both fish and inputs, and the low level of exports of farmed fish. The rate of integration is 68.4% under scenario 1, just below 70% which as a rule of thumb is considered a good rate of integration. Prices for imported farmed fish are consistently lower when looking at prices paid in Cambodia, however average prices in the global market are consistently higher. This means that the nominal protection coefficient, when compared to prices of farmed fish as it enters Cambodia is higher than 1, while it is below 1 when comparing to international prices. This illustrates that farmed fish exported to Cambodia is of inferior quality and a 'by-product' of the farmed fish sector of the neighbouring countries.

The economic risk analysis examines price risk, logistical and Infrastructural risks, policy risks, and food safety and phytosanitary risks, and weather-related risks. A summary of these and other risks is provided in the section below (major issues / risks). Overall, the economic sustainability of the value chain seems under threat due to the low profits made at farm-level, resulting from competition with neighbouring countries. Costs of inputs are high as they are also partially imported, or depend on seasonal supplies (wild capture fish). Employment in the chain is significant, but only in terms of self-employment and as a large portion of that work is not profitable at present, it is at a risk of disappearing.

6.1.2 Is this economic growth inclusive?

Among value chain actors, farmers earn the least from the aquaculture sector. Only the intensive farmers are presently operating at a profit, when taking into account all costs of production including family labour. Those earning the highest profits for an individual actor are traders. This is mainly because they deal with larger volumes, as their profit per unit of fish is low compared to the other downstream actors. Retailers earn most per unit of product.

It has been estimated that the aquaculture value chain (primary actors) generates 82,880 jobs (full-time equivalent) under scenario 1. The majority of these jobs are self-employment or family labour (93% is self-employed), while the remainder is hired labour. The majority of these jobs are at farm-level (63%). Almost all of the wage labour jobs are either labourers for the lifting, loading and carrying and some drivers, and the majority are men. Most wage labour is year-round but there is also some seasonal work. Average wages are between 3.70 and 5.60 Euro per day.

In terms of the social inclusiveness of aquaculture development, the poorest people in rural communities are less likely to participate than medium to better-off households. This is attributed to lack of land for pond production, limited availability of family labour and lack of finance. Women are proportionately more represented in the semi intensive systems and small cage production than intensive ponds and large scale cage production. The participation of landless people in aquaculture is through cage production. Therefore attention to these categories of production will help to benefit women producers and those without land. Inclusivity can be enhanced if interventions relating to credit and finance, technical information and advice for aquaculture are tailored to different scales of operation and made available for women and youth.

6.1.3 Is this VC socially sustainable?

In considering the social sustainability of aquaculture value chains it is important to understand the different roles of aquaculture in livelihoods. As indicated, these vary according to system and location. An important social requirement in aquaculture development is to ensure that development efforts recognise these different economic capacities and circumstances, tailoring interventions appropriately.

Further development of large scale intensive aquaculture may negatively impact vulnerable groups unless working conditions are improved. The intensive sector will also need improved health and safety provision and attention to workers' conditions of employment. There is a need to increase awareness of the content of the CAMCODE among fisheries personnel, local government, NGOs and other stakeholders. It is important that the labour conditions are monitored, particularly health and safety, working hours and chemical hazards. The social sustainability of aquaculture value chains will also require investors in aquaculture enterprises to ensure full compliance with Cambodian land law with regard to identification of locations, tenure rights, local consultation, social and environmental impact assessment and compensation, supported by awareness raising among district and commune leaders and encouraging local reporting of infringements.

Recognition of women's role in aquaculture is supported by the FIA’s National action plan on Gender Mainstreaming and Elimination of worst forms of child labour, however, gender strategies and action plans need active promotion among fisheries personnel and value chain actors, with emphasis on training, practical implementation and monitoring, and resources to support this. Despite high rates of fish consumption, the levels of child and maternal malnutrition remain high. Poor sanitation and water pollution which affect aquaculture production and health and nutrition, need further action at commune level, particularly around the Great Lake. A sustained programme of improvements in sanitation and latrine construction is needed to reduce infections and improve water quality.

A strategy to strengthen groups with common interests to access technical information and inputs could be supported by actions to strengthen group governance. Expansion of seed producer training and networks in areas where there is market demand, would improve access to seed, information and improve productivity. The use of mobile phones and information technology could be a cost effective way to reach many small producers.

Water and sanitation are important areas requiring improvement. Social sustainability can be enhanced by further training and support in appropriate systems for different types of producers and processors. Training and support could be extended to ensure greater coverage of cage producers.

6.1.4 Is the VC environmentally sustainable?

The question whether or not the Cambodian value chain is sustainable from an environmental perspective cannot easily be addressed. From a GWP perspective there are high contributions in production systems operating with inclusion of homemade feed (pangasius and mixed fish) due to GWP emissions from the production of rice (as an important food source). Local sources of fish (trash fish) contribute to a lesser extent; however the drawback of these production conditions is the depletion of local fish stocks. In general GWP effects are mainly a result of the feed ingredients (rice), operational processes (transport, energy used in production) are relatively low in Cambodia, due to the artisanal production processes, and the low use of commercial feed sources. Snakehead cultures harbour most of the extraction effects, whereas mixed fish, and intensive and semi-intensive pangasius production harbour the majority of fresh water and marine eutrophication.

Human toxicity (both cancer and non-cancer effects) is mainly a result of all production processes which require combustion of fossil fuels in the production system. These processes combust toxic components in the air, water and soil. The majority of the processes are not taking place in the aquaculture part of the process, however transport, and rice production do contribute here. Toxicity through the release of antibiotics and medicine is not considered due to the selected model. The release of these components is considered in the freshwater toxicity, which also has a feed back to humans through the use of water. However, the models are not developed specifically for application in Asia, and therefore do not directly consider the use of untreated river water prior to consumption.

Freshwater Ecotoxicity (endpoint) is highest in pangasius semi-intensive and snakehead (both cage and pond) culture. The main reason is found in the release of antibiotics, medicine, and chemicals affecting the ecosystem. These also have a potential feedback to human health. Intensive pangasius culture, and intensive snakehead pond cultures have a high impact on freshwater ecotoxicity, the underlying reason is the use of antibiotics and chemical drugs in these cultures in a more intensive way then the semi-intensive production systems of pangasius and mixed fish. The snakehead culture in cages has a higher impact for freshwater ecotoxicity; this is also traced back to the application of medicine in the production system. In this respect the entire industry requires a boost in disease management, at a level of regulation, supplying industry and farmers' level.

Marine Eutrophication is similar in all production chains using rice products as a primary food source, which are mixed fish pond culture, and pangasius cultures. Paddy rice production is the main contributor of the total N eq output, primary production of rice contributes approximately 2/3 to the total N eq output. This is the case for mixed fish and pangasius cultures.

Other contributions are mainly a result of the digestibility of the feed, and release of undigested nutrients (N) via water, and sediment. In snakehead cage cultures the release of N is higher than in pond systems. The reason is the more direct interaction with the surrounding waters, and thus greater direct release to the natural system. In snakehead cultures the contribution from paddy rice production is substantially lower than pangasius and mixed fish production due to the lower inclusion of rice bran in the feed. All together emissions of N eq are up to 90% higher in the mixed fish and pangasius cultures, mainly due to the feed inclusion. Changes in feed efficiency and sourcing of feed may reduce these numbers.

Freshwater Eutrophication is similar in all production chains which use rice products as a primary food source - mixed fish pond culture and pangasius cultures. Rice bran has a relatively high phosphorus content, which in turn is not suitable for complete digestion by the fish. This results in emission of P to the environment. In general P content in fish based diets is relatively high, however the P content of snakehead feed is relatively low due to the use of trash fish (with a relatively low P content).

Improvement of feed sourcing in snakehead cultures, may lead to higher P releases due to the likely increase of P in the feed. Feed management and feed sourcing may contribute to more efficient feed use and thus a reduction of P emissions.

In mixed fish and pangasius cultures, feed management, sourcing and composition may favour reduction of feed emissions, since rice bran is high in P content in comparison to many other sources. Human toxicity effects are considered relatively low, and are mainly contributed by rice production, fertiliser production, and transport and diesel use in the total value chain.

The high inclusion of rice as a feed source contributes to human toxicity effects due to the pesticide use in the production chain. Conversion to alternative selections of raw material for the feed would benefit human toxicity effects; however these will also impose competing claims on local sources of raw materials. However, due to the use of rice by--products in aquaculture, one could argue that the circular economy is well developed in this perspective.

Resource depletion: One of the main concerns about the environmental sustainability of aquaculture is the pressure on local fish stocks for use as feed in aquaculture. The current situation is under regulated, and there are indications of excessive pressure on the fisheries system (declining catches). Therefore, reliance on local sources needs to be reduced and optimised, and sustainable management of local sources is required. Improvement to the efficiency feed and efficiency in the use of local sources in the entire aquaculture chain is recommended. In particular, culture practices for snakehead require a reduction in reliance on local resources.

6.2 Major issues/risks

6.2.1 Competition with imported fish

The economic analysis has shown that at present market prices, some farmers are operating at a very small profit. This was also confirmed by anecdotes of farmers ceasing fish production to migrate to other countries to participate in wage labour. Attempting to compete with Thailand and Vietnam on species for which they have an international supply chain and a competitive advantage, seems unreasonable given the present state of the sector and the enabling environment. Further exploration of alternative species and wisely promoting production systems are recommended. In addition, further development of the enabling environment for the sector is advised to improve competitiveness; however this is a process that requires long-term investments.

