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AQUACULTURE IN MYANMAR: FISH FARM TECHNOLOGY, PRODUCTION ECONOMICS AND MANAGEMENT

By

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Food Security Policy *Research Papers*

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EXECUTIVE SUMMARY

Fish farming (aquaculture) has grown rapidly in Myanmar over the last two decades and plays an increasingly important role in national fish supply, but its technical and economic characteristics have been poorly studied. This report addresses this knowledge gap by presenting data from the first statistically representative survey of fish farms conducted in Myanmar - the Myanmar Aquaculture-Agriculture Survey (MAAS).

MAAS was implemented in May 2016. A total of 242 fish farming households (151 growout farms and 73 nurseries) were interviewed in a 'cluster' of 25 village tracts as part of a larger survey that covered 1102 households in 40 village tracts in the main fish growing areas of Myanmar in Ayeyarwady and Yangon regions. As estimated from satellite images, the village tracts surveyed contained 57% of the total area of inland fish ponds in the Ayeyarwady Delta. Surveyed farms represent the entire population of fish farming households resident in these village tracts.

Survey results provide a comprehensive 'benchmark' of the characteristics of inland aquaculture in Myanmar. Features analyzed include: farm productivity and profitability; farm size; production cycle duration; use of feed, seed and other production inputs; demand for labor; harvesting and marketing behaviors; technological change; the economic and social characteristics of fish farming households; and land access and tenure.

The following results stand out:

1. High returns

Aquaculture generates much higher earnings per hectare than crop farming. The average gross margin earned by fish farmers with growout farms is nearly $650/acre ($1600/ha). Surveyed crop farming households in 'aquaculture cluster' village tracts make an average annual gross margin of just $150/acre ($380/ha) across all field crops. Gross margins for individual crops in these village tracts range from $85/acre ($210/ha) for monsoon paddy, to $175/acre ($430/ha) for black gram.

Fish farming households are twice as well-off as the general **population** of village tracts in the aquaculture cluster. Fish farming households' estimated consumption expenditure (a proxy for income) averages $1525 per capita per year, compared to $718 per capita for all households in the cluster. Households with large growout farms are 4.2 times wealthier than the cluster population average, with average consumption expenditures of $2980 per capita.

2. Job creation

Aquaculture creates more on-farm employment opportunities than agriculture. Considering all inputs of family labor, hired casual labor and hired long-term labor, fish farms require almost four times more labor per acre than crop farms (94 person days/year, versus 24 person days/year). This difference reflects the constant nature demand for labor on fish farms, the strongly seasonal nature of demand for labor on crop farms, and the high degree of agricultural mechanization that has taken place in the areas surveyed.

Small fish farms create much more employment than large fish farms. Small growout farms generate demand for 152 person days of labor per acre/year. Medium sized and large growout farms generate demand for 41 days and 17 days, respectively. These differences reflect economies of scale in the employment of certain types of labor.

Fish farms pay higher wages than crop farms, especially for women. The daily wage for work on fish farms averages $4.22/day. Workers on crop farms earn 27% less on average ($3.32/day). Further, the gender gap in wages is smaller in aquaculture than in agriculture: Women employed in crop farming receive about 2/3 of the average male daily wage for their work, whereas women employed in aquaculture earn 3/4 of the male daily wage.

Fish farming remains a male-dominated activity. Only 20% of individuals who reported aquaculture to be their primary occupation were women. In addition, women represent only 13% of the casual workforce on fish farms. These figures are lower than the corresponding shares in crop farming, where women represent 27% of farmers and 33% of wage workers.

3. Numerous nurseries and small farms

Nurseries are an important but overlooked farm segment. Specialized nurseries growing juvenile fish ("seed") for sale to growout farms account for 41% of all aqua-farms. Almost all nurseries (97%) are less than 10 acres in size. Nursery operators own approximately only half as much land as crop farmers: an average of 3.7 acres of land, with a median area of just 1.7 acres. The average gross margin earned by nurseries $680/acre ($1681/ha) is comparable to the average return from fish growout farms, and considerably higher than that from small and medium growout farms.

Small farms dominate by number, large farms dominate by area. Contrary to the conventional wisdom that Myanmar's fish farms are all very large, half (51%) of all growout farms are less than 10 acres in size. These farms account for only 9% of total surveyed pond area, however. Conversely, large farms (those over 40 acres), account for 21% of farms but 70% of surveyed pond area. Operators of growout farms own more than three times as much land as crop farming households on average (30.5 acres, versus 8.0 acres).

4. Specialized commercial activity

Fish production is highly commercial. Although 93% of households reported consuming some of the fish they harvested, either directly or as gratuities to workers, fish consumed in these ways represented less than 1% of fish produced among farms in all size categories.

Fish farming is a specialized activity. Households who farm fish operate little agricultural land on average (0.5 acres and 1.4 acres for households with specialized nurseries and growout farms respectively).

5. Variable yields

Yields are modest. The average yield across all farms was 1.9 t/acre (4.8 t/ha). This level is comparable to yields from small well managed commercial carp farms in Bangladesh, but approximately half as much as is typical in Andhra Pradesh, India, where carp-farming technologies are well advanced.

Productivity is highly variable. The worst performing 20% of farms had yields 11 times lower than the best performing 20% of farms (0.2 t/acre or 0.6 t/ha, versus 2.8 t/acre or 6.9 t/ha). Much of this variability can be accounted for by differences in investment capacity - the best performing quintile of farms spend almost nine times more on operating costs than the least productive quintile.

***Larger farms have higher yields**,* contrary to expectations. Average productivity ranges from 1.5 t/acre (3.8 t/ha) on small farms, to 2.5 t/acre (6.1 t/ha) on large farms. This reflects longer average production cycles, better access to credit, and higher levels of feed use among larger farms. Large farms spent almost twice as per acre of pond on floating and sinking pelleted fish feeds than small farms, and 2.3 times as much on peanut oilcake. Expenditure on rice bran, a cheaper but less efficient feed, was similar across farms of different sizes.

6. Simple technologies

Use of fertilizers is extremely limited. Pond fertilization is a simple, low cost technique that can significantly improve farm productivity by stimulating blooms of plankton that provide natural food for fish. However, only 25% of farms surveyed used any kind of fertilizer, and fertilizers accounted for less than 1% of total operating costs. This finding suggests significant scope to increase fertilizer application.

Use of pelleted fish feeds is low. Pelleted feeds are formulated to ensure a complete diet for farmed fish, facilitating more efficient feed conversion and faster fish growth than other commonly used feeds such as rice bran. Only 15% of farms use any manufactured pelleted feeds. This is considerably lower than in other Asian countries (e.g. Bangladesh 38%, China 90%). The main feeds are byproducts from agricultural processing; most importantly rice bran (used by 86% of farms) and peanut oilcake (44% of farms). On average, more productive farms spent a smaller share of their feed budgets on rice bran than less productive farms, and a higher share on pelleted feeds.

7. Crop diversity

The vast majority of farms are polycultures, meaning that they stock multiple fish species in the same pond. Eighty six percent of farms stock more than one species, and the average number of species stocked per farm is 3.3. Carp species dominate production. The three most commonly stocked fish - rohu (94% of farms), catla (74%), mrigal (60%) - are all carps. The three next most commonly farmed fish are non-carp species; pangasius (28% of farms), tilapia (11%), and pacu (8%). Almost half of farms stock only carp species, and fewer than 5% stock no carp at all.

The range of species farmed is limited, but increasing gradually. Farmers were asked about the year in which they first produced the species they presently stocked on their farm. In 1995, 93% of farmers stocked one of four major species (rohu, catla, mrigal, and pangasius). By 2015, this share had fallen to 77%, indicating that some species diversification had taken place.

Small farms specialize more in the production of non-carp species. Small farms are most likely to farm non-carp species, and obtain higher average yields of tilapia and pacu than medium or large farms growing these species. In contrast, yields of rohu and pangasius from large farms are almost double those of small farms. Nine percent of small farms stock freshwater prawn, a high value crop that is not produced by any medium or large farms.

8. Production costs

Feed is by far the largest operating cost, accounting for 70% of variable costs. Feed costs average $1400/acre ($3300/ha), or a total of $16,800 for an average-sized farm. This is followed by seed (9% of operating costs), and non-feed inputs (7%), consisting primarily of fuel. Labor accounts for only 4% of operating costs.

Price pressures may be eroding farm profitability. From 2006 to 2016, the nominal price of the most widely used fish feed, rice bran, rose by 38 percentage points more than the nominal farmgate price of rohu. Given the high share of feed in operating costs, this suggests that the average profitability of fish production probably fell over this period.

9. Finance

Large farms have better access to credit. Twenty six percent of farms reported receiving credit from the main buyer of their fish. It is more common for large farms to receive credit (55% of farms) than small or medium (both 17%). Interest accounted for only 2% of operating costs, averaged across all farms, despite most loans being taken from informal lenders at high rates. This figure reflects relatively limited levels of credit utilization.

Pelleted feeds are available on credit, other feeds are not. Suppliers of agricultural byproducts such as rice bran rarely provide these to farmers on credit. However, 28% of users of sinking pellets and 53% of users of floating pellets received part or all of these inputs on credit. Three quarters (75%) of farmers who obtained pelleted feeds on credit were required to sell harvested fish back to the credit provider.

10. Non-farm linkages

Aquaculture creates demand for goods and services from off-farm enterprises. For example, 78% of farms utilize rented boats or motor vehicles to deliver harvested fish to market, and 93% of farms purchase ice for transporting fish. Two thirds of growout farms (66%) purchase fingerlings, primarily from nurseries. Small farms are more likely than medium or large farms to purchase seed from nurseries.

11. Market concentration

The market for pelleted fish feeds is highly concentrated. Sixty percent of all pelleted feed used by surveyed farmers, including 65% of all sinking feed and 51% of floating feed, was sourced from a single company.

Marketing channels are simple. Among farms of all sizes, the main buyer of harvested fish was overwhelmingly a fish trader (96%). Most farms (92%) sold their entire harvest to directly a single buyer. Three quarters of buyers (76%) were traders located at the main Yangon fish wholesale market, San Pya. Almost all farms (96%) paid a commission on sales, averaging 4.9%. Despite the high value of most sales, 98% of transactions were settled in cash, with just 2% of payment taking place via bank transfer.

12. Landholdings and tenure security

Ownership of fish farms is becoming more concentrated. The mean size of growout farms rose from 14 to 22 acres from 2006-2016. As a result, the weighted Gini coefficient for land used for growout farming increased from 0.55 in 2001, to 0.73 in 2016.

Small fish farms have less secure land tenure than large farms. Only 16% of ponds on small farms were reported to have La Na 39 (the land use title document that permits conversion of agricultural land to non-agricultural uses), compared to 60% of ponds on large farms.

Implications for policy and programing

These findings have the following implications for the design of policies and interventions aimed at promoting the growth of aquaculture.

1. **Fish farming should be recognized and promoted as a mechanism for generating rural growth**. Average returns from aquaculture are four times higher than those earned from crop farming. In addition, aquaculture creates numerous economic linkages within the rural economy where farms are located. These include demand for labor, intermediate inputs (e.g. fish seed from nurseries) and services (e.g. transport). However, yields and profitability are highly variable, and small farms in particular perform sub-optimally. Simple management improvements could enhance their performance.

2. **Small farms (sized 10 acres or less) and nurseries should be the principal target of policy and technical interventions**. Considered together, these account for 70% of all fish farms. Small farms create greater relative demand for labor and many goods and services than large farms. However, they remain disadvantaged in terms of tenure security, access to credit, and their capacity to invest in adequate levels of production inputs. Overcoming these constraints would help boost small farm productivity and profitability and bring them closer to that of larger farms.

3. **Smaller farms have a competitive advantage in the production of non-carp species** – especially tilapia, pacu and freshwater prawn, as indicated by small farms attaining higher yields of these species than medium or large. Investments in these species should be prioritized; especially by supporting the establishment of privately operated mono-sex tilapia hatcheries, and research to overcome bottlenecks in the hatchery production of freshwater prawn.

4. **Conduct research and outreach on use of fertilizers**. Pond fertilization is a simple low cost technique that can significantly improve production efficiency, and is widely adopted by fish farmers elsewhere in Asia. Research is needed to understand farmers' attitudes toward and use of fertilizers, identify management protocols for optimal fertilizer use under Myanmar conditions through field trials, and disseminate results and recommendations to users.

5. **Identify mechanisms for providing commercial loans, tailored to the needs of actors in aquaculture value chains**. Operating costs for these enterprises are high and access to even informal forms of credit is currently limited.

6. **Encourage private investment in the feed sector** to increase competitiveness, lower feed prices, and improve ease and terms of access to pelleted fish feeds.