6.2.2 Animal health and food safety

The Cambodian value chain is very dynamic, and many small-scale actors are involved in the value chain. The trade system is highly informal, and animal health and food safety control measures are not in place. Knowledge exists about the risk of diseases in terms of financial and production risks, however an adequate system to prevent, foresee and avoid disease is not yet in place. At present, the transport systems for fish, both domestically and from imports, contribute to the spread of diseases, by fish and through the water in which they are transported. In most cases, transport of fish and associated water is not regulated, nor is a control and verification process in place. This enables the spread of diseases without any oversight on direction, extent and conditions. There is an extensive range of medication, probiotics and chemicals available in Cambodia. This promotes widespread use in aquaculture processes (as also seen in the data). However, farmers mostly rely on their own (often insufficient) knowledge, and provision of advice from the government or private suppliers. Many farmers indicated that better quality and more accessible knowledge, and the organisation of control and advice, throughout the production chain would considerably benefit the avoidance of disease and the mitigation of problems. Therefore a more robust disease management, mitigation and control system is recommended, at the level of producers, the supplying industry, and regulations. In addition, hygiene practices in the chain are highly limited, which could lead to food safety risks. At present there is limited information available about the degree to which this leads to threats to human health.

6.2.3 Use of low-value freshwater capture fish for home-made feeds

The feed for both snakehead and pangasius culture is mainly composed of rice inputs, and trash fish from local fisheries or imports. The local fisheries are often not well regulated or controlled. The extent to which trash fish is extracted without license is not well known, and should be further evaluated based on the current regulations. The benefit of trash fish extraction is that the feed sourcing comprises a low CO2 eq emission, since the fisheries require relatively low amounts of energy. Furthermore, in economic terms, the use of freshwater fish for home-made feed makes a high contribution to the indirect value added of the aquaculture sector. However, there are potentially high local effects on the ecosystem when extracting small fish in an uncontrolled and non-organised way (as currently is the case), and this type of feed has a particularly high Feed Conversion Ratio in comparison to other feed sources. There are also potential negative economic effects for the capture fisheries sector. In addition, the potential effect of redirecting this fish away from human consumption, particularly for the poor could be significant (but is not well understood). Reasons for the use of trash-fish are mainly economic, as farmers perceive this feed source to be more affordable (in particular when it is extracted by farmers themselves). Programmes to develop the accessibility of local commercial feed formulated for the species and conditions available in Cambodia are recommended.

6.2.4 Pesticides from Mekong to product and vice versa: accumulation in fish through fresh water trash fish

During the LC Inventory, data on pesticides in fisheries products from fresh water fish in Cambodia have not been generated. Data on commercial farming in Vietnam indicates extensive debates on the pesticide and residue uptake by Mekong fisheries and aquaculture. Several studies have indicated that pesticides are not directly a problem in export samples from aquaculture in Vietnam. However, these studies have analysed for production of fillets only, whereas in Southeast Asia almost the entire fish is consumed by humans or enters the aquaculture chain. Besides this, fish produced for export markets are not fed with trash fish from the same basin (but with pellet based feed). There may be a potential risk from the accumulation of residues in feed fish as well as in consumption fish fed with local Mekong species in Cambodia. In particular, the potential concentration of pesticides in the Mekong river basin may pose a risk, since substantial rice production (and associated residues) has a direct influence on fish and the potential accumulation of residues. The extent to which this may pose a human health risk is not known or documented, and can thus not be quantified at present. It is advisable to analyse the content of residues in both feeding fish as well as end products to ensure that no human health issues are introduced with new aquaculture procedures (or species), especially considering a circular economic cycle in which accumulation in the aquaculture products may occur.

6.2.5 Lack of Good Aquaculture Practices

In general, aquaculture in Cambodia is performed on a traditional and low technology basis. From a sustainability perspective this is not directly considered a risk. However, the lack of efficiency, knowledge (capacity and transfer), level of organisation, and application of best practice farming is considered a risk for sustainable continuation of a large part of the production system. Due to the low level of organisation by farmers, the high influence of the supplying industry on the production sourcing materials, and due to high competition in price and quality of imported fish, there is a wide range of pressures on the production chain. The pressures are different in the different regions in Cambodia. Further investment in farmer support and knowledge transfer, inclusive of both men and women, is needed for the required impact and sustainable development.

6.2.6 Lack of farmer based organisations and capacity

The lack of farmer-based organisations which relates to the complex social and political history of Cambodia, limits the bargaining power of producers in the value chain and arrangements which could benefit both farmers and production conditions. It also inhibits cost effective access to information and training and input markets. There are examples of farmers who are organised mainly in relation to seed supply, which directly benefits the connected farmers. The arrangements are however mainly project and donor based, which tend to be of a temporary character. A strategy to strengthen groups with common interests to access technical information and cooperate in input access, could be supported by actions to strengthen group governance capacity.

6.2.7 Working conditions

Further development of large scale aquaculture enterprises risks negatively impacting vulnerable groups unless working conditions are improved. There is a need to increase awareness of the content of the CAMCODE among fisheries personnel, local government, NGOs etc. It is important that the conditions of labour employed are monitored, particularly issues around health and safety, hygiene and working hours and hazards of chemical use for producers.

6.2.8 Land and water governance

Weak land and water governance in relation to further investment in and expansion of aquaculture could have detrimental effects on local communities, who generally have a low level of awareness of tenure rights and reluctance to seek remedy in case of environmental impacts. Further investment in large scale aquaculture should be conditional on following the provisions of Cambodian land law with regard to identification of locations, respect for tenure rights, local consultation and consent, social and environmental impact assessment and compensation and mitigation of livelihood impacts.

6.2.9 Gender and aquaculture

Lack of women's participation in consultation and decision-making processes may risk women's interests being underrepresented. Recognition of women's role in aquaculture production as well as processing and trading is supported by the FIA's National action plan on Gender Mainstreaming and Elimination of worst forms of child labour. However, strategies and action plans need active promotion both among fisheries personnel and value chain actors, with more emphasis on training, practical implementation and monitoring, together with the resources to support this.

6.2.10 Nutrition and sanitation

The nutritional status of children is affected by waterborne diseases and parasites linked to the absence of latrines. A sustained programme of improvements in sanitation and latrine construction is needed to reduce infections and improve water quality.

6.2.11 Lack of water

Another risk, which is mainly external, is the lack of sufficient and continuous water supply, especially in particular geographic areas, and the potential effects of longer dry seasons, and shorter and heavier wet seasons. This poses economic risks as we have seen examples of lack of water resulting in investments being eliminated (e.g. a hatchery being forced to sell / consume its broodstock due to lack of water). Zoning plans to better address and guide water availability are advised.

6.3 Relevant issues requiring further in depth analysis

The aquaculture value chain in Cambodia was the first study in the VCA4D project and therefore suffered from a degree of inefficiency as all processes were being decided on. This particular value chain has a high degree of complexity with many different systems in which fish is being produced and a high number of species. Limited reliable data was available, which meant the collection of more primary data was required than was initially envisaged. These factors together meant that the amount of time available for the implementation of the study was insufficient to use the methodology and data to the fullest extent.

The following areas of enquiry are in need of more in-depth analysis:
Functional analysis:

- Better understanding of consumers and markets.
- In-depth assessment of food safety risks
- Further assessment of other (local) species for culture that have less competition in the market

Economic analysis:

- Further development of different scenarios of potential economic contribution of the sector 1) if commercial feed is produced locally; 2) if seed is all produced locally; 3) when the sector switches from home-made feed to commercial feeds.

- Better understanding of the economics of home-made versus commercial feeds under different conditions.

Social analysis:

- Improved understanding of land access and labour conditions in large scale aquaculture production and processing enterprises.
- The food security / nutrition effects of the use of freshwater capture fish in home-made feeds

Environmental analysis:

- Better understanding of the environmental effects of extraction of trash fish for home-made feeds. An analysis of the impacts of overall fisheries pressure in the Tonle Sap area, including extraction patterns of fish for aquaculture (domestic and export market) is recommended. The impact of extraction of young fish prior to reproduction, multi- annual fish in high quantities, and one year fish in high quantities should be evaluated. Methods used could be MSY (Maximum Sustainable Yield) analyses of the entire ecological system and for local ecological impacts. In addition, adequate fisheries management plans, education and enforcement are required to guide this process.
- Better understanding of potential human health risks from the accumulation of residues in feed fish as well as in consumption fish fed with local Mekong species in Cambodia.

6.4 Observations/ recommendations regarding the methodology

The methodology for the economic analysis, in particular the software AFA, has some transaction costs for those unfamiliar with the program. For future VC studies it may be recommended to provide more hands-on training to the economic experts to use the software. There also seems to be a tension related to the appropriate profile of the economic expert. Most value chain researchers will be mostly focussed on the micro-economic elements of value chain analysis, while macro-economists would most likely be less familiar with the functional analysis and the analysis for individual actors. It is highly recommended to further develop the guidelines available for the economic analysis with inputs from those economic experts that have already used it. As with the environmental analysis it may also make sense to team the economists up with someone who has already used the method for practical guidance on the types of data to focus on. The combination of a macro and micro level perspective yields important insights and therefore the methodology seems highly useful to provide policy makers with appropriate information for decision making.

For the social analysis, the six thematic areas and sub questions provide a multi-dimensional framework for the analysis which is presented in this report. The analysis was summarised in the social analysis excel spread sheet, together with the scoring assessment. Achieving a balanced allocation of time between field visits and secondary data analysis was quite challenging since both are important and are complementary in developing the overall picture of social conditions in the value chain and the potential issues which might arise in its future development. Consolidation of experience from different value chain social analyses will help to refine approaches which are appropriate for different value chain relationships; for example, how to apply questions on working conditions for both independent smallholder production and private commercial enterprises. Furthermore, the sharing of tools used in field data collection can assist in future studies. For example, in this study, the participatory development of seasonal calendars yielded a range of important insights.

From an environmental perspective the LCA methodology is highly suitable for quantifying environmental indicators of interest. The methodology is a suitable tool to quantify the effects of different scenarios for specific production processes and developments (eg. feed modification scenarios). However, the indicators which are used to calculate environmental impacts do not necessarily represent the hot spots in the relevant value chains. In case of the Cambodian aquaculture value chain, certain environmental risks, such as local fish resource depletion, and the open system for fish transport, and lack of disease management are not considered. For future comparison, it is advised to visit the same set of producers to collect data on the advancements made over time.

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8. Annexes

8.1 Annex 1: List of secondary data sources

Topic	Coverage	Source	Comment
Aquaculture production 2015	Volumes of Freshwater fish, Eel, Frog, Giant freshwater prawn, Turtle, Shrimp, Mud crab, Mussel, Blood cockle, Marine fish, Crocodile, and fingerlings produced in aquaculture by province (2015) in tons	Fisheries Administration	Official statistics, but experts and FiA officers have expressed doubts about reliability.
Ponds, cages, pens data 2015	Numbers and area of ponds, cages, and pens available and in operation by province (2015)	Fisheries Administration	
Hatchery data 2015	Numbers of fish hatcheries, and amount of fish fingerlings produced (2015)	Fisheries Administration	
Cantonment aquaculture annual reports 2016		Fisheries Administration	
Fish and fingerling import license and quota 2015-2017	Two year quota for imports of fish and fingerlings by company	Fisheries Administration	
Agricultural Census 2013	Data on aquaculture production (number, land size) of households outside Phnom Penh with agricultural landholdings of >0.03 ha (2013)	Ministry of Agriculture, Forestry and Fisheries	Data only covers those households that have land, excluding households with cage culture.
Retail prices of fish products 2010-2016	Monthly retail prices of catfish, snakehead in live, dried, and chilled forms in KMR/ kg (2010-2016)	Agricultural market information, Ministry of Agriculture, 2016	Prices are for farmed and capture fish, coverage of species is limited. Need to validate
Partial survey of feed importing companies	Volumes of aquafeed imports from December 2015-June 2016 of 10 feed importers	Mr. Chea Phalla, IFReDI	Seems to be incomplete
National accounts 2014	National accounts 2014	National Institute of Statistics of Cambodia: https://www.nis.gov.kh/index.php/en/#	
Cambodia input-output tables 2011	Cambodia input-output tables 2011	OECD-STAT: http://stats.oecd.org/Index.aspx?DataSetCode=IOTS	

8.2 Annex 2: Sampling framework details

Step 1: Species selection

We have made a sub-selection of the key species and treat the low trophic polyculture species as one group with a homogenous price. The key species identified are:

- Pangasius/ black ear pangasius
- Snakehead
- Giant snakehead
- Climbing perch
- Clarias/ hybrid catfish/ red tail catfish
- Polyculture species (Chinese carb, Indian carp, silver barb, tilapia, macrobrachium)

The first 5 species are mainly grown in monoculture, that differ in production systems and have distinct market prices and target consumers. Frogs and freshwater prawn were excluded.

Step 2: Systems selection for each species

We tabulated the key systems in which each species are most commonly produced.

	Extensive	Semi-intensive	Intensive	Cage
Pangasius/ black ear		X	X	X
Snakehead/ giant snakehead			X	X
Climbing perch			X	
Clarias/ hybrid catfish			X	X
Polyculture (Chinese carb, Indian carp, silver barb, tilapia, pangasius, macrobrachium	X	X	*	*

X: are major systems for this species; *: are minor systems for this species, they were excluded from the survey.

Step 3: Listing of key locations for species X system combinations and variations between locations

We tabulated the key locations for each system

Provinces	Extensive and rice-fish	Semi intensive pond	Intensive pond	Cage
Battambang	*	X		X
Kampong Chhnang				X
Kampung Cham			*	
Kampung Speu	X			
Kampung Thom			*	
Kandal			X	X
Phnom Penh			X	X
Prey Veng	X	X		
Pursat		X	*	X
Siem Reap	*	X	*	X
Takeo	X	X		
Tbong Khmum				

X are major locations for this system; *are minor locations for these systems.

Variations by locations are mainly based on:

- The level of access to pelleted feed and seed
- The level of access to low value fish and/or processing waste as feed input

- The level of access to agricultural by-products (e.g. rice bran) as feed input
- The level of access to product markets

Extensive ponds: these are quite similar systems all over the country, except for freshwater prawn (only in Takeo there is semi-intensive fresh-water prawns). Takeo is the main area for rice fish farming. Extensive polyculture can be found all over the country. The second province chosen was selected because of different characteristics due to higher poverty levels, and location close to the lake, and the remoteness of the extensive systems.

Semi-intensive ponds: Delta province vs Tonle Sap provinces

1. Pursat / Battambang (different systems due to processing waste used for feed (many processors in Battambang and Pursat)
2. Siem Reap (similar to 1 in terms of production processes but les access to processing waste for feed and agricultural by-products)
3. Prey Veng/ Takeo/ Kampung Speu (main producers of low trophic polyculture)

Intensive ponds:

1. Kandal and Phnom Penh: mainly rely on pelleted feed and agr. inputs from other parts).
2. Pursat: production costs lower than in Kandal and Phnom Penh Pursat (lower production costs because of easy access to low value fish so main use for production and also better access to rice bran for homemade feed)

Cages:

1. Kandal / Phnom Penh: easy access to inputs (imported seed and feed) and markets, long terms investments in cage structures (stainless steel cages and mesh)
2. Siem Reap/ Battambang: Easy access to inputs and markets (slightly less than 1), and easy access to low value fish for feed and wild seed, simpler structures (wooden cages), easier to move
3. Kampung Chnnang/ Pursat: Less easy access to inputs and markets, long term investments in cages (like 1)

Step 4: Sample size identification

This was based on a combination of scope for the enumerators to collect the data and the minimum sample size as indicated above.

Summary by system and species

	Semi-intensive	Intensive	Cage	Total
Pangasius/ black ear	5 + 5 + 5	5 + 5	5 + 5 (in location 1 & 2)	35
Snakehead		5 + 5	5 + 5 + 5	25
Giant snakehead		5 + 5	5 + 5 + 5	25
Climbing perch		5 + 5		10
Clarias/ hybrid catfish		5 (in location 1)	5 + 5 (in location 2 & 3)	15
Polyculture (Chinese carb, Indian carp, silver barb, tilapia, pangasius, macrobrachium	5 + 5 + 5			15
	30	45	50	125
Locations for survey	1) Pursat 2) Siem Reap 3) Takeo	1) Kandal/ Phnom Penh 2) Pursat	1) Kandal/ Phnom Penh 2) Pursat 3) Siem Reap	
Scales to cover	S,M	S,M,L	S,M	

Step 5: Listing of main processed products produced and locations of production

Species	Products	Cambodian name	Location	Sample
Pangasius	Dried	Trey giet	Kandal, Pursat	10
Pangasius	Fermented	Paaok	Battambang (imported fish)	3
Pangasius	Fermented	Giet prahoeum	Kandal (local fish)	3
Snakehead	Dried	Trey giet	Siem Reap, Kampung Thom, Pursat	*3
Giant snakehead	Dried	Trey giet	Siem Reap, Kampung Thom, Pursat	*3
Clarias	Smoked	Trey chha-eur	Battambang (Pursat, Kandal)	3
Clarias	Dried (small volumes)	Trey giet	Siem Reap, Kampung Thom	0
			Total	22/25

Volumes: 1) Kandal, 2/3) Pursat, 2/3) Battambang, 4) Siem Reap, 5) Kampung Thom. There may be some overlap between snakehead and giant snakehead processors.

Step 6: Categorization of types of intermediaries (differ in volumes, price)

Intermediaries mostly deal in either fresh or processed products. Some intermediaries specialize in one to three different species.

Species	Fresh	Processed
Pangasius/ black ear	5	5
Snakehead/ giant snakehead	5	5
Climbing perch	5	5
Clarias/ hybrid catfish	5	
Polyculture (Chinese carb, Indian carp, silver barb, tilapia, pangasius, macrobrachium)	5	
	16 interviews?	10 interviews?

These interviews will be conducted in all locations where the producer interviews are done. Need to ensure inclusion of intermediaries of different sizes and types (collectors selling in landing sites; wholesalers selling in landing sites that are not collectors; Collectors selling directly to retailers.

Step 7: Categorization of retailers:

Retailers deal in either fresh or processed products as their main product, but are likely to deal in many or all of the species within this product category. We therefore select a few retailers of each type (fresh/ processed) in each location. Due to resource restrictions we have decided to leave out the service sector (hotels, restaurants) and supermarkets.

8.3 Annex 4. Main freshwater aquaculture species of Cambodia

Species name	Native / Exotic	Farming system	Production volume	Products
Striped catfish (Pangasius hypophthalmus)	Native	Cage, Pond	High	Fresh, dried, fermented
Basa fish (Pangasius bocourti)	Native	Cage	High	Fresh
Black ear catfish (*Pangasius larnaudii*)	Native	Cage	Low	Fresh
African catfish (*Clarias gariepinus*)	Exotic	Pond	High	Smoked, dried
Walking catfish (*Clarias batrachus*)	Native	Pond	High	Smoked, dried
Hybrid catfish (Clarias macrocephalus x C. gariepinus)	Exotic	Cage, Pond	Medium	Fresh, dried
(Asian) Red tail catfish (*Hemibagrus Wyckioides)*	Native	Pond	Low	Fresh
Climbing perch (Anabas testudineus)	Native	Pond	Low	Fresh, dried
Giant snake head (*Channa micropeltes*)	Native	Cage, Pond	High	Fresh, dried
Snake head (Channa striatus)	Native	Cage, Pond	High	Fresh, dried
Silver barb (Barbonymus gonionotus)	Native	Cage, Pond, Rice field	High	Fresh
Nile tilapia (Oreochromis niloticus)	Exotic	Cage, Rice field, Pond	Medium	Fresh
Chinese carp: • Grass carp (Ctenopharyngodon idellus) • Common carp (Cyprinus carpio) • Silver carp (Hypophthalmichthys molitrix) • Bighead carp (Hypophthalmichthys nobilis)	Exotic	Pond, Rice-field	Medium	Fresh
Indian carp: • Catla (Catla catla) • Mrigal (Cirrihinus mrigal) • Rohu (Labeo rohita)	Exotic	Pond, Rice field	Low	Fresh
Hoven's carp (Leptobarbus hoevenii)	Native	Cage, Pond	Low	Fresh
Marbled sand goby (Oxyeleotris marmorata)	Native	Cage, Pond	Low	Fresh
Snakeskin gourami (Trichogaster pectroralis)	Native	Pond, Rice field	Low	Fresh
Red tailed tinfoil (*Barbonymus altus*)	Native	Pond, Rice field	Low	Fresh
Giant freshwater prawn (*Macrobrachium rosenbergii*)	Native	Pond	Low	Fresh