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1. INTRODUCTION

1.1. Study background

Aquaculture (fish farming) has grown rapidly in Myanmar over the last two decades and plays an increasingly important role in national fish supply (Belton et al., 2015), but its technical and economic characteristics have been inadequately studied. This report addresses this knowledge gap, presenting benchmark data from the first statistically representative survey of fish farms conducted in Myanmar - the Myanmar Aquaculture-Agriculture Survey (MAAS).

MAAS was implemented in May 2016. Data were collected from a total of 1102 rural households, including crop farmers, fish farmers, and the landless, located in 40 village tracts[1] in four townships (Twantay, Maubin, Nyaungdon, Kayan) in Ayeyarwady and Yangon regions. All the village tracts surveyed lie in a zone within a radius of 60 km from Myanmar's largest city and main commercial center, Yangon. The households surveyed represent a total population of about 37,000 households. Details of the sampled households and their landholdings are provided in Table 1.

Table 1: Summary statistics on households surveyed in MAAS

	In sample		In the represented economy (weighted)		Weighted farm size (acres)	
	N	%	N	%	Mean	Median
All households	1,102	100	37,390	100	-	-
Fish farming households*	224	20	2,450	7	14.1	3
Crop farming households	329	30	9,604	26	6.8	4
Non-farm households	549	50	25,336	68	0	0

*Note: Fish farming households here includes both growout farms and specialized nurseries

A subset of 242 fish farming households (151 growout farms and 73 nurseries) were interviewed in 25 village tracts (the 'aquaculture cluster' village tracts identified in Figure 1), representing a total of 2450 fish farming households.

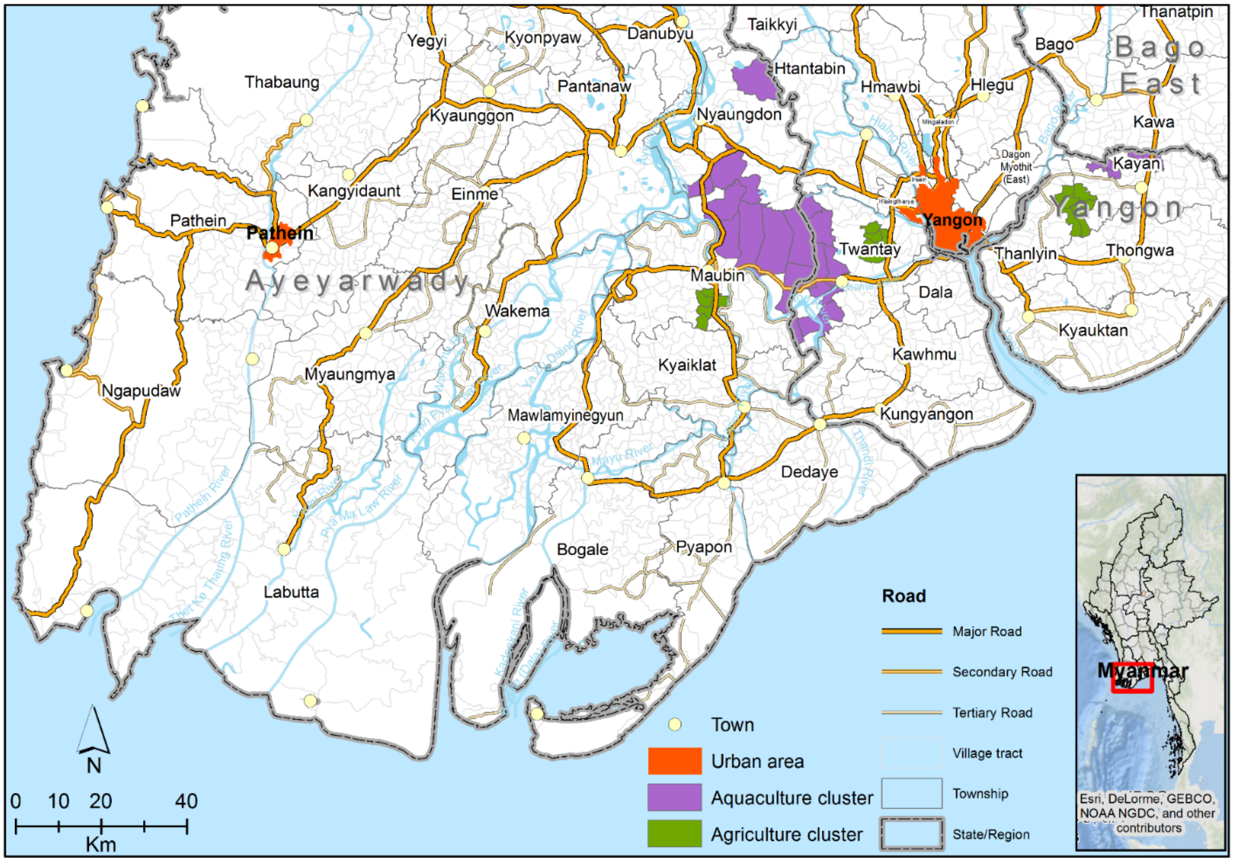
Analysis of satellite images conducted as part of the sampling process indicates that 57% of the total area of inland fish ponds in Myanmar lies within the village tracts surveyed. Farms surveyed were selected to represent the entire population of fish farming households resident in the 25 village tracts.[2] Given that 90% of Myanmar's inland fish ponds are located in Ayeyarwady and Yangon regions (DOF, 2014), the sample can be considered to represent approximately half the area under freshwater aquaculture in Myanmar. A detailed summary of the survey methodology is provided in Annex 1.

This report provides a comprehensive 'benchmark' of data on the technical, economic and social characteristics of inland aquaculture in Myanmar in 2016. It covers the following topics: farm productivity and profitability; farm size; the duration of the production cycle; use of seed, feed and other production inputs; demand for labor; harvesting and marketing practices; technological change; socioeconomic characteristics of fish farming households; land access and tenure.

[1] A village tract is the smallest administrative sub-unit in Myanmar, usually composed of 5-10 villages

[2] Fish farms operated by non-residents of these village tracts (i.e. absentee owners and companies) were not captured in the survey. The data presented here thus tend to underrepresent very large farms, sized 100 acres or more.

Figure 1. Location of Surveyed Village Tracts



1.2. Farm typology

Two types of fish farms were surveyed: 1) specialized nurseries, comprising 41% of all aqua-farms, growing juvenile fish ("fingerlings") for sale to growout farms (41% of aqua-farms); and 2) "growout" farms producing food fish for the market (59% of aqua-farms). All economic and technical analysis presented in this report pertains to growout farms, except where explicitly stated otherwise.

In the analysis that follows, we divide growout farms into three size categories as follows: 'small' (<10 acres, 51% of growout farms); 'medium' (between 10 and 40 acres, 28%); 'large' (40 acres and above, 21%). Among growout farms, 80% are 'semi-intensive', which we define simply here as those where fish are fed exclusively on agro-processing byproducts such as rice bran and peanut oilcake. 'Intensive' farms (defined here as those using pelleted fish feeds at any time during the production cycle) account for 16% of growout farms. Four percent of growout farms sampled are 'integrated' with poultry houses built above ponds that provide nutrients for fish in the form of droppings and spilt feed.

1.3. Nomenclature

We refer to fish by their English common names in this document. A list of Myanmar, English and scientific names is provided below to assist readers.

Myanmar name	English name	Scientific name
Nga myitchin	Rohu	*Labeo rohita*
Nga gaung pwa	Catla	*Catla catla*
Nga gyinn pyu	Mrigal	*Cirrhinus cirrhosis*
Nga dan	Pangasius	*Pangasianodon hypophthalmus*
Nga mote	Pacu	*Colossoma brachypomum*
Tilapia	Tilapia	*Oreochromis nilotica*
Shwe war nga gyinn	Common carp	*Cyprinus carpio*
Nga kone ma gyi	Silver barb	*Barbonymus gonionotus*
Nga ku	Walking catfish	*Clarias spp.*
Pazone doke	Giant freshwater prawn	*Macrobrachium rosenbergii*

1.4. Units

To aid interpretation by both national and international audiences, in the remainder of this report all measures of volume, yield, prices are reported in both local and international units (e.g. viss/acre and MMK/acre, and t/ha and $/ha). One viss is equal to 1.6 kg. One hectare is equal to 2.47 acres. Simple area is reported only in acres.

Prices are reported in both Myanmar Kyat (MMK), and US Dollars ($), at a typical 2016 exchange rate of MMK 1200 = $1.

2. FARM PRODUCTIVITY AND PROFITABILITY

This section presents data on the performance of growout farms. Results are based on a detailed technical survey of one pond from each sampled growout farm. Farms with both growout ponds and nursery ponds were considered as growout farms. The largest growout pond on each farm was selected as the sample pond.

2.1. Growout farm productivity

Average growout farm productivity is modest, reflecting the predominantly semi-intensive nature of most production. The average yield across all farms was 4.8 t/ha (1228 viss/acre); similar to the yields achieved by small commercial carp farms in Bangladesh (Jahan et al., 2015) but well below average yields of 9 t/ha achieved by carp farmers in Andhra Pradesh, India (Belton et al., 2017).

Farm size and average productivity are positively correlated. This pattern reflects longer average production cycles, better access to credit and higher levels of feed use on larger farms. Average yields range from 3.8 t/ha (952 viss/acre) for farms under 10 acres in size to 6.1 t/ha (1543 viss/acre) for farms over 40 acres (16 ha) (Figure 2).

Figure 2. Average yield, by farm size

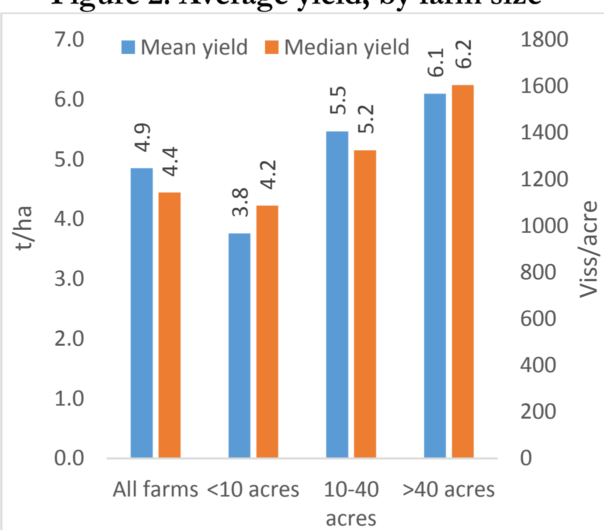
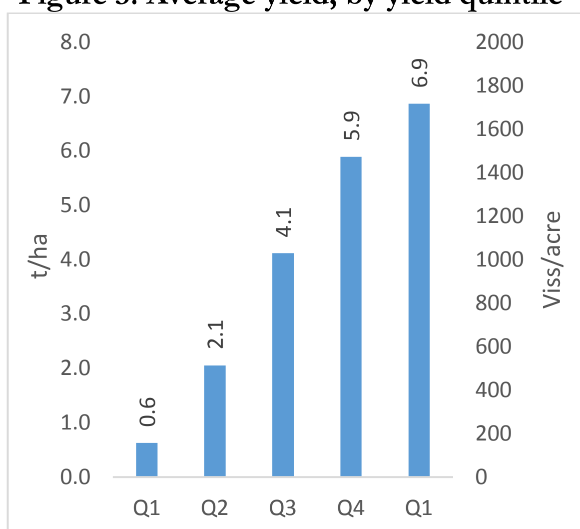


Figure 3. Average yield, by yield quintile



There is an extremely broad spread of reported yields (Figure 3). Ranking farms from lowest to highest yielding and dividing them into 5 equally sized groups ("yield quintiles"), reveals that the worst performing 20% of farms (quintile 1) produce an average of just 0.6 t/ha (162 viss/acre). This is 11 times less than the yield achieved by the best performing 20% of farms (6.9 t/ha, or 1774 viss/acre).

Unusually severe flooding occurred in some the areas surveyed in 2015, but event this does not account for the productivity gap between the lowest and highest yield quintiles. About 40% of households reported some losses due to flooding, and 15% of households estimated that their losses amounted to more than 30% of their crop. Although this explains some of the very low yields reported, accounting for flood losses only raises the average yield by 3%. Disease is also unlikely to account for this range of yields as our scoping research indicated that fish mortality rates are usually incremental, and seldom catastrophic.

The productivity gap is more likely explained by differences in technology linked to variation in investment capacity among farms. Yields among the worst performing 20% of farms reflect very limited utilization of feed inputs. The lowest yield quintile used just 1.75 t/ha of feed (443 viss/acre), as opposed to 15 t/ha of feed (3800 viss/acre) in the highest yield quintile.

Figure 4. Average yield by species (harvesting farms only)

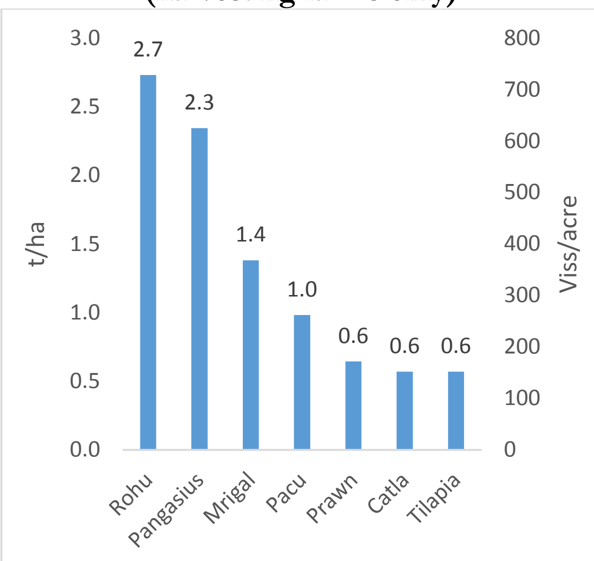
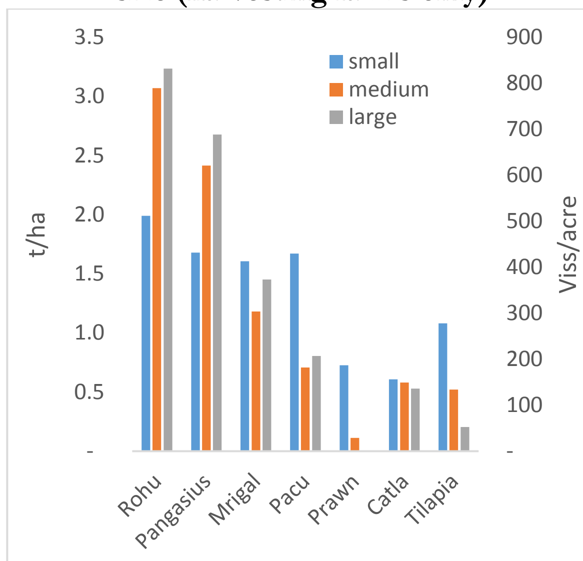


Figure 5. Average yield by species and farm size (harvesting farms only)



The highest yielding single species produced in Myanmar is rohu, with productivity averaging 2.7 t/ha (690 viss/acre).[3] Yields of pangasius are close to those of rohu, averaging 2.3 t/ha (593 viss/acre). Myanmar's pangasius yields are far lower than in other countries in the region - e.g. 33t/ha in Bangladesh (Jahan et al., 2015). This is because it fulfills a relatively minor role in semi-intensive polycultures dominated by carp species, whereas elsewhere in the region it is grown in monoculture or as the major species in intensively managed polyculture. Average yields for other individual species are low, ranging from 1.4 t/ha (350 viss/acre) for mrigal, to 0.5 t/ha (144 viss/acre) for catla and tilapia (Figure 4).

Yields of individual species vary with farm size. Yields of rohu and pangasius are about 1.6 times higher on large farms than on those under 10 acres. There is less yield variation by farm size for other carp species, and small farms obtain higher yields of pacu, tilapia and freshwater prawn than medium or large farms, suggesting that smaller ponds are advantageous for the management of these species (Figure 5).

This is to be expected. It is easier to distribute feed inputs evenly, exchange water regularly, perform complete harvests or grade fish during partial harvests in a small pond than a large one. These aspects are more important for the production of species such as tilapia and pacu than Indian major

[3] Most farmers produce multiple species in the same pond, so species-specific yields are lower than total yields per hectare.

carps such as rohu. The former require regular external feed inputs to obtain optimal growth and have a low market size, which they attain quickly, and, whereas the latter need space in order to reach the large sizes demanded by the market, and derive most of their nutrition from plankton blooms in the pond, making feed management less crucial.

2.2. Growout farm budgets and gross margins

The average profitability of fish farming is high in comparison to production of commonly farmed agricultural crops in Myanmar. For instance, average gross margins (revenue minus variable costs) for aquaculture (growout farming) are 7.6 times higher than those earned by farmers producing monsoon paddy in 'aquaculture cluster' village tracts, and 4.2 times higher than the annual average gross margin from field crop cultivation (taking into account production in both monsoon and dry seasons). Details are presented in Table 2.

Table 2. Average gross margins for aquaculture and agriculture in 'aquaculture cluster' village tracts

	Aquaculture (growout)	Monsoon paddy	Dry season paddy	Green gram	Black gram	Annual income (all field crops)
$/ha	1596	209	317	369	429	379
Million MMK/acre	0.78	0.10	0.15	0.18	0.21	0.18

Aquaculture gross margins vary widely by farm size and across yield quintiles, however. Table 3 presents data on gross margins, disaggregated by fish farm size and yield quintile.[4] The all farm average gross margin is $1600/ha (MMK 775,000/acre). The median gross margin is about half the mean ($823/ha, or MMK 400,000/acre). This finding highlights the abundance of low intensity fish-farming as well as the high degree of variation in yields and profitability across farms. Average gross margins for the whole farm stand at $11,250 (MMK 13.5 million).

Table 3. Aquaculture gross margins by farm size and yield quintile

Unit	All fish growout farms	<10 acres	10-40 acres	>40 acres	Q1	Q2	Q3	Q4	Q1
$/ha	1,600	389	1,283	2,891	724	509	972	2,041	2,988
Million MMK/acre	0.78	0.19	0.62	1.40	0.35	0.25	0.47	0.99	1.45

Larger growout farms earn the highest average gross margins per unit area, in line with the positive correlation between farm size and average yield. Gross margins for farms over 40 acres (16 ha) reach $3,000/ha (MMK 1.4 million/acre); about eight times higher than those of farms sized under 10 acres (4 ha), which have gross margins of just $389/ha (MMK 189,000/acre).

[4] Due to the presence of highly weighted outliers in the dataset, gross margin averages were computed without using household weights.

The most productive 20% of growout (yield quintile 5) generate gross margins of $3,000/ha (MMK 1,450,000/acre): four to six times higher than those in quintiles 1 and 2, which earn an average of $724/ha (MMK 350,000/acre) and $509/ha (MMK 250,000/acre) respectively. The average gross margins of both small fish farms and those in yield quintile 2 are comparable to the average returns among crop farms in aquaculture cluster village tracts (MMK 189,000/acre; $389/ha), indicating suboptimal performance, and very substantial potential to raise productivity and returns through targeted interventions.

The value and structure of farm operating costs are key to explaining the high variability of gross margins. The most productive 20% of farms (yield quintile 5) spend almost nine times more per acre on operating costs than the least productive 20% (Figure 6). Farms in the middle of the yield distribution spend about four times more on operating costs than the least productive quintile of farms, but less than half as much as farms in the most productive (quintile 1 = $994/ha or MMK 483,000/acre; quintile 3 = $4,072/ha or MMK 2.0 million/acre; quintile 5 = $8,700/ha or MMK 4.2 million/acre).

Figure 6. Growout farm operating costs by yield quintile

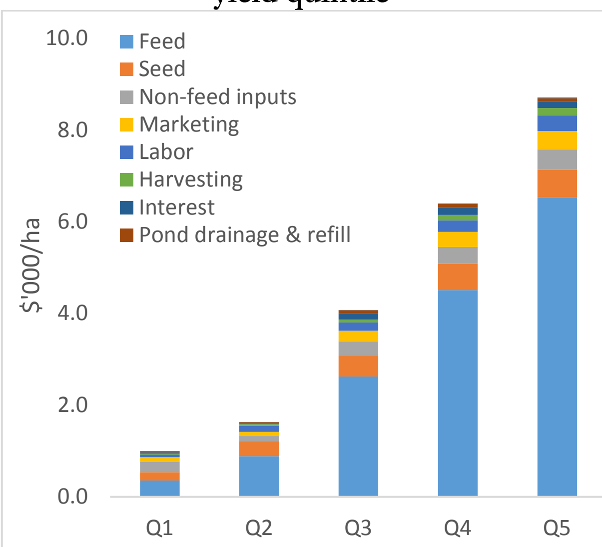
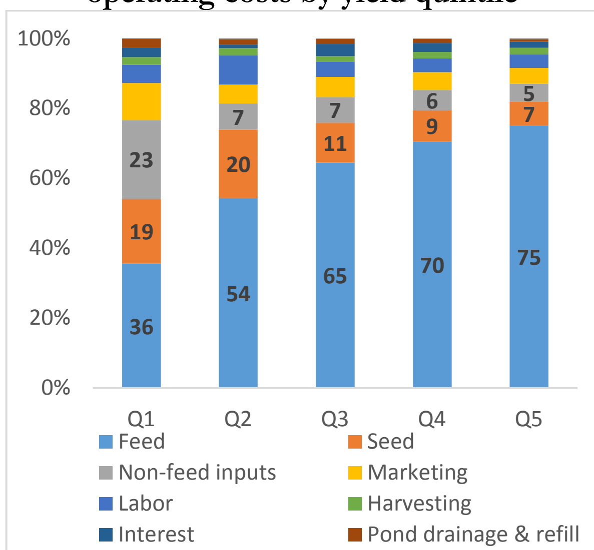


Figure 7. Structure of growout farm operating costs by yield quintile



Small farms have lower total budgets than medium and large farms, and allocate a lower share of these budgets to feed than bigger farms, suggesting that they lack capital to purchase these inputs in sufficient quantities. The least productive farms (yield quintile 1) allocate only one third (36%) of their operating costs to feed. The most productive farms allocate three quarters (75%) of their much larger budgets to feed (Figure 7). Figure 8 depicts average farm cost structure.

2.3. Specialized nurseries

Specialized nurseries produce fingerlings exclusively, for sale to growout farms. Describing nursery farm management in detail is beyond the scope of this report, but for comparative purposes we present the average gross margin and cost structure for specialized nursery farms in the sample in Table 4 and Figure 9.

Figure 8. Structure of average farm operating costs

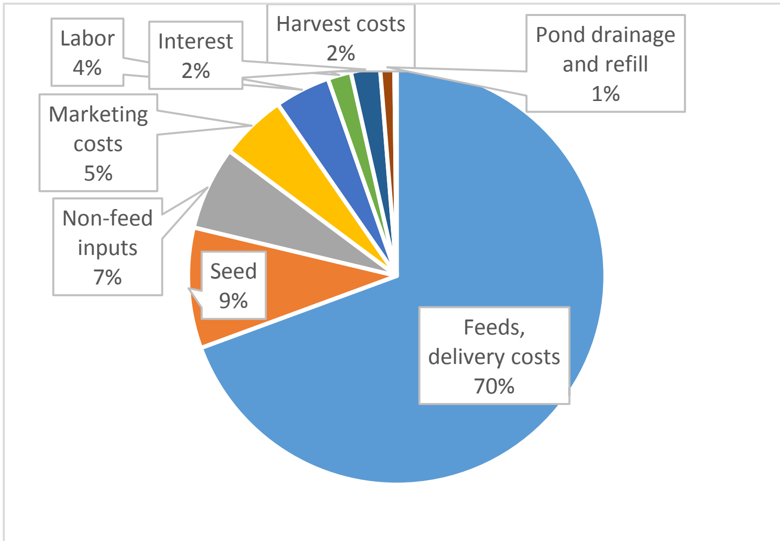
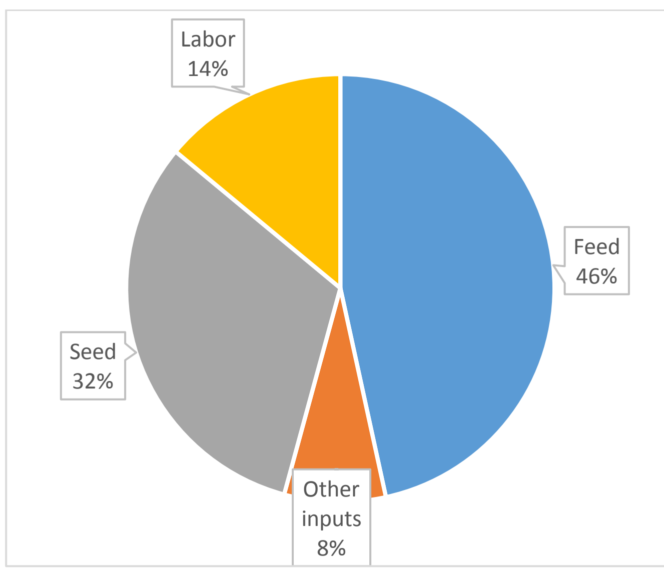


Table 4. Nursery farm costs and revenues

	Value	
Item	$/ha	MMK/acre
Feed	1,806	877,409
Other inputs	296	143,806
Seed	1,232	598,543
Labor	542	263,320
Total operating costs	3,876	1,883,077
Total revenues	5,558	2,700,243
Gross Margin	**1,682**	**817,166**

Figure 9. Nursery farm cost structure



This analysis reveals that (as expected) nursing has a different cost structure to growout farming. The share of feed in operating costs is lower (46%), while seed (eggs or hatchlings) represents a much higher share of costs (32%). Specialized nurseries generate a similar average gross margin to growout farming activities (MMK 817,000 or $1,700/ha).