Source: Adapted from http://www.fao.org/fishery/countrysector/naso_cambodia/en#tcN90085

8.4 Annex 5: Additional tables and figures social analysis

	Cage culture	Semi intensive	Intensive	All
Households	40	87	24	151
Total population in survey	269	527	149	945
HHlds consuming fish from own aquaculture	28	69	15	112
Population of consuming hhlds	202	449	102	753
Total production available (net of losses) kg	69,280	300,137	1,086,728	1,456,145
Available per household	1,732.00	3,450	45,280	9,643
Volume sold kg	67,560	294,523	1,082,850	1,444,933
Volume sold kg/hhld	1,689	3,385	45,119	9,569
Volume consumed kg	959	3,610	2,208	6,777
Consumption kg/hhld consuming	34.3	52	147	61
Consumption kg/capita in consuming hhlds	4.747	8.04	22	9.00
% consumed of total fish available	1.38	1.20	0.20	0.47
Households giving away	28	58	16	102
Volume given away kg	761	2,004	1,670	4,435
Kg per households giving away	27.2	34.55	104.37	43.48

Table A5-1. Aquaculture sales, consumption and gifts. (Source: Producers survey 2017. N=151)

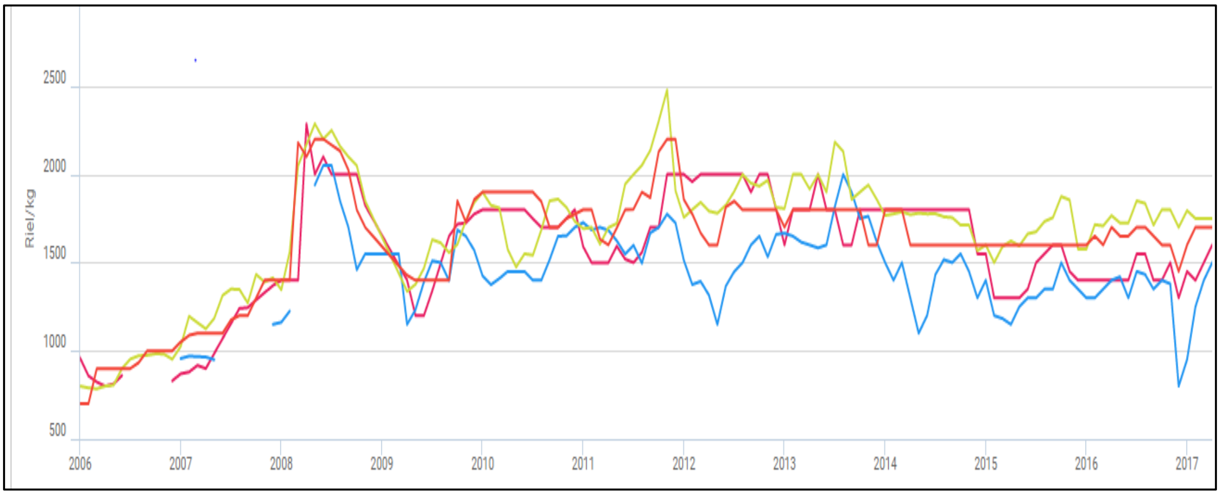

Table A5-2. Wholesale monthly prices of rice 2006-2017 in four markets in Cambodia (FAO)

Banteay Meanchey — Battambang
Kampong Chhnang — Phnom Penh

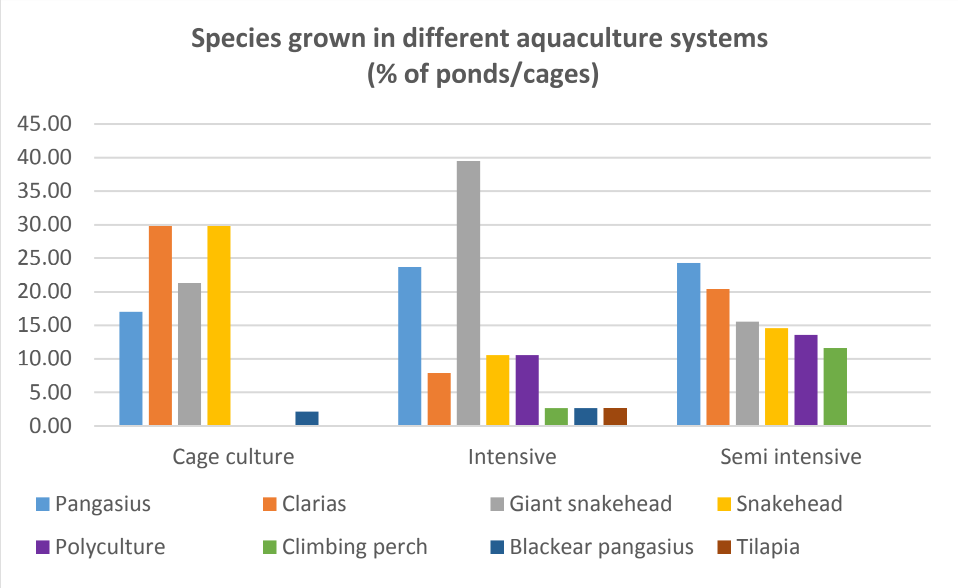

TABLE A5-3. SPECIES GROWN IN DIFFERENT AQUACULTURE SYSTEMS. SOURCE: VALUE CHAIN SURVEY – PRODUCERS.

4.1 Are Working Conditions throughout the VC socially acceptable and sustainable?

4.1.1 Respect of labour rights

- *To what extent do companies involved in the value chain respect the standards elaborated in the 8 fundamental ILO international labour conventions and in the ICESCR and ICCPR?*
- *Is freedom of association allowed and effective (collective bargaining)?*
- *To what extent do workers benefit from enforceable and fair contracts*
- *To what extent are risks of forced labour in any segment of the value chain minimised?*
- *To what extent are any risks of discrimination in employment for specific categories of the population minimised?*

4.1.2 *Child Labour*

- *Degree of school attendance in case children are working (in any segment of the value chain)?*
- *Are children protected from exposure to harmful jobs?*

4.1.3 Job safety

- *Degree of protection from accidents and health damage (in any segment of the value chain)?*

4.1.4 Job attractiveness

- *To what extent is remuneration in accordance with local standards?*
- *Are conditions of work attractive for youth?*

4.2 Are land and water rights socially acceptable and sustainable?

4.2.1 Adherence to VGGT

- *Do the companies/institutions involved in the value chain declare adherence to the VGGT?*
- *If large scale investments for land acquisition are at stake, do the involved companies/institutions apply the 'Guide to due diligence of agribusiness projects that affect land and property rights'?*

4.2.2. Transparency, participation and consultation

- *Level of prior disclosure of project related information to local stakeholders?*
- *Level of participation and consultation of all individuals and groups in the decision-making process?*
- *To what extent prior consent of those affected by the decisions was reached?*
- *Level of accessibility of intervention policies, laws, procedures and decisions to all stakeholders of the value chain?*

4.2.3 Equity, compensation and justice

- *Do the locally applied rules promote secure and equitable tenure rights or access to land and water?*
- *In case disruption of livelihoods is expected, have alternative strategies been considered?*
- *Where expropriation is indispensable: is a system for ensuring fair and prompt compensation in place (in accordance with the national law and publically acknowledged as being fair)?*
- *Are there provisions foreseen to address stakeholder complaints and for arbitration of possible conflicts caused by value chain investments?*

4.3. Is Gender and social inclusion throughout the VC acknowledged, accepted and enhanced

4.3.1 Economic activities

- *Are risks of women being excluded from certain segments of the value chain minimised?*
- *To what extent are women active in the value chain (as producers, processors, workers, traders)?*

4.3.2 Access to resources and services

- *Do women have ownership of assets (other than land)?*
- *Do women have land rights equal with men?*
- *Do women have access to credit? Access to other services (extension services, inputs...)?*

4.3.3 Decision making

- *To what extent do women take part in the decisions related to production?*
- *To what extent are women autonomous in the organisation of their work?*
- *Do women have control over income? Do women earn independent income?*
- *Do women take part in decisions on the purchase, sale or transfer of assets?*

4.3.4 Leadership and empowerment

- *Are women members of groups, trade unions, farmers' organisations?*
- *Do women have leadership positions within the organisations they are part of?*
- *Do women have the power to influence services, territorial power and policy decision making?*

Do women speak in public?

4.4. Are Food and nutrition conditions acceptable and secure?

4.4.1 Food availability

- *Is the local production of food increasing? Are food supplies increasing on local markets?*

4.4.2. Accessibility of food

- *Do people have more income to allocate to food? Are (relative) consumer food prices decreasing?*

4.4.3 Utilisation and nutritional adequacy

- *Is the nutritional quality of available food improving? Are nutritional practices being improved?*
- *Has dietary diversity increased?*

4.4.4 Stability

- *Is the risk of periodic food shortage for households reduced? Is excessive food price variation reduced?*

4.5. Is Social capital enhanced and equitably distributed throughout the VC?

4.5.1 Strength of producer organisations

- *Do formal and informal farmer organisations /cooperatives participate in the value chain?*
- *Are farmer groups, cooperatives and associations able to negotiate in input or output markets?*
- *How inclusive is group/cooperative membership?*
- *Do groups have representative and accountable leadership?*

4.5.2 Information and confidence

- *Do farmers in the value chain have access to information on agricultural practices, agricultural policies, and market prices?*
- *To what extent is the relation between value chain actors perceived as trustworthy?*

4.5.3 Social involvement

- *Do communities participate in decisions that impact their livelihood?*
- *Are there actions to ensure respect of traditional knowledge and resources?*
- *Is there participation in voluntary communal activities for benefit of the community*
- *Investment in social relationships*

4.6. What are the standards of Health, education and training infrastructure and services and do the VC operations contribute to improving them?