3. FARM CHARACTERISTICS AND MANAGEMENT

3.1. Farm size

Households operating fish growout farms possess over three times more land on average than crop farming households in the aquaculture cluster. Households operating growout ponds own an average of 29 acres of land (median 10 acres), and farm an average of 30 acres (median 12 acres). The average crop farming household owns 9.8 acres of land (median 6.1).The all household average area of land owned (including households without agricultural land) is 4.2 acres, with a median of just 0.16 reflecting very high levels of landlessness (Table 5).

Table 5. Mean and median owned and operated landholdings by household type

	Sample size	Area of land owned (acres)		Area of land operated (acres)	
Household type	N	Mean	Median	Mean	Median
All households	1,102	4.2	0.16	3.5	0
Crop farms	329	9.8	6.1	9.1	6
Specialized nurseries	73	3.1	2.0	3.7	2.0
Growout farms (<10 acres)	127	4.1	3.0	5.7	4.0
Growout farms (10-40 acres)	50	19.1	16.0	20.0	16.0
Growout farms (>40 acres)	47	109.9	92.0	112.9	92.0
All growout farms	224	28.7	10.0	30.4	12.4

The largest fish farm surveyed was 604 acres in size. However, scoping work indicated that much larger farms, sized in the 1000's of acres also exist. Farms of this size are often operated by companies or absentee owners, and were not captured by our household survey. Even among owner-operated growout farms, the size distribution of is highly skewed. Growout farms sized over 40 acres account for only 21% of farms but 70% of pond area, whereas those under 10 acres account for 51% of farms but own only 9% of total pond area.

There is little difference in the average area of semi-intensive, intensive and integrated growout farms, which range from 26.8-32.8 acres. The average number of ponds per growout farm is 3.1, rising from 1.5 for small farms to 6.1 for large farms. The average growout pond measures 14 acres. About 10% of ponds used for aquaculture are rented, leased, or sharecropped in. Those ponds tend to be larger on average than owner-operated ponds (26 acres vs. 14 acres).

Many farms dedicate some of their own ponds to nursing, particularly on larger farms. Among farms over 10 acres in size, 80% have at least one nursery pond. This share is 62% for farms below 10 acres. Although 58% of all ponds are dedicated to nursing (including both specialized nurseries producing for sale and those vertically integrated into growout farms, producing fingerlings for own use), nursery ponds account for only 15% of total pond area.

Forty one percent of all fish farms are specialized nurseries (i.e. producing fingerlings for sale to growout farms). Almost all (97%) of these are under 10 acres in size. Their operators own approximately half as much land on average as crop farmers, and eight times less than operators of growout farms (mean 3.7 acres, median 1.7 acres). If specialized nurseries are considered as small farms, 71% of all fish farms in surveyed village tracts (i.e. nurseries plus growout farms under 10 acres) are small. The average number of ponds operated by specialized nursery households is 1.9.

Households operating both specialized nurseries and growout farms tend to specialize in aquaculture, operating little agricultural land (0.5 and 1.4 acres on average respectively).

3.2. Production cycle

The growout production cycle usually begins in the early to mid-monsoon season (June-August). Most production cycles end in the dry season months of November-April, coinciding with diminishing availability of water and scarcity of wild freshwater fish in the market (Figure 10).

Farm size and the duration of the production cycle are positively correlated. The average production cycle for small farms lasted 9.3 months, as compared to 10 months and 11.7 months for medium and large farms, respectively. The longest reported production cycle was 32 months.

Growout ponds had been drained an average of 15 months prior to the time of the survey. The duration was longer for semi-intensive ponds (16 months) than for ponds integrated with poultry (12 months). The latter are drained annually to prevent water quality from deteriorating badly due to excess nutrient loading. Ponds remain empty for an average of 6 weeks between draining and refilling.

Figure 10. Start and end date of production cycle, by share of farms reporting

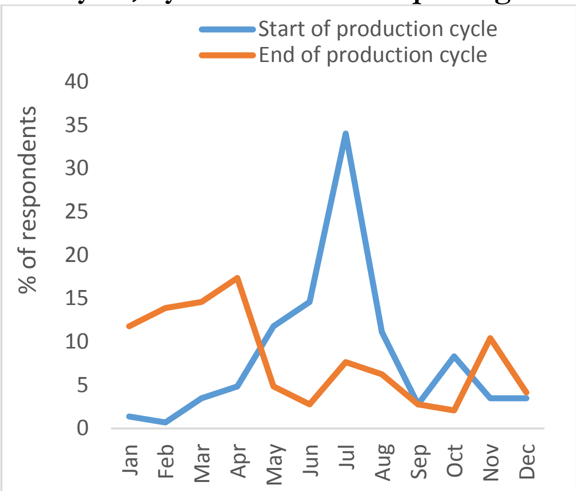
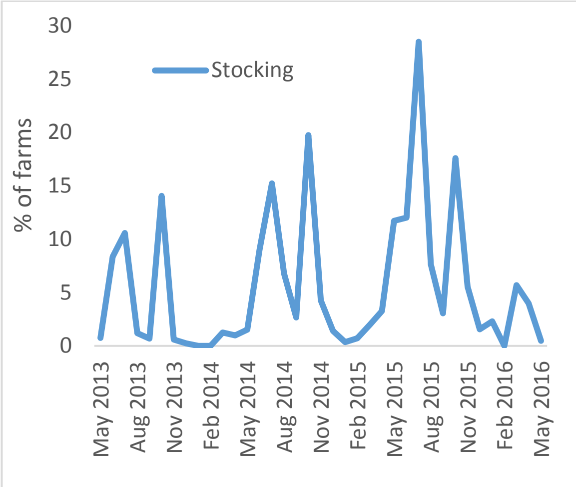


Figure 11. Share of farms stocking fish, by year and month

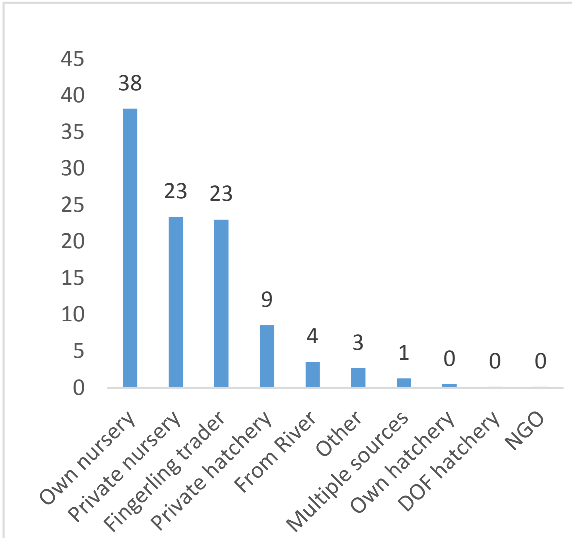


3.3. Seed

Fish seed accounts for 9% of farm operating costs. There are two main annual peaks in stocking seed, the first in June-July at the onset of the monsoon, the second during late-monsoon in October (Figure 11). Small farms stock seed more frequently on average than those above 10 acres.

Seed for growout operations can be produced in nursery ponds on-farm for own use, or sourced from off-farm. Larger farms are more likely to nurse their own seed. Among small, medium and large farms, 13%, 72% and 84% respectively have at least one nursery pond (45% overall). Most farms with nurseries are self-sufficient in fingerling production.

Figure 12. Source of seed stocked



However, despite the tendency for larger farms to vertically integrate nursing functions the market for seed is vibrant: 66% of all growout farms obtain at least some of their fingerlings from off-farm. Among large, medium and small farms, 40%, 48% and 85%, respectively source fingerlings from off-farm.

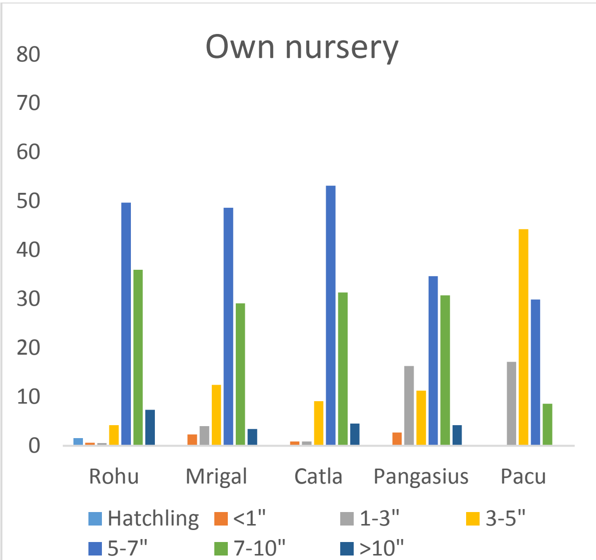
Sources of purchased seed include specialized nurseries (23% of all seed stocked), fingerling traders who buy and sell seed from nurseries (23%), and private hatcheries (9%). Four percent of fish seed is captured from the wild (likely mrigal fingerlings). Almost none of the seed stocked in the village tracts surveyed originates from government hatcheries or NGOs. The remainder of fingerlings stocked originate from growout farms' own nurseries (Figure 12).

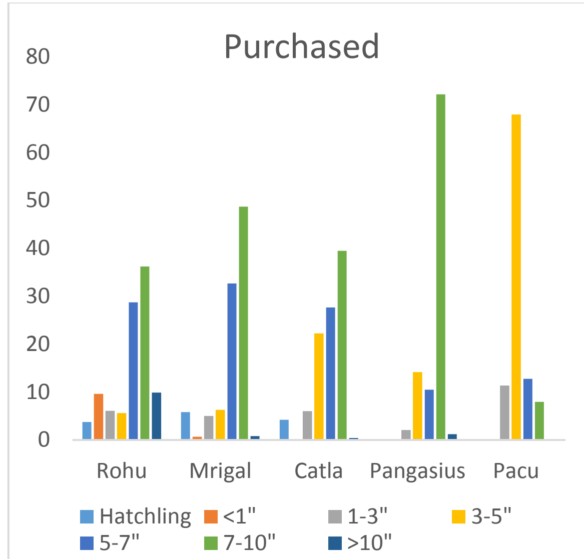
The average size of stocked fingerlings is quite large. The commonest sizes are 5-7" and 7-10", for all main species other than pacu (3-5"). Purchased seed tends to be stocked at larger average sizes than self-produced seed (Figure 13).

Small farms stock seed at larger average sizes than medium and large farms. This may be related to the tendency of smaller farms to stock seed sourced from nurseries, and to run shorter production cycles than large farms, thus requiring large seed in order to attain marketable size in time. Among small farms, 47% of seed stocked is 7-10" in size, whereas 76% of seed stocked by large farms is sized from 3-7".

Small farms are more likely than medium or larger farms to purchase seed from nearby nurseries. As shown in Figure 14, 76% of farms under 10 acres that purchased seed did so within the village where they were located, as compared to around one third of larger farms. Conversely, 78% of farms over 40 acres sourced seed from another township or region, suggesting that the quantities of seed required by larger farms cause them to source from further afield than small farms.

Figure 13. Share of farms (%) stocking fish seed from own nursery and purchased sources, by size of seed stocked and species





The vast majority of farms in the sample (86%) stock fish in polyculture. The average number of species stocked per farm is 3.3. Large farms stock more species on average than small (3.8 versus 2.7).

Figure 14. Place of origin of purchased seed[5]

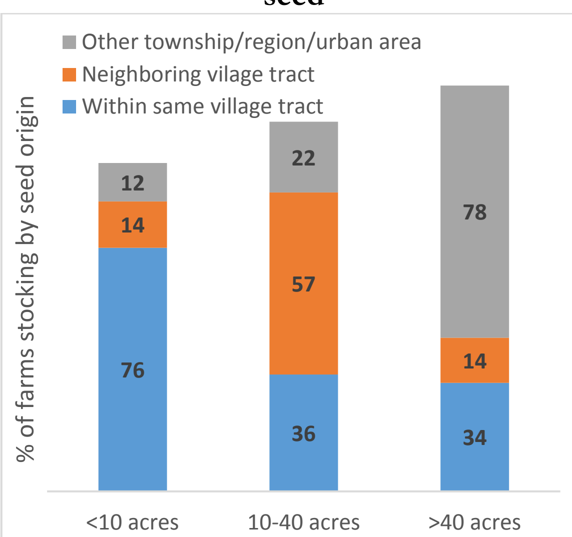
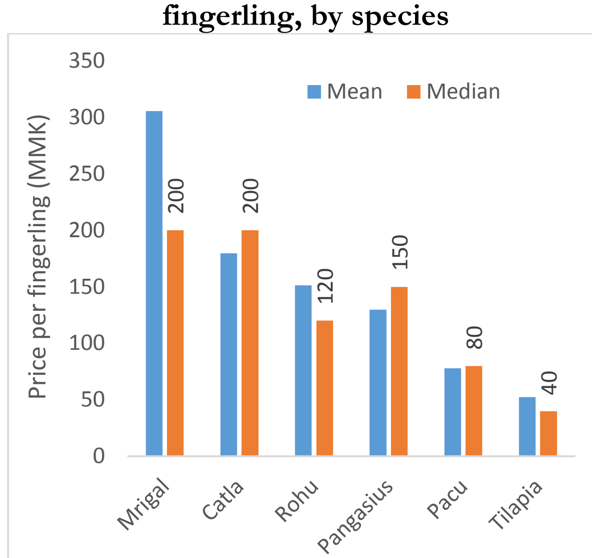


Figure 15. Mean and median cost per fingerling, by species



[5] Values add up to more than 100% as seed can be purchased from multiple sources.

Production is dominated by carp species. The three most commonly stocked species are Indian major carps - rohu (94% of farms), catla (74%), mrigal (60%). The three next most widely stocked species are non-carps: pangasius (28% of farms), tilapia (11%), and pacu (8%). With the exception of common carp, no farm reported stocking Chinese carp species.

Almost half of farms stock only carp species, and fewer than 5% of the sample stock no carp at all.[6] Around half of farmers stocked a mix of carp and non-carp species. Small farms are more likely to stock non-carp species. The percentage of small and medium growout farms who do not stock any carp is respectively 7% and 2%, whereas not a single large farm in the sample reported stocking no carp species. Only 14% of farms raise fish in monoculture, with most of these specializing in production of rohu.

Interestingly, 9% of small farms reported stocking giant freshwater prawn, but no medium or large farms did so. As such freshwater prawn, which has a much higher value than other commonly farmed species, presents an important opportunity for small farms in Myanmar. However, prawn hatcheries in Myanmar are known to face difficulties in producing sufficient prawn post-larvae (PL) to meet demand due to high PL mortality rates, severe limiting the extent of production at the present time.

Average stocking density per acre is low, at 3334 fish/ha (1350 fish/acre). For comparison, in Andhra Pradesh, India, stocking 10" carp fingerlings at a density of 7500-10,000/ha is the norm (Padiyar et al, 2014).

Stocking density is negatively correlated with farm size, falling from 4754/ha (1925/acre) to 1069/ha (433/acre) from small to large farms. As fingerlings stocked in small farms tend to be bigger than those stocked in large farms, this implies that the average biomass of fish stocked per acre on small farms is several times higher on average than for large farms.

This bifurcated pattern appears to be the result of distinct production strategies tailored to pond area and investment capacity. Large farms employ sparse stocking, relatively high feeding rates and long production cycles to deliberately target production of a small number (per acre) of large sized individual fish with a high unit value and high total biomass. In contrast, small farms attempt to maximize harvested biomass given the resources available to them, by stocking large fingerlings to gain a 'head start' in growth, but feeding relatively little and harvesting quickly.

Seed of carp species was more expensive on average than that of non-carps. The median price of carp seed ranged from MMK 120-250 per piece, while the median price per piece of non-carp species other than pangasius is cheaper, ranging from MMK 40-80. Mrigal seed (mainly wild seed harvested from rivers) is most expensive on average, and tilapia (widely available from free breeding populations in ponds) is cheapest (Figure 15).

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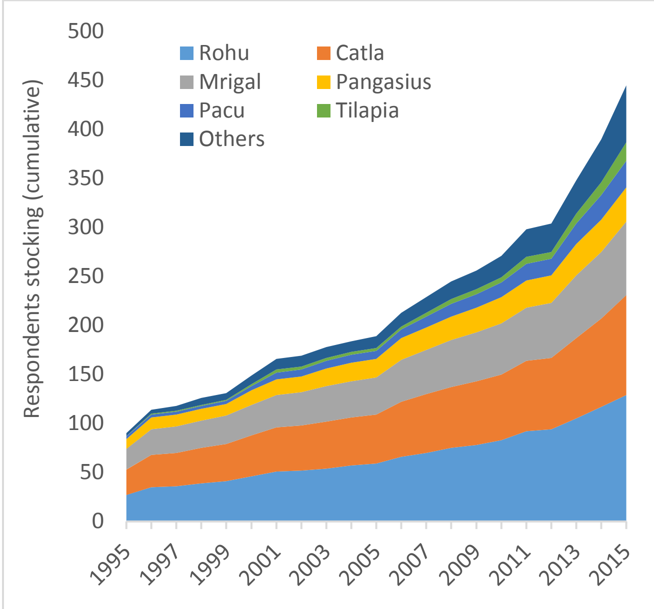
[6] The share of carp farmers may be even higher, as we assumed that all observations with missing species information or unknown vernaculars were non-carps.

Figure 16. Cumulative number of respondents farming species, by species and year



The average outlay on stocking was $195/ha (MMK 95,000/acre). The stocking costs of small farms were considerably higher than those of medium and larger farms, in keeping with the higher densities employed by the former - $241/ha (MMK 117,000/acre), versus $148/ha (MMK 72,000/acre) and $178/ha (MMK 86,000/acre), respectively.

As seen in Figure 16, some diversification in the species stocked has occurred over time, but the pace of this change is incremental. Respondents were asked to report the first year they had stocked each of the species they farmed. Species other than the three main Indian major carp species and pangasius accounted for just 7% of all responses in 1995. By 2016, this share had risen to 23%.

3.4. Feed

Feed is the major cost in aquaculture, accounting for 70% of operating costs on average among the farms surveyed. We classify all growout farms into four categories according to their feed use: rice bran alone, rice bran and other agro-processing by-products, pellets in combination with other feeds, pellets only. These four categories correspond approximately to diets of increasing nutritional value. About one quarter of farms use rice bran exclusively, and another 62% use rice bran in combination with other agricultural by-products (oilcakes, brewery waste, etc.). Nine percent of farms use pellets in combination with other feeds, while only 6% use pelleted feed exclusively.

The agro-processing byproducts most widely used as feeds were rice bran (used by 86% of farms) and peanut oilcake (44% of farms). Other oilcakes (mainly sesame), brewery waste and broken rice were each used by 6-12% of farms (Figure 17). Similar shares of small, medium and farms used rice bran. Large farms were more than three times as likely to use peanut oilcake as small ones, likely reflecting its relatively high price (Table 6).

Table 6. Average feed prices

Feed	Price (MMK/viss)	($/kg)
Sinking feed (pellet)	813	0.42
Floating feed (pellet)	1064	0.55
Rice bran	460	0.24
Peanut oilcake	974	0.51
Other oilcake	423	0.22
Broken rice	763	0.40
Brewery waste	217	0.11

Commercially manufactured pelleted feeds are formulated to ensure a complete diet for farmed fish, and facilitate more efficient feed conversion and faster fish growth than agricultural byproducts, which are nutritionally incomplete. Overall, only 16% of farms use any manufactured pelleted feeds, which is considerably lower than in neighboring countries. For example, 38% of farms in Bangladesh use pelleted feeds (Hernandez et al., in press), as do 90% of carp and tilapia farms in China (Chiu et al, 2013).

There are two types of pelleted feed: floating and sinking. Floating feeds are generally more easily digestible than sinking feeds, and facilitate more effective feed management as overfeeding can be avoided. They generally have more efficient feed conversion ratios than sinking feeds, but are more expensive. Approximately twice as many farms used sinking pelleted feeds (14%) than floating pellets (8%), with some farms utilizing both.

Figure 17. Share of farms using feed inputs, by feed type, and share of feed type in total value of feed inputs (%).

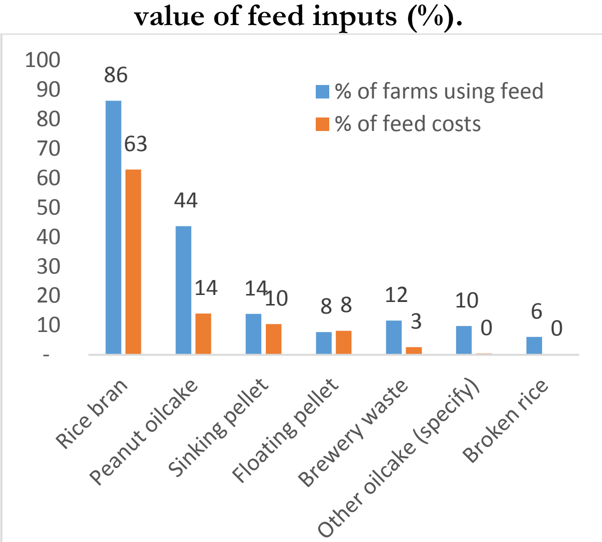
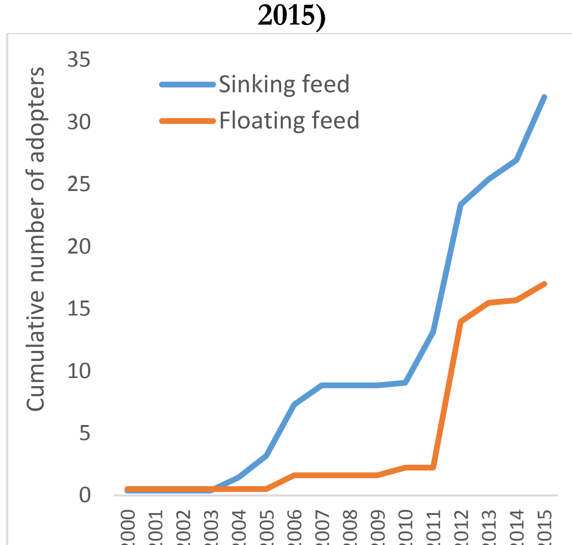


Figure 18. Cumulative adoption of pelleted feed, by adoption year and feed type (2000-2015)



Medium sized farms were most likely to use any kind of pellets (28%), compared to both small farms (13%) and large farms (7%). Medium and large farms are equally likely to use sinking or floating feed. However, small farms are more likely to use sinking feed (12%) than floating feed (3%).

The market for pelleted feeds is highly concentrated. Sixty percent of all the pelleted feed used by surveyed farmers was sourced from a single company (Htoo Thit), including 65% of all sinking feed and 51% of floating feed. The second largest company is Myat Swan, which produces about 15% of sinking feed, but no floating feed.

Adoption of pelleted feeds increased gradually from the early-2000s. Adoption of sinking feeds has grown more steadily floating feeds, picking up slightly in the mid-2000s and then increasingly rapidly from 2011 onwards. In contrast, adoption of floating feeds was minimal before 2011, climbed rapidly from 2011-2012 and grew more slowly thereafter (Figure 18).

Feed costs are substantial, averaging $3300/ha (MMK 1.6 million/acre), or a total of $16,800 (MMK 22 million) per farm. Among farms using specific feeds, average costs per acre were as follows: $1544/ha (MMK 750,000/acre) for sinking feeds; $1260/ha (MMK 612,000/acre) for floating feeds; $2470/ha (MMK 1.2 million/acre) for rice bran; $700/ha (MMK 340,000/acre) for peanut oilcake.

Medium and large farms use more feed per acre (proxied by value) than small farms. Large farms spend almost twice as much per acre on floating and sinking feeds than small farms, and 2.3 times as much per acre on peanut oilcake. However, expenditure per acre on rice bran is roughly the same for farms of all sizes.

The average farm uses feed at a rate of 12.6 t/ha (5.1 t/acre) of pond. Medium sized farms use feed most intensively (14.8 t/ha, 6.0 t/acre). Small farms use least (8.6 t/ha, 3.5 t/acre). Farms using only pellets applied 12.4 t/ha (5.0 t/acre), while farms using only rice bran applied 9.6 t/ha (3.9 t/acre) on average. That farms using high nutritional value, expensive feeds use them in greater quantities than farms using only cheaper, less nutritive rice bran, suggests that the latter are financially constrained in their input choices.