4.6.1 Health services

- *Do households have access to health facilities?*
- *Do households have access to health services?*
- *Are health services affordable for households?*

4.6.2 Housing

- *Do households have access to good quality accommodation?*
- *Do households have access to good quality water and sanitation facilities?*

4.6.3 Education and training

- *Is primary education accessible to households?` provided by the investors in the value chain?*
- Are secondary and/or vocational education accessible to households?
- Existence and quality of in-service vocational training provided by the investors in the value chain

4.6.4 Mobility

8.5 Annex 6 Results of the environmental assessment

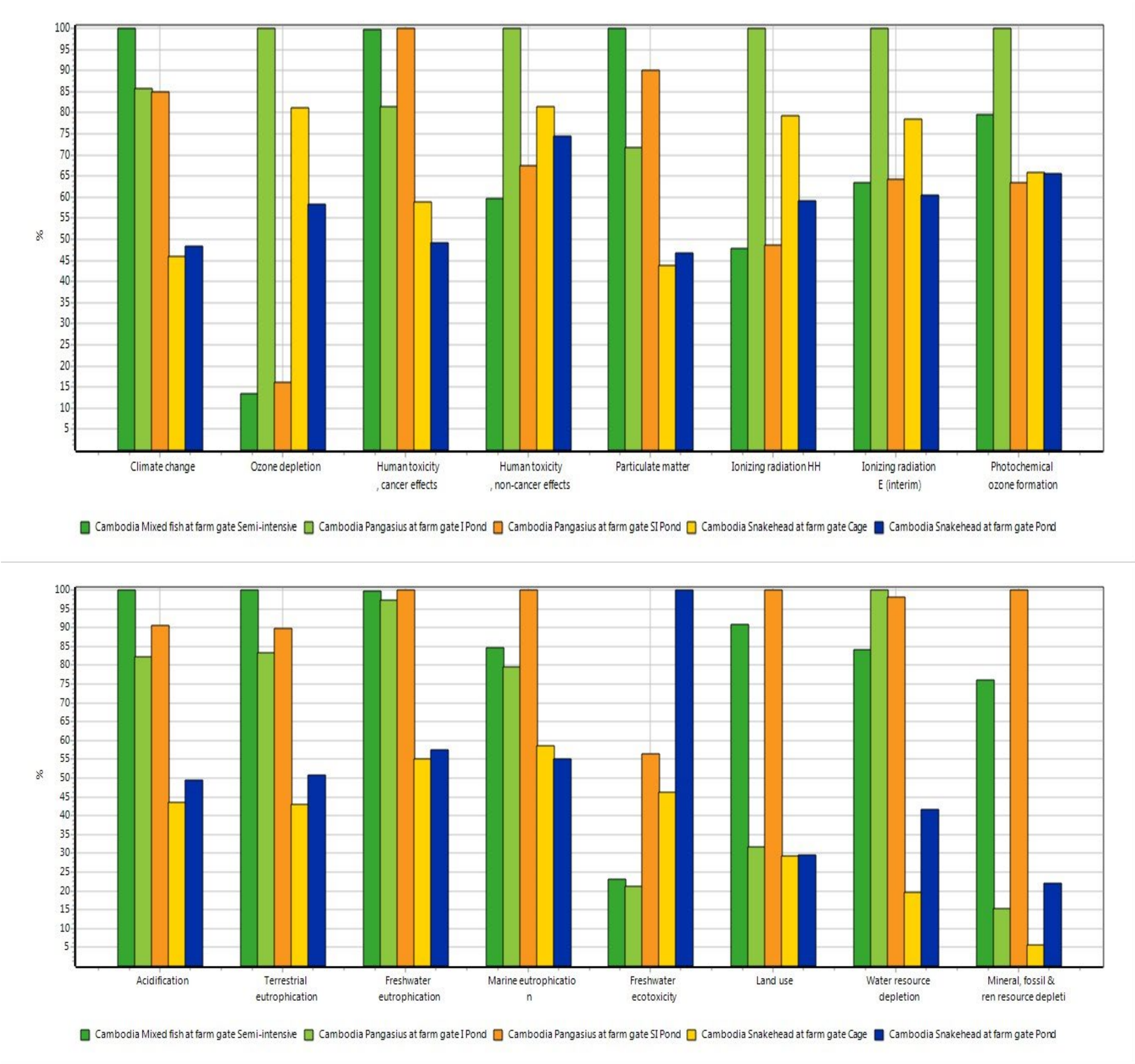

FIGURE 8.1. COMPARISON OF LCA RESULTS OF THE FOUR DIFFERENT PRODUCTION-SPECIES SYSTEM (METHOD: ILCD MIDPOINT 2011+).

The analyses show relative impacts in relation to the highest impact. The individual scores are presented in separate tables (Annex Excel). The y-axes represent the percentage of contribution in relation to the production system with the highest contribution (set at 100%).

Figure 8.2. Contribution analysis of the relative process steps for the individual value chains (Method ILCD Midpoint 2011+)

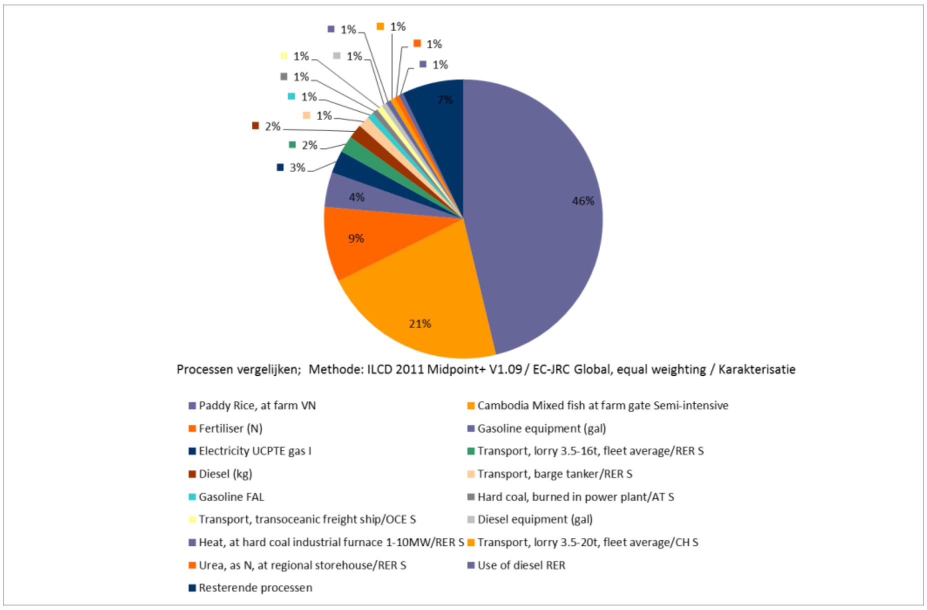

FIGURE 8.3 OVERVIEW OF THE RELATIVE CONTRIBUTION OF CO2 EQ PER KG OF MIXED FISH PRODUCTION IN A POND SYSTEM.

Paddy rice contributes to the largest extent (46%), due to the high inclusion in feed. The production at a farm level contributes with 21%. This is mainly due to the contribution of lime, and waste production processes (pond conversion).

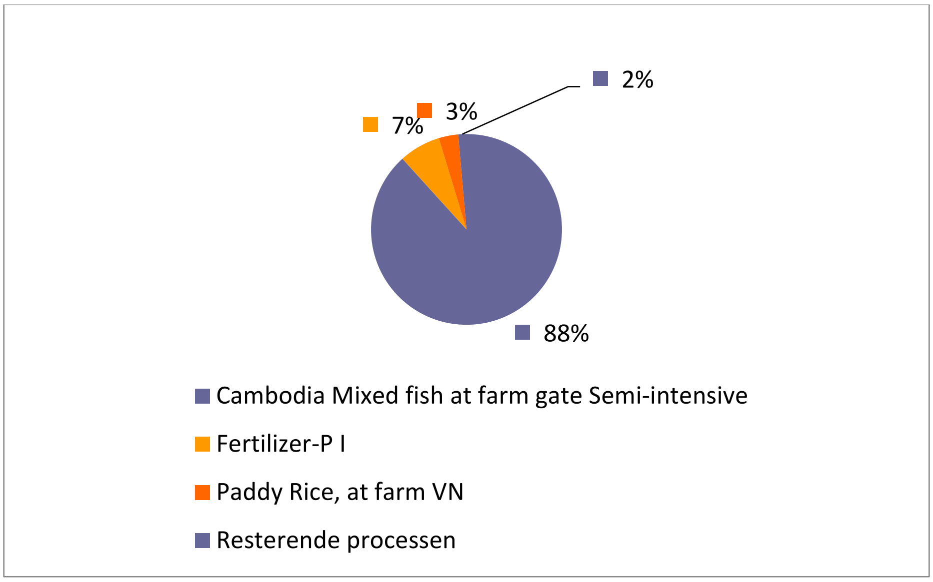

FIGURE 8.4 OVERVIEW OF THE RELATIVE CONTRIBUTION OF FRESHWATER EUTROPHICATION P EQ PER KG OF MIXED FISH PRODUCTION IN POND SYSTEM.

The production system contributes to the largest extent, due to the high excretion of P as a result of undigested P. The production at a farm level contributes with 88%.

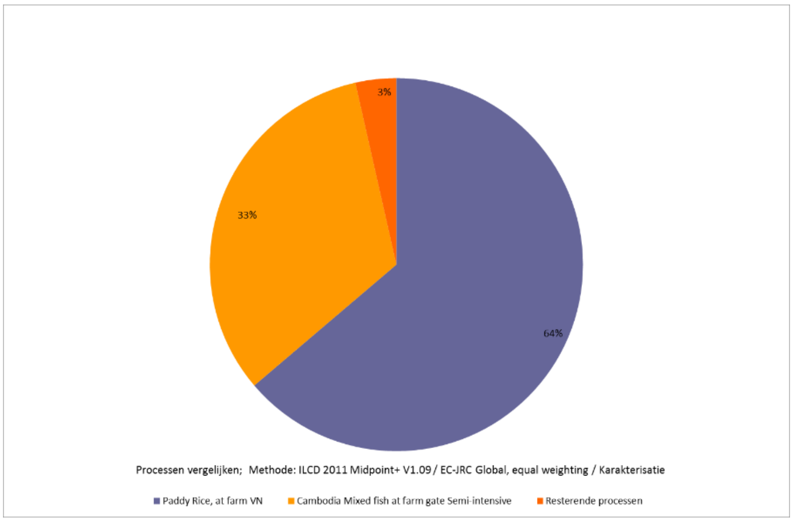

FIGURE 8.5 OVERVIEW OF THE RELATIVE CONTRIBUTION OF MARINE EUTROPHICATION N EQ PER KG OF MIXED FISH PRODUCTION IN POND SYSTEM.