On average, more productive farms spent a greater share of their feed budget on floating and sinking pelleted feeds than less productive farms, and a smaller share of their feed budgets on agricultural byproducts. Farms in yield quintile 5 farms spent 48% of their feed budget on rice bran and 43% on pelleted feeds. Farmers in the middle of the yield distribution spent 70% of their feed budgets rice bran. For households in the least productive yield quintile, rice bran accounted for only 42% of feed expenditure, but these farms also spent 25% of feed budgets on "other" feeds, including agricultural byproducts such as brewery waste and broken rice (Figure 19).

Value chain finance was rarely available for the purchase of agro-processing byproducts. Only 6% of farms who purchased rice bran or peanut oilcake did so using credit provided by the supplier (Figure 20).

Finance was more readily available for the purchase of pelleted feeds. Twenty five percent of users of sinking pellets and 36% of users of floating pellets received part or all of these inputs on credit. As floating feeds are more recently introduced than sinking feeds, this suggests that supplying these on credit may represent a strategy by manufacturers, aimed at growing the market.

Figure 19. Share of feed costs (%) by feed type and farm yield quintile

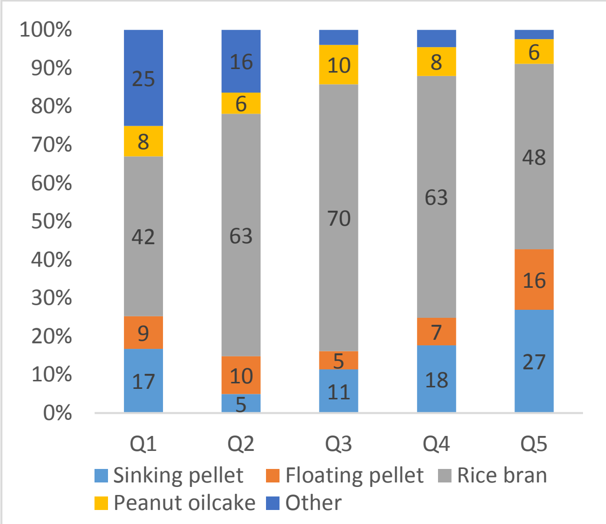
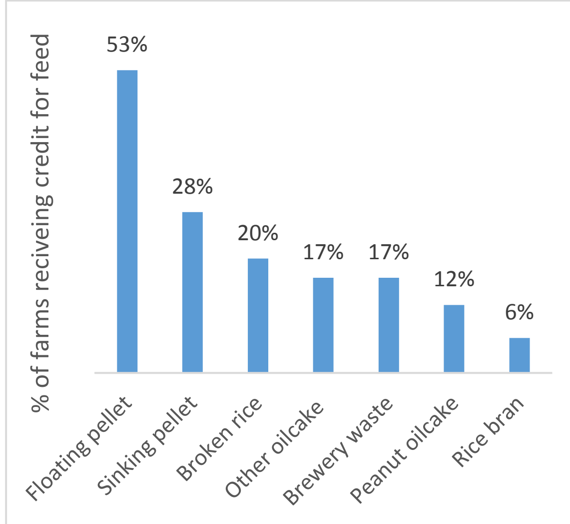


Figure 20. Share of farms receiving feed inputs on credit



Credit provided for feed is usually tied to output, meaning that farms who purchase feed on credit are obligated to sell harvested fish to the feed supplier. The share of feed credit tied to output was 90% overall. Specifically, it was 80% for pellets, and over 90% for all other feeds.

A significant share of agircultral byproducts and pelleted feeds used by farms (about 40%) were sourced directly from mills or factories. Around half of feed purchases (52%) were made through traders. There were no salient differences among small, medium and large farmers in terms of where feed was sourced.

Urban centers are important links in input supply. Most sellers of feed materials were located in nearby towns or in Yangon. Approximately half of rice bran and sinking feed was obtained from Yangon, with just under 30% coming from the nearest town, and most of the remainder from the village tracts where farms were located. Most peanut oilcake was purchased from the nearest town, followed by other townships/regions. Floating feeds were procured mainly from the nearest town, followed by Yangon.

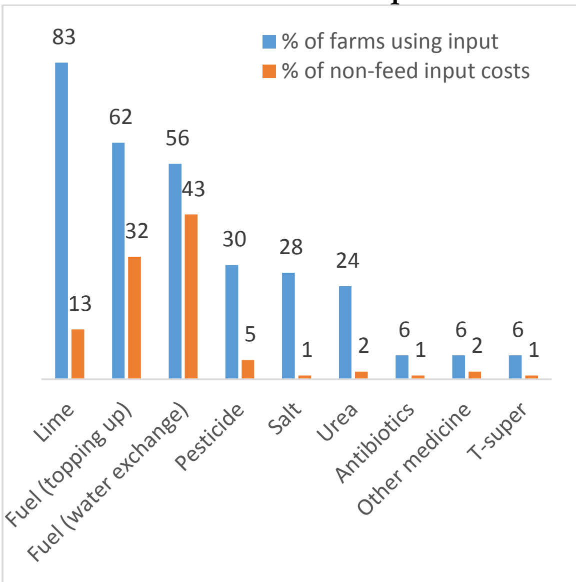
3.5. Non-feed inputs

Non-feed inputs accounted for 7% of operating costs. They can be divided into fuel, fertilizers, and products for treating disease or regulating water quality. The share of farms using the most common of these inputs and their share of non-feed input costs are illustrated in Figure 21.

Lime, which is used to improve water quality, was the most widely used input, with 83% of farms applying. However, it accounted for only 13% of expenditure on non-feed inputs, reflecting its low cost per unit.

Fuel, mainly used to power water pumps, was the second most commonly used non-feed input. Pumps can be used to ‘top up’ water lost due to evaporation and seepage, or to exchange pond water with fresh water from outside the pond (e.g. from a canal or river), to improve its quality. Sixty two percent and 56% of farms used water for topping up ponds and water exchange, respectively. Fuel accounted for by far the largest share of expenditures on non-feed inputs, amounting to 75% of all non-feed input costs.

Figure 21. Share of farms using non-feed inputs by input type, and share of input in total value of non-feed inputs.



Pond fertilization is a simple, relatively low cost management technique that can significantly improve fish farm productivity. Fertilizers are applied to stimulate blooms of plankton, which provide an important source of natural food for fish.

Application of fertilizers was extremely limited. Overall, only 25% of farms used any kind of fertilizer. Compare this to Bangladesh, where 74% of fish farms use one or more fertilizers (Ali et al., 2016). Fertilizers accounted for just 3% of non-feed input costs (far less than 1% of total operating costs), indicating very significant scope to increase their application. Among those farms that used fertilizer, 24% of farms used urea, 6% T-super (a phosphate fertilizer), and 4% manure.

Salt is used to treat parasite infections in fish. 28% of farms used salt, suggesting that parasite infections are common. Antibiotics and other medicines may be used to treat outbreaks of disease, or as prophylaxes. A low share of farms reported using antibiotics and other medicines (6% each). Together these account for only 3% of non-feed input costs. Numerous farmers reported disease problems during scoping interviews, however. Low levels of medicine use therefore suggest that disease outbreaks are rarely treated.

Pesticides are sometimes used prior to stocking fingerlings to remove any unwanted wild fish that might predate upon stocked seed. The most common chemical used for this purpose is rotenone, a plant extract which acts specifically on fish and breaks down rapidly afterward. This practice was followed by 30% of farms, with pesticides making up 5% of non-feed input costs.

Interestingly, small farms spent approximately twice as much per acre on fuel as large farms, while large farms spent roughly twice as much per acre on fertilizers, lime and pesticides as small farms. This suggests several possibilities: small farms may be unable to afford or access inputs used in farm management, or they may lack knowledge of how use them, or they may be less prone to poor water quality and disease than larger farms (perhaps because they apply fewer feed inputs). Alternatively, exchanging water may prove less prohibitively expensive for small farms than it would on for large farms because of the smaller volumes of water pumped.

The substantial majority of almost all non-feed inputs were purchased from traders in markets. These were mostly located in the nearest town (underlining the importance of these rur-urban areas as centers for input supply), followed by Yangon.

3.6. Labor

This subsection details the characteristics of labor employed in aquaculture by small, medium and large fish growout farms. It also presents details of labor use in crop farming by agricultural households, for comparative purposes.

The most striking finding is that, on average, fish farms generate demand for almost four times more person days of labor (unpaid family labor, plus hired casual labor and hired long-term labor) per acre/year than crop farms (24 days versus 94 days). Low demand for labor in paddy cultivation is likely to reflect high levels of agricultural mechanization in the study area, as well as use of other labor saving practices such as broadcasting paddy seed.

Among fish farms, those under ten acres in size generated by far the greatest demand for labor (152 days/acre/year). Fish farms over 40 acres generate just 17 days of demand for labor per acre/year – lower than that of crop farms (Figure 22).

Differences in labor demand per unit area among fish farms in different size categories are likely to reflect economies of scale for certain types of labor (e.g. the number of person hours required to guard a 20 acre pond may be the same as needed for a 5 acre pond). Conversely, large, well-resourced farms are more likely to invest in capital intensive labor saving technology such as mechanical backhoes for pond construction and maintenance.

Low demand for labor from crop farms relative to small and medium fish farms appears to reflect the highly strongly seasonal nature of demand from the former. For example, tasks such as feeding and guarding fish have to be performed daily throughout the production cycle, which averages close to one year, whereas jobs like weeding field crops are performed only occasionally.

These differing seasonalities are reflected in the duration of employment by long term farm workers. On fish farms, long term workers are hired for almost twice as long on average as on crop farms (10.4 months per year, as compared to 5.6 months). Large fish farms are more likely to employ long term labor than small fish farms (96%, versus 22%). Almost all farms employ both own family labor and hired casual hired labor (87-100%, regardless of crop and farm size) (Figure 23).

Figure 22. Total labor inputs per acre/year for fish and crop farms

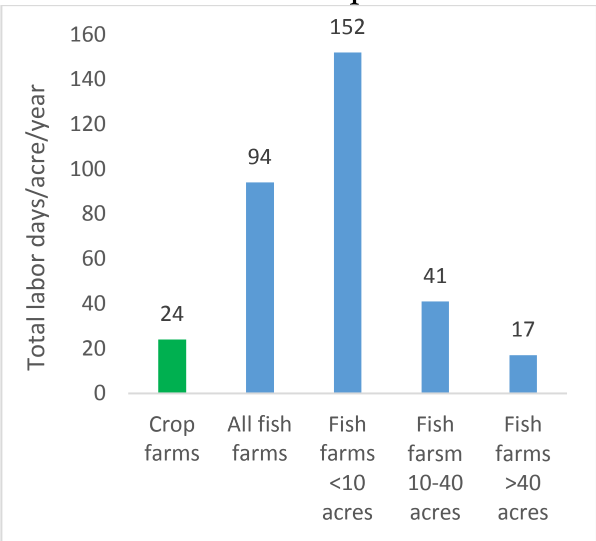
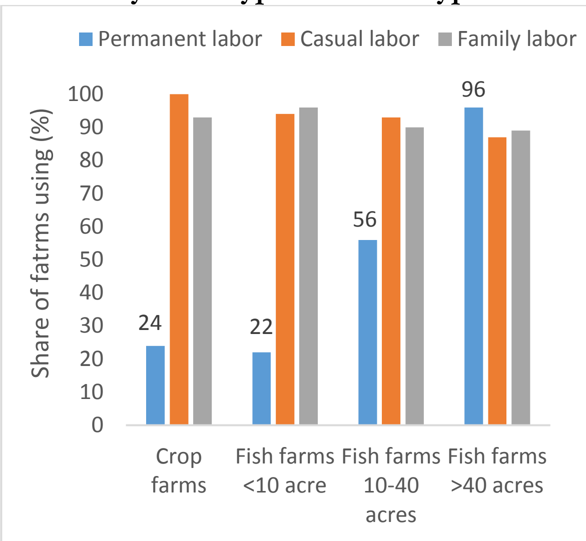


Figure 23. Share of farms employing labor by labor type and farm type



In addition to offering more opportunities for employment than crop farms, fish farms tend to pay higher wages. The average daily wage on fish farms was 27% higher than that paid to crop farm workers ($4.22 or MMK 5075/day, versus $3.32 or MMK 3987/day)[7].

Further, the gender wage gap is smaller in aquaculture than agriculture. Women working in crop farming receive about two thirds of the daily wage earned by men (MMK 2929/day versus MMK 4940/day), whereas women employed in fish farming receive 75% of the male daily wage on average (MMK 3854/day versus MMK 5255/day). This is significant because women have fewer options for casual wage labor than men. For instance, while men have a range of options for higher-paying day jobs, such as transportation work that pays upwards of $5.30 (MMK 7000) per day on average, no other comparable activity paid higher average daily wages to women than work on fish farms. Thus, even although aquaculture remains a relatively small employer of women (about five times more women reported participating in agricultural wage work than in aquaculture wage work), it is also one of the best-paying options.