Rice production contributes the largest portion of the total N release (64%). The production system contributes to the second largest extent, due to the high excretion of N as a result of undigested P.

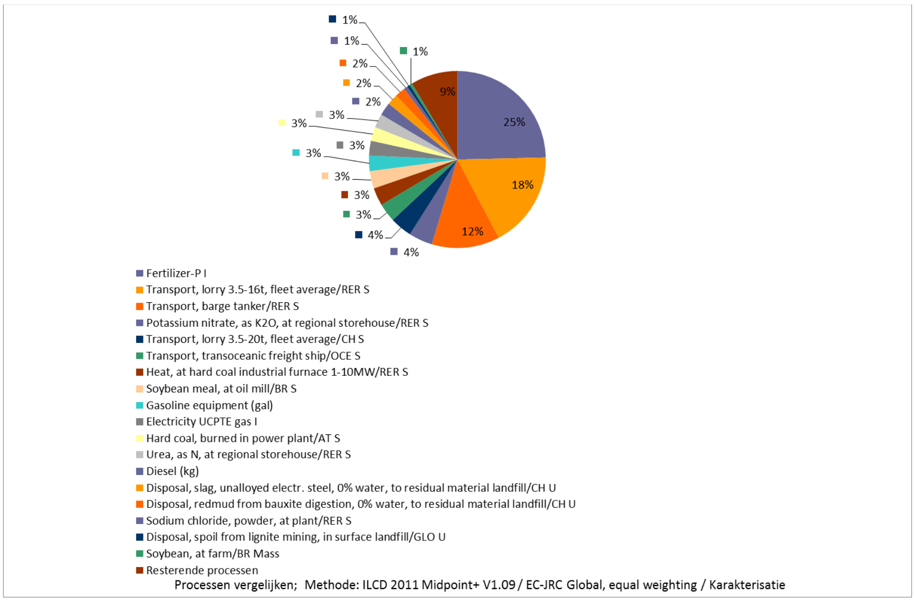

FIGURE 8.6 OVERVIEW OF THE RELATIVE CONTRIBUTION OF HUMAN TOXICITY CTUH PER KG OF MIXED FISH PRODUCTION IN POND SYSTEM.

Fertilizer use, and energy consumption (road, ship and local coal consumption) contribute highest in similar contribution levels.

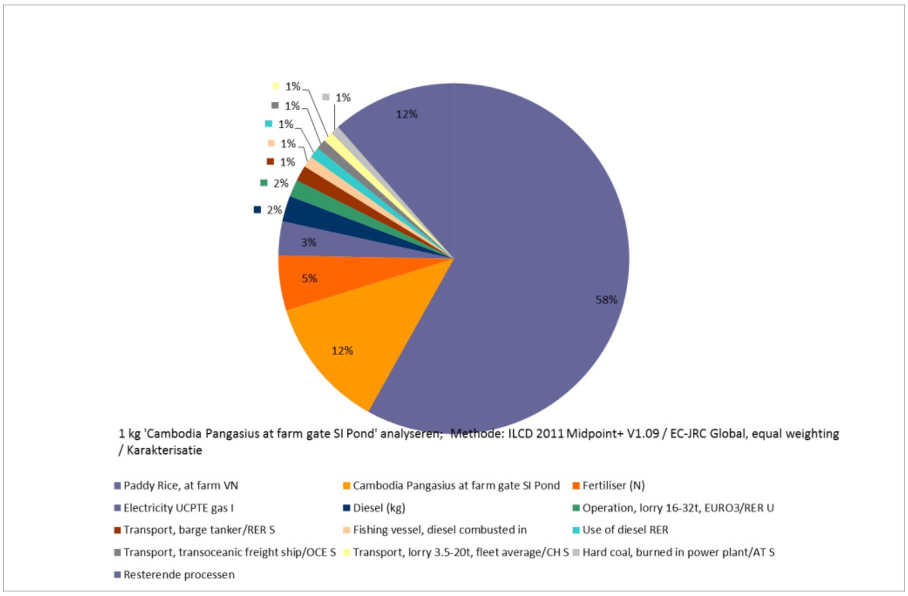

FIGURE 8.7 OVERVIEW OF THE RELATIVE CONTRIBUTION OF CO2 EQ PER KG OF SEMI INTENSIVE PANGASIUS POND PRODUCTION. PADDY RICE CONTRIBUTES TO THE LARGEST EXTENT, DUE TO THE HIGH INCLUSION IN FEED. THE PRODUCTION AT A FARM LEVEL CONTRIBUTES WITH 12%. THIS IS MAINLY DUE TO THE CONTRIBUTION OF LIME, AND WASTE PRODUCTION PROCESSES (POND CONVERSION).

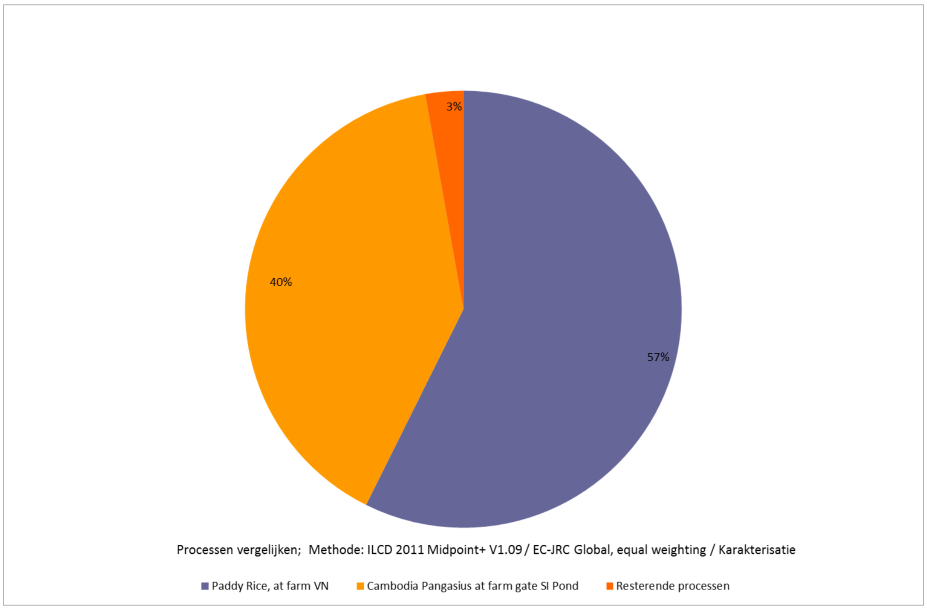

FIGURE 8.8 OVERVIEW OF THE RELATIVE CONTRIBUTION OF FRESHWATER EUTROPHICATION P EQ PER KG OF SEMI INTENSIVE PANGASIUS POND PRODUCTION. THE PRODUCTION SYSTEM CONTRIBUTES TO LARGE EXTENT, DUE TO THE HIGH EXCRETION OF P AS A RESULT OF UNDIGESTED P (40%).

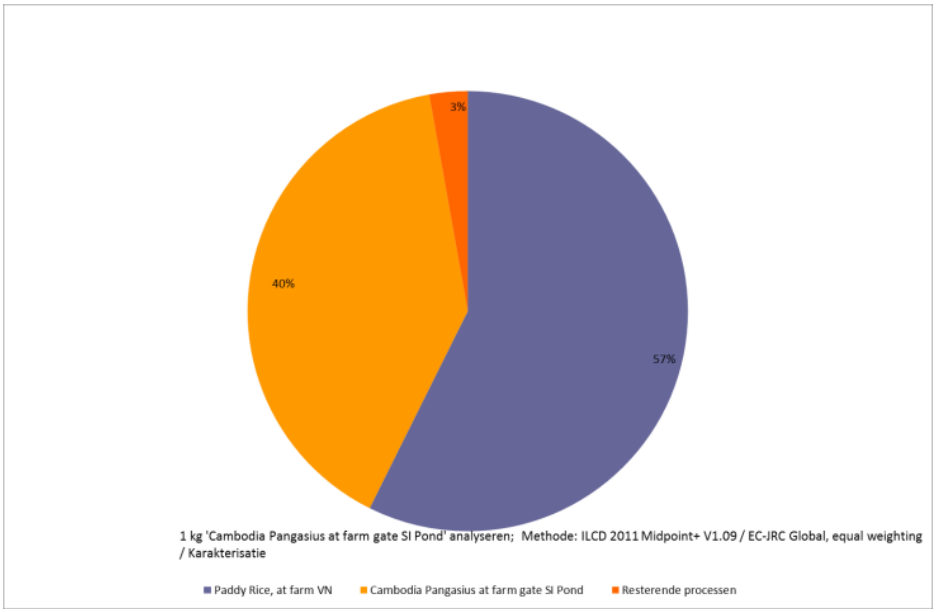

FIGURE 8.9 OVERVIEW OF THE RELATIVE CONTRIBUTION OF MARINE EUTROPHICATION N EQ PER KG OF SEMI INTENSIVE PANGASIUS POND PRODUCTION.

Rice production contributes the largest portion of the total NH3 release (57%). The production system contributes to the second largest extent, due to the high excretion of N as a result of undigested P. The production at a farm level contributes with 57%.