Crop agriculture creates more gender balanced demand for labor than fish farming. Men and women work approximately equal shares of labor days in crop farming, in the case of both family and hired casual labor. Never-the-less, despite being male dominated, aquaculture's high demand for labor per unit area means that it creates slightly greater levels of demand for female labor per acre farmed than crop agriculture (Table 7).

[7] These figures are calculated on the basis of reported cash payments of daily wages (i.e. excluding payments in kind, such as meals, and work compensated on a piece rate basis)

Table 7. Average annual labor days worked per acre by family labor and hired casual labor (male and female), by farm type and size[8]

Farm type	Family labor days			Hired casual labor days			Total labor (family + casual)
	Male	Female	Male + Female	Male	Female	Male + Female	
Crop farms	7	6	9	7	9	12	20
Fish farms <10 acres	67	11	70	126	24	131	196
Fish farms 10-40 acres	26	12	29	16	1	16	42
Fish farms >40 acres	6	8	8	5	1	5	12
All fish farms	44	11	47	76	13	79	118

There is some gender differentiation of labor in the activities performed by men and women, and between family and hired casual labor on growout farms. Men family members devote most of their labor to feeding and guarding fish, whereas women family members dedicate most time to pond repair and feeding fish. Harvesting fish accounts for the largest share of both male and female hired labor, followed by guarding ponds and feeding fish for men, and repairing ponds for women (Table 8).

Table 8. Shares of family and hired casual labor (male and female) by fish farming activity

Activity	Family labor		Hired casual labor	
	Male	Female	Male	Female
Pond construction/ repair	15%	52%	11%	26%
Feeding fish	37%	29%	20%	9%
Guarding ponds	21%	10%	23%	0%
Harvesting/ marketing	19%	5%	31%	56%
Buying/ stocking seed	3%	3%	5%	8%
Buying/ transporting feed	4%	1%	11%	1%
Total	100%	100%	100%	100%

3.7. Machinery and equipment

Equipment needs for aquaculture are related first and foremost to water management. Among the growout farmers interviewed, 76% owned a surface water pump. Groundwater pumps are much less common, owned by fewer than 5% of farms. Boat ownership is also common. Half the fish farming households in the sample (49%) own a small motorized boat, and 16% own a large motorized boat.

[8] Figures in the sub-total and total columns differ from the sum of male and female, and family and casual labor columns because of weighting.

The cost of pumps used for aquaculture has been falling steadily as the volume of imported goods (mainly from China) has increased, making them increasingly accessible. The average real (inflation adjusted) cost of surface water pumps purchased prior to 2010 was $1750 (MMK 2.1 million), while the average cost for those purchased after that year was $500 (MMK 0.6 million).

Similarly, the average purchase cost of a small boat has dropped from $4416 (MMK 5.3 million) before 2010 to $1083 (MMK 1.3 million) in the years afterward. This latter price reduction is likely the result of local manufacture of fiberglass boats which, as observed during scoping, has emerged in recent years.

4. HARVESTING AND MARKETING

4.1. Harvesting

Fish production is highly commercially oriented in the areas surveyed. Although 93% of farms reported consuming some of the fish they harvested, either directly or as gratuities to workers, the quantities consumed represented less than 1% of total production, ranging from just 25 kg on small farms, to 117 kg on large farms.

Small farms were harvested more times on average during the preceding 36 months than those above 10 acres, reflecting the shorter duration of their production cycle. This in turn is likely to reflect the more limited capacity of poorly resourced small farms to sustain financial outlays on feed inputs over prolonged periods.

Figure 24. Proportion of farms harvesting key species

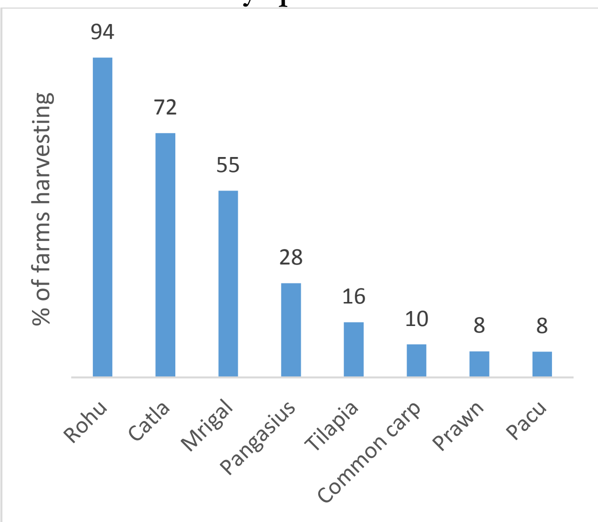
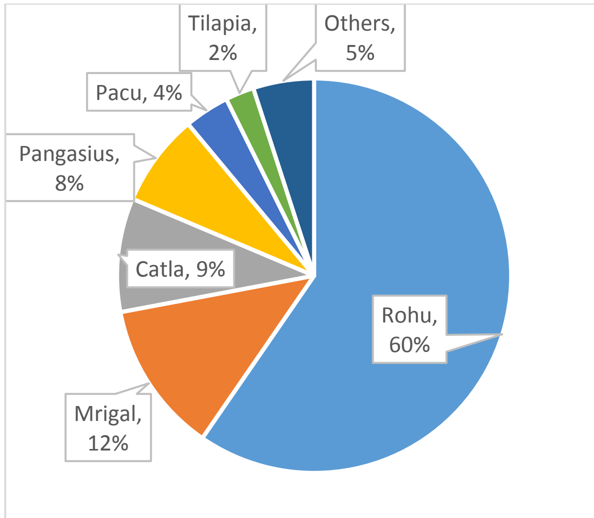


Figure 25. Share of fish species by quantity harvested



As expected, Indian major carps account for the three most commonly harvested fish, with rohu dominant (94% of farms harvesting) (Figure 24). Around one quarter (28%) of farms harvested pangasius, 16% harvested tilapia, and 10% harvested giant freshwater prawn and pacu.

A slightly different picture emerges when each species' contribution to the total quantity of fish produced is considered. Rohu make up 60% of the fish produced, by volume, on farms in our sample. This is lower than is commonly recognized (the conventional wisdom is that rohu account for 70-80% of total production). The second largest share of production is accounted for by the high value carp mrigal (12%), with another carp, catla, and a non-carp species, pangasius, each accounting for similar shares (9% and 8%) of the total volume of fish harvested (Figure 25).

Nineteen percent of the volume of fish produced is comprised of non-carp species. Although this indicates a greater degree of diversity in production than is generally recognized, the number and volume of non-carp species produced is still low compared to that in other countries in the region.

Small farms tend to produce cheaper species and smaller (and therefore cheaper) size grades of farmed fish that are most readily accessible to poorer consumers. For all major farmed species, the average size of fish harvested from farms under 10 acres is smaller than that for fish from large farms. This pattern likely reflects the longer average duration of growout cycle and lower stocking densities in the latter. The average size of harvested fish ranges from 1-1.9 kg (0.7-1.2 viss) for rohu, 2.9.-3.4 kg (1.3-2.2 viss) for pangasius, and 0.6-1 kg (0.4-0.6 viss) for tilapia (Figure 26).

Figure 26. Average size of fish at harvest, by species and farm size (kg and viss)

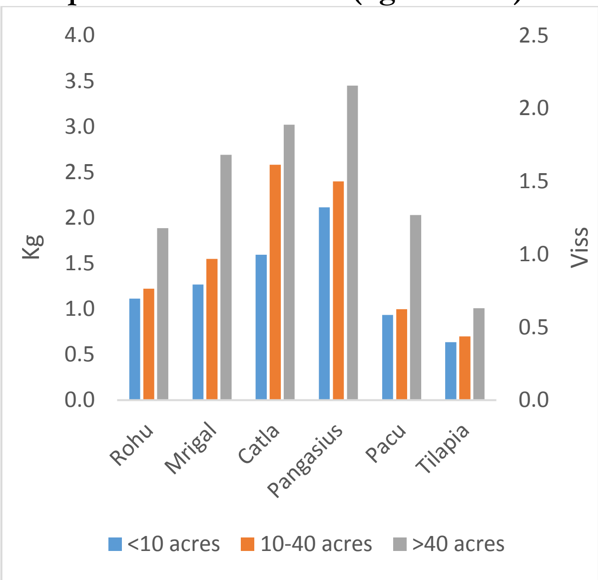
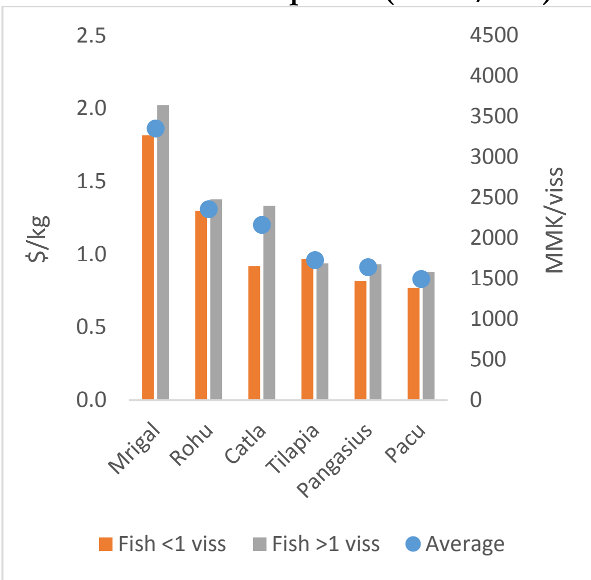


Figure 27. Average farmgate price of fish by harvested size and species (MMK/viss)



The unit value of carps is positively correlated to the size of individual fish harvested. For instance, mrigal weighing less than 1 viss each have a market value of $1.82/kg (MMK 3485/viss), whereas fish weighing more than 1 viss sell for an average of $2.02/kg (MMK 3885/viss) – a difference of 11% (Figure 27).

The prices of non-carp species are the lowest among major species of fish farmed, ranging from $0.84/kg (MMK 1596/viss) for pacu to $0.96/kg (MMK 1842/viss) for tilapia (Figure 26). Carp species fetch the highest average values. Mrigal was the most expensive carp, with an average farmgate value of $1.86/kg (MMK 3574/viss); 43% more than the next highest value species, rohu $1.30/kg (MMK 2512/viss).

The vast majority of farms (93%) use ice when harvesting to maintain the quality of fish during transport to market. Among medium and large farms, 99% reported using ice. Ice was almost always purchased by the farmer (98% of respondents). It was most commonly sourced from the nearest town (71% of farms), followed by Yangon. The largest farms were most likely to obtain ice from Yangon (51% of farms over 40 acres), perhaps suggesting that that they required larger quantities than were available locally.

Poorly developed road infrastructure in many pond farming areas means that the most common means of transporting fish from farm to market is by boat (63% of farms), followed by unrefrigerated truck (18%). Small farms are most likely to utilize boats (75%), while large farms are most likely to utilize unrefrigerated trucks (35%). Only 4% of farms reported using refrigerated trucks to transport fish. Whatever the mode of transport utilized, it was almost always arranged by the farmer (98% of respondents).

A vibrant rural market for water and road transport services exists in the areas survey. 78% of farms utilized rented vehicles, while 19% used transport of their own. Small farms were more likely to depend upon transport rental services than large (84% of farms versus 71%). Conversely, large farms were more likely to own their own means of transport than small (24% versus 13%).

4.2 Marketing

For farms of all sizes, the main buyer of harvested fish was overwhelmingly a fish trader (96%). Zero sales were made direct to consumers, and only 0.3% to retailers and 0.2% direct to factories or cold storage facilities. Fifteen percent of farms using commercially manufactured pelleted feeds reported selling their fish to a feed company from which they had obtained credit.

Most farms (92%) sold their entire harvest to a single buyer. Three quarters of these buyers (76%) were located at Myanmar’s main wholesale market, San Pya, in Yangon. The next most important location for buyers was the nearest town (14%). Only 5% of sales were routed through Yangon’s recently opened second fish wholesale market, Shwe Padauk (Figure 28).

Larger farms were most likely to sell to San Pya (91% of sales) and least likely to sell to the nearest town (1%). Conversely, small farms were comparatively less likely than large to sell to San Pya (67% of sales), but more likely than large to sell to the nearest town (24% of sales), suggesting a greater degree of reliance on local traders who collect and aggregate small quantities of fish.