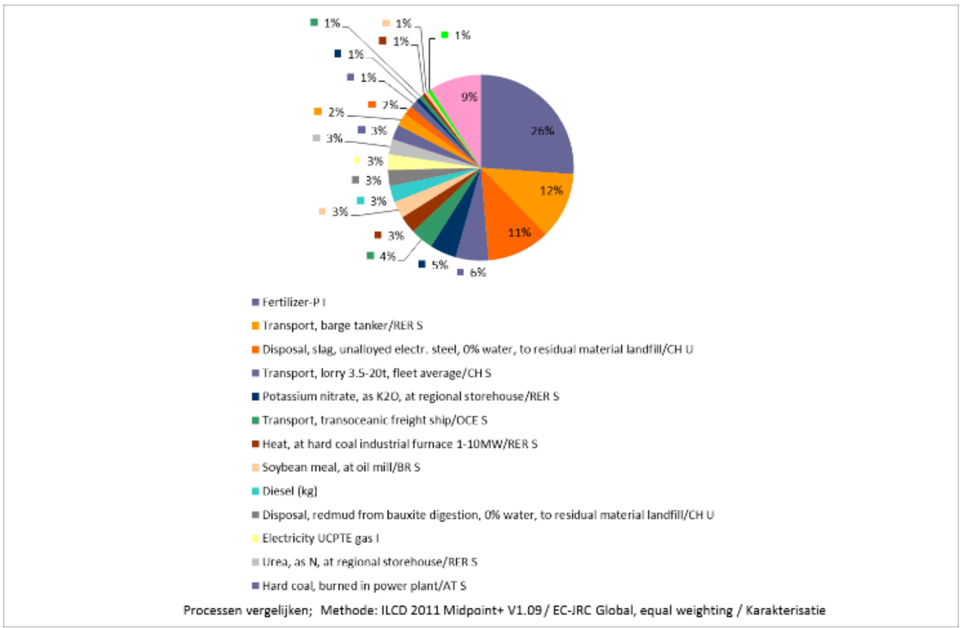

FIGURE 8.10 OVERVIEW OF THE RELATIVE CONTRIBUTION OF HUMAN TOXICITY CTUH PER KG OF SEMI INTENSIVE PANGASIUS POND PRODUCTION.

Fertilizer use, and energy consumption (road, ship and local coal consumption) contribute highest in similar contribution levels.

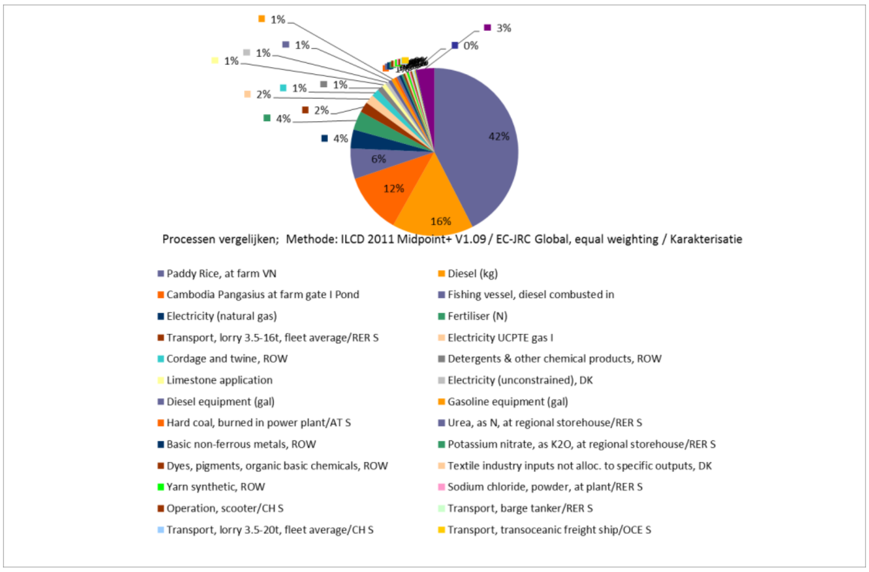

FIGURE 8.11 OVERVIEW OF THE RELATIVE CONTRIBUTION OF CO2 EQ PER KG OF INTENSIVE PANGASIUS PRODUCTION IN A POND SYSTEM.

Paddy rice contributes to the largest extent (42%), due to the high inclusion in feed. The production at a farm level contributes with 16%. This is mainly due to the contribution of lime, and waste production processes (pond conversion).

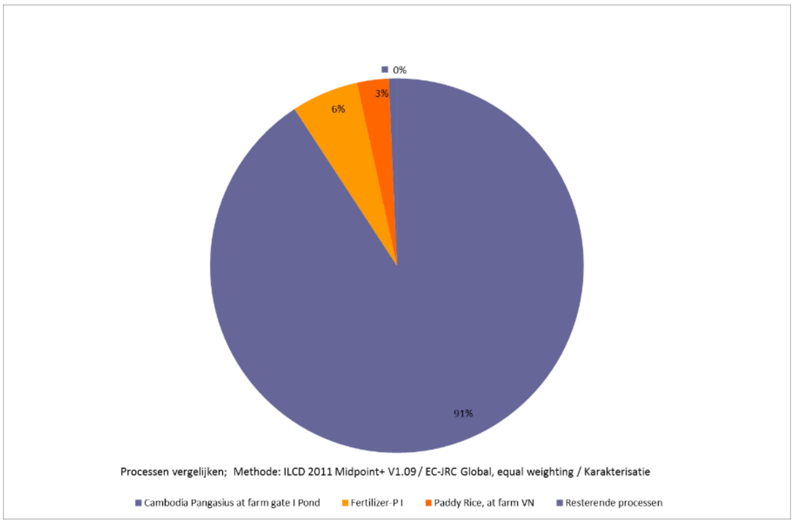

FIGURE 8.12 OVERVIEW OF THE RELATIVE CONTRIBUTION OF FRESHWATER EUTROPHICATION P EQ PER KG OF INTENSIVE PANGASIUS PRODUCTION IN A POND SYSTEM.

The production system contributes to the largest extent, due to the high excretion of P as a result of undigested P. The production at a farm level contributes with 91%.

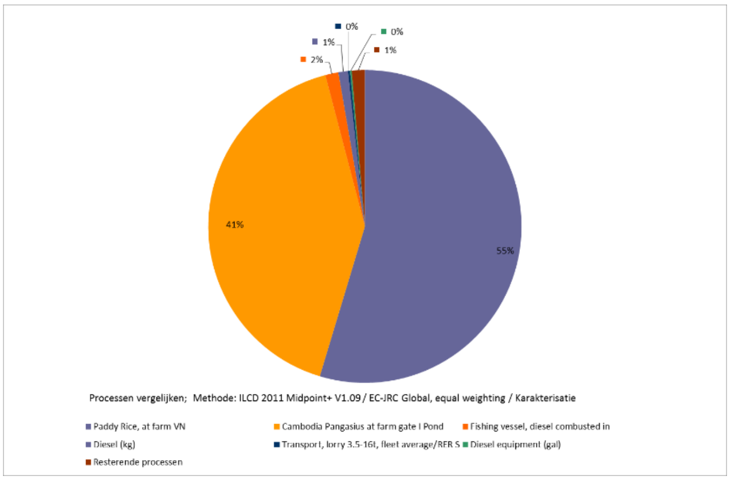

FIGURE 8.13. OVERVIEW OF THE RELATIVE CONTRIBUTION OF MARINE EUTROPHICATION N EQ PER KG OF INTENSIVE PANGASIUS PRODUCTION IN A POND SYSTEM.

Rice production contributes the largest portion of the total NH3 release (55%). The production system contributes to the second largest extent, due to the high excretion of N as a result of undigested P (41%).

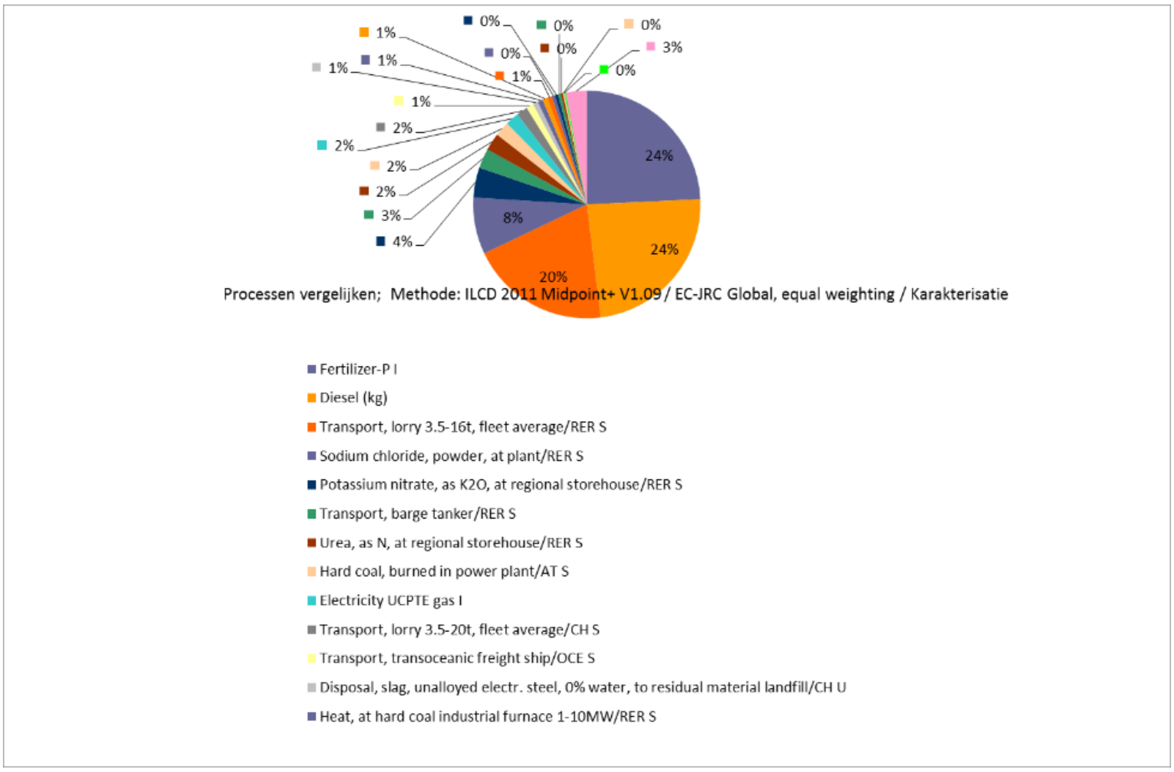

FIGURE 8.14 OVERVIEW OF THE RELATIVE CONTRIBUTION OF HUMAN TOXICITY CTUH PER KG OF INTENSIVE PANGASIUS PRODUCTION IN A POND SYSTEM.

Fertilizer use, and energy consumption (road, ship and local coal consumption) contribute highest in similar contribution levels.

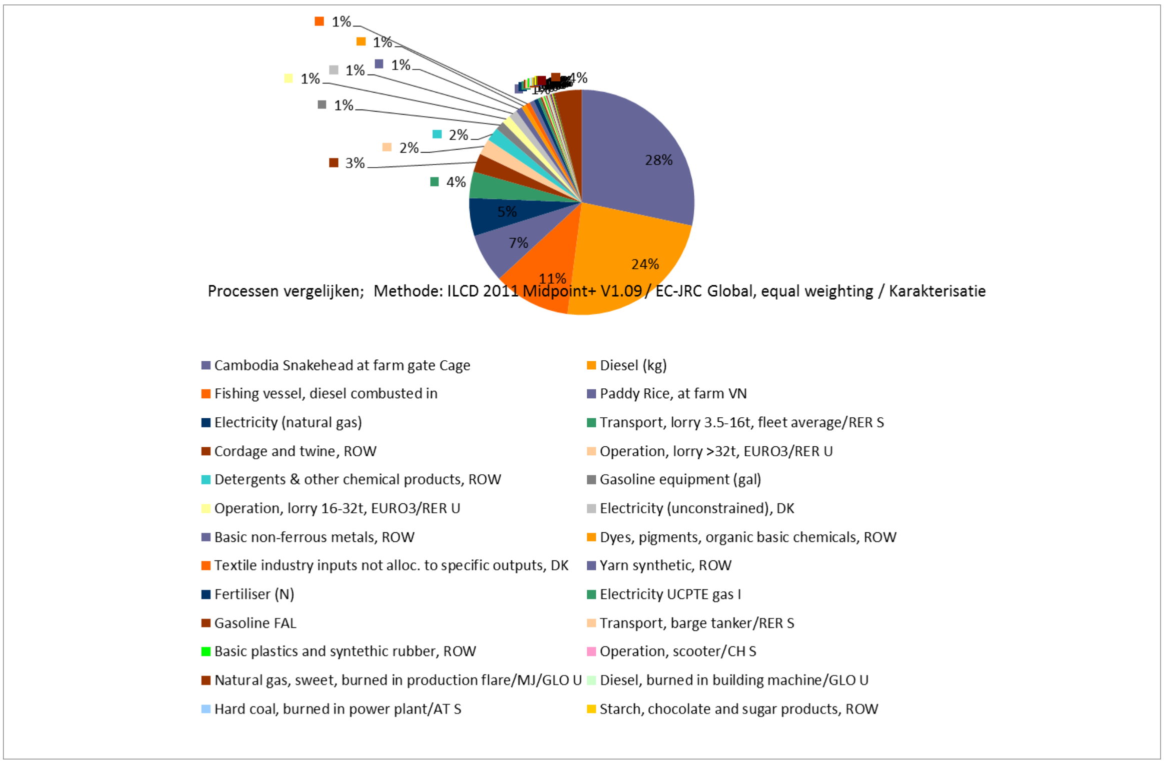

FIGURE 8.15 OVERVIEW OF THE RELATIVE CONTRIBUTION OF CO2 EQ PER KG OF SNAKEHEAD PRODUCTION IN A POND SYSTEM.

Paddy rice contributes to the largest extent, due to inclusion in feed (28%). The production at a farm level contributes with 24%. This is mainly due to the contribution of lime, and waste production processes (pond conversion).

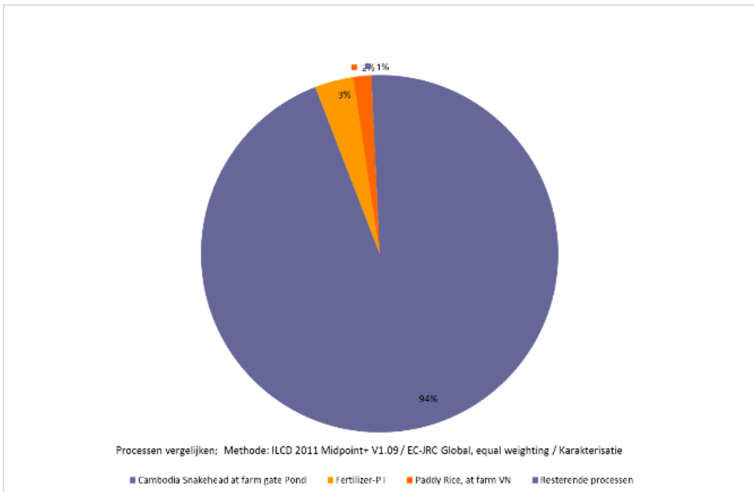

FIGURE 8.16 OVERVIEW OF THE RELATIVE CONTRIBUTION OF FRESHWATER EUTROPHICATION P EQ PER KG OF SNAKEHEAD PRODUCTION IN A POND SYSTEM.

The production system contributes to the largest extent, due to the high excretion of P as a result of undigested P. The production at a farm level contributes with 94%.

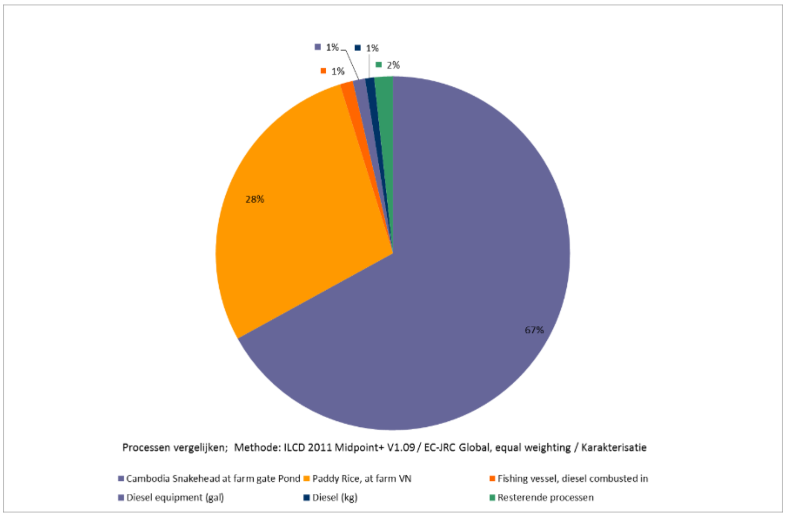

FIGURE 8.17 OVERVIEW OF THE RELATIVE CONTRIBUTION OF MARINE EUTROPHICATION N EQ PER KG OF SNAKEHEAD PRODUCTION IN A POND SYSTEM.

Rice production contributes the largest portion of the total NH3 release (67%). The production system contributes to the second largest extent, due to the high excretion of N as a result of undigested P. The production at a farm level contributes with 28%.

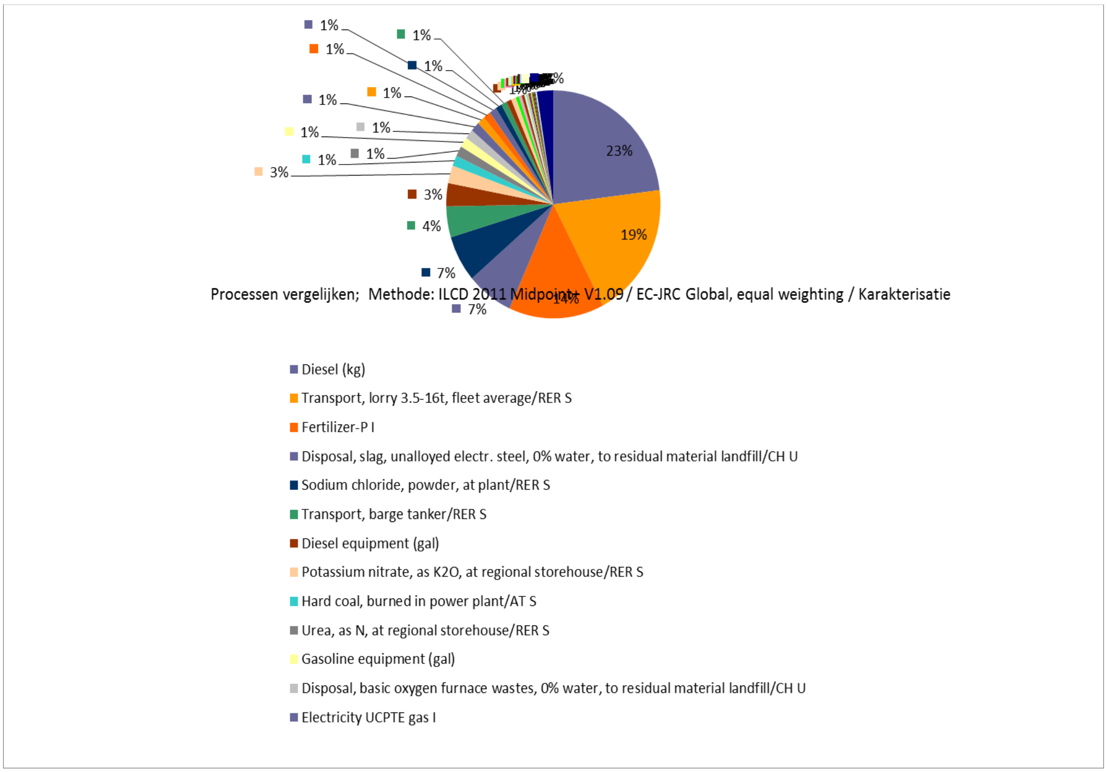

FIGURE 8.18 OVERVIEW OF THE RELATIVE CONTRIBUTION OF HUMAN TOXICITY CTUH PER KG SNAKEHEAD IN A POND SYSTEM.