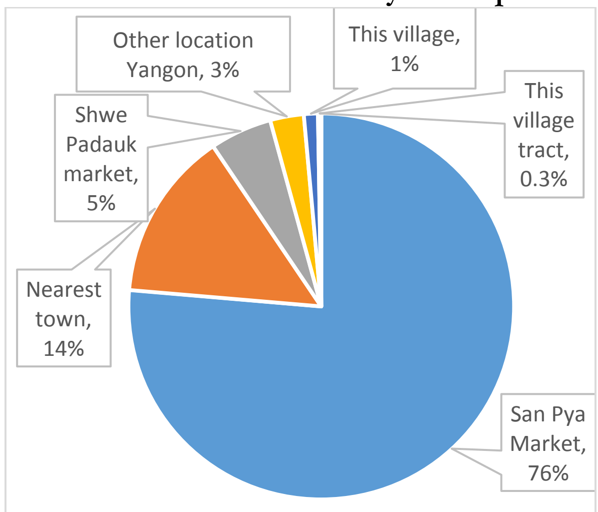
Farms using pelleted feeds were far more likely to sell in Shwe Padauk (28% of sales) than semi-intensive or integrated farms (1% and 5%, respectively). This is likely because Myanmar’s main feed manufacturer runs an affiliated fish trading business at Shwe Padauk, to which farms availing feed on credit from the company are required to sell their fish.

Large farms have the best access to credit from fish traders. Twenty six percent of farms reported having received credit from the main buyer of their fish. It was more common for large farms to avail credit (55%) than for small and medium farms (both 17%).

Almost all sales of fish were transacted in cash (only 2% via bank transfer). In 62% of cases the farmer received payment immediately. In the remaining 37% of cases there was a delay, representing de facto credit from the farm to the trader. However, the average delay was brief, at only 2 weeks. Payment to larger farms was more likely to delayed (55% of payments) than payment to small farms (23%).

Delayed payments to small farms were settled more quickly on average than delayed payments to large farms (1.1 weeks, versus 3.2 weeks, respectively). Small farms were not therefore placed at a disadvantage in this respect. This pattern suggests that payment was generally delayed where large volumes were transacted, suggesting cash flow difficulties for the trader.

Figure 28. Distribution of sales by initial point of sale



Almost all farms (96%) paid a commission on sales made through the main buyer, averaging 4.9%. Commissions account for the majority of marketing costs, and represent the largest share of operating costs after non-feed inputs. Small and medium farms paid almost the same rate of commission on sales (4.5% and 4.6%, respectively). Farms over 40 acres paid a higher average rate of commission (6.4%). Given that large farms are more likely to borrow from traders than small and medium farms, this differential may represent an implicit interest rate, paid in addition to the explicit interest paid on loans made to farmers.

5. HISTORICAL TRENDS IN PRODUCTION PRACTICES

This section compares recall data on a number of farm characteristics and indictors of performance and technological change, for the years 2016, 2011, and 2006, to identify long run trends in growout farm characteristics and performance.

Fish farm size increased significantly over the period from 2006 to 2016. The median size of sampled fish farms increased from 8 acres to 10, while mean size rose from 16 to 22 acres. It is unclear whether this trend resulted from farm consolidation occurring as small farms were acquired by larger operators, or whether it was driven by the conversion of 'new' land into ponds (Figure 29).

Figure 29. Average size of growout farms 2006-2016

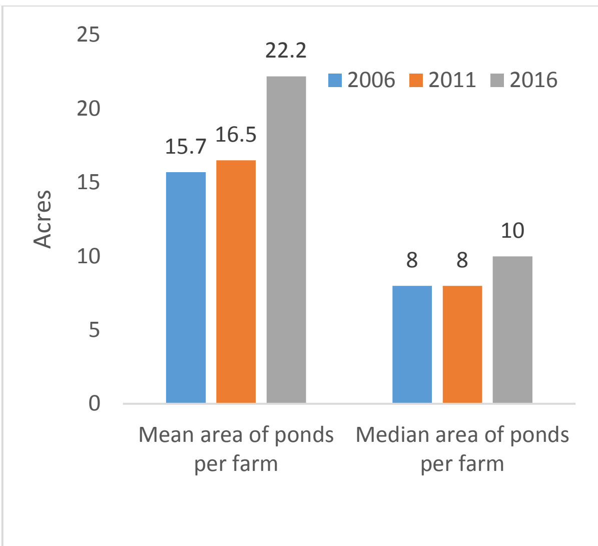
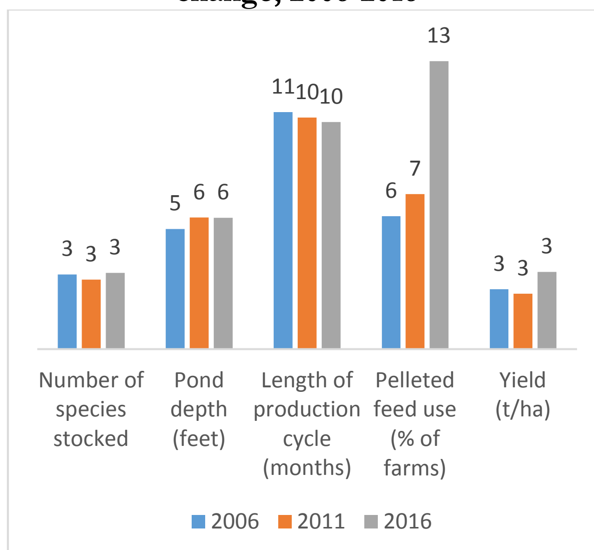


Figure 30. Indicators of technological change, 2006-2016



Farming technologies appear to have changed only marginally from 2006-2016. The average number of species stocked per farm remained unchanged at three over this period. Pond depth increased slightly, from five feet to six feet (Figure 30). This is significant because increasing pond depth is one means by which fish farm productivity may be increased, as deeper ponds allow fish to be stocked at higher densities.

The reported average yield per cycle remained unchanged between 2011 and 2016 at 3 t/ha, but a shorter average production cycle likely equates to a slightly improved annualized yield.[9] The slight reduction in the average length of the production cycle (down from 11 months to 10 months) may be linked to the increased use of pelleted fish feeds over this period, up from 6% of farms to 13%.

The performance of rohu, the most widely farmed fish, also shows little variation over time. Farmers reported that rohu accounted for around 80% of harvested fish in all three years. The average survival rate of rohu (number of fish harvested as a share of fish stocked), which is an indicator of

[9] The yield figures presented here are direct estimates given by farmers, thus they differ slightly from the statistical estimates we computed using reported harvest and acreage data.

fish health, also remained constant at around 80%, indicating that mortality was rather low on average, and has not increased over the last decade. This finding contrasts with reports from the field suggesting that disease problems have worsened significantly in recent years (Figure 31).

Figure 31. Indicators of rohu performance, 2006-2016

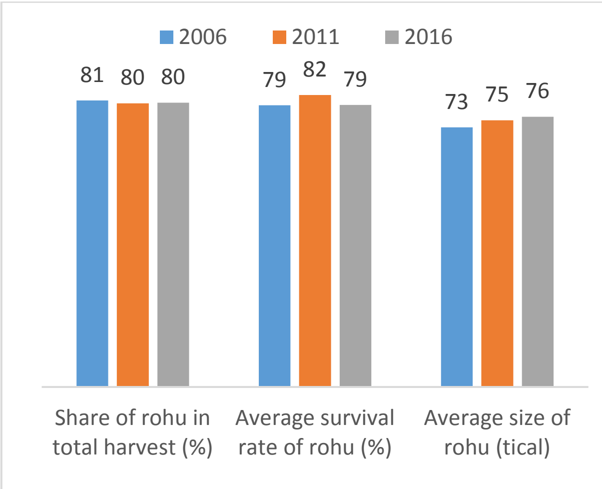
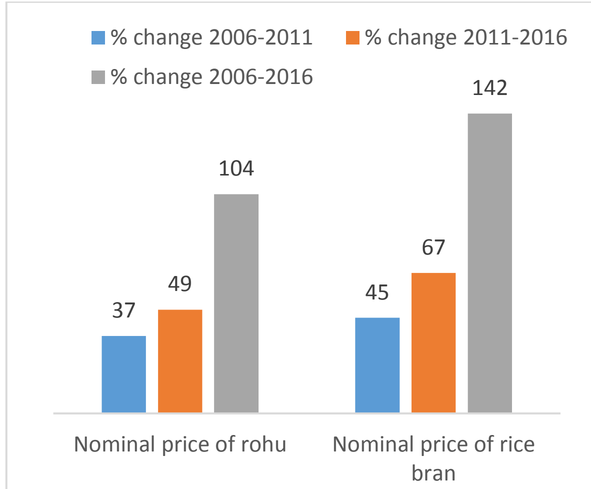


Figure 32. Nominal price of rohu and rice bran, 2006, 2016



The reported average size of rohu harvested also remained almost static, at 73-76 tical[10] (1.2kg). This finding also contradicts anecdotal reports that average the size of farmed fish has fallen within the last ten years in response to a shift in the orientation of production from export to domestic markets.

Finally, the nominal price of rice bran increased by 38 percentage points more than that of rohu over the decade, suggesting that the profitability of fish production eroded over this period, if gains in efficiency were not made elsewhere. For each of the three recall years, respondents were asked for the price per viss of rohu sized one viss, and the price of a 60 pound bag of rice bran (the standard unit in which the most widely used feed is purchased). Figure 32 shows that the nominal rice bran price rose at faster rate than the nominal price of rohu, particularly after 2011, increasing from around MMK 3000 per bag to more than MMK 7000 ($2.50 to $5.80/bag). This trend suggests that the demand for rice bran from aquaculture increased at a faster rate than the supply from paddy cultivation.

[10] 1 viss = 100 tical

6. FARM HOUSEHOLDS AND LANDHOLDINGS

6.1. Household characteristics

As expected, the educational status of the heads of fish farming households was superior to that of the population of the aquaculture cluster (5 percentage points lower for those with no education, 6 percentage points higher for those with high school attendance). This trend was more strongly pronounced for households with growout farms than household with nurseries. This suggests that the former group had higher than average socioeconomic stratus before they started to farm fish.

The overall ethnic profile of fish farming households differed little from that of the population of the aquaculture cluster (64% Bamar, 35% Karen), but nursery operators were more likely than average to be Karen (55%), and growout farmers more likely to be Burman (75%).

Contrary to the popular opinion that religious prohibitions on killing animals have inhibited the adoption of aquaculture in Myanmar, there was little difference between the religious identification of fish farmers (93% Buddhist) and the entire surveyed population (89% Buddhist).

Figure 33. Previous primary occupation of individuals reporting aquaculture as their present primary occupation, by farm type

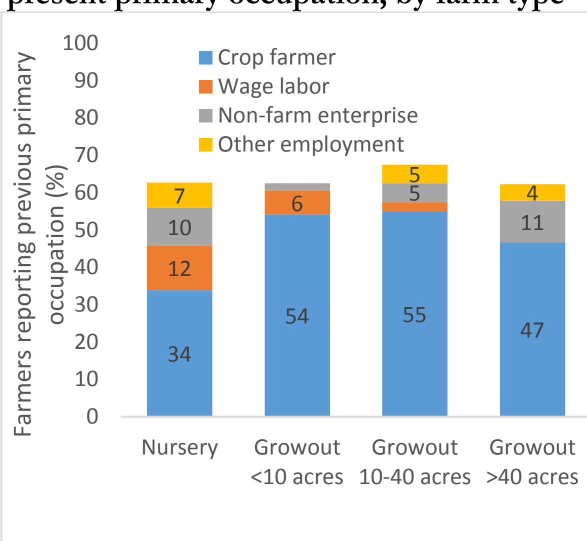
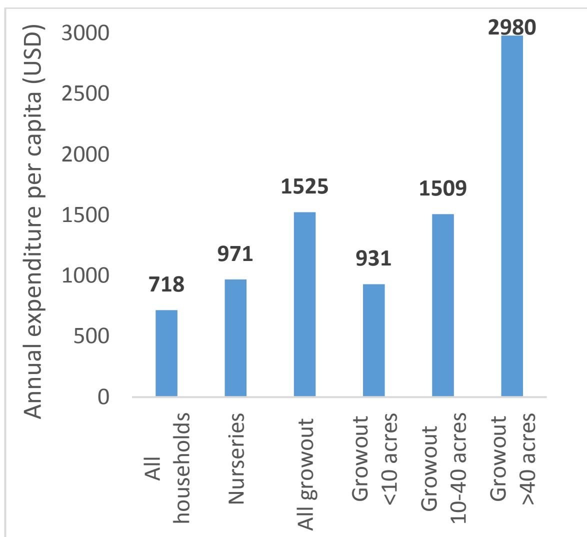


Figure 34. Average annual expenditure per capita, by household type



Among individuals who reported their primary occupation to be 'aquaculture', 40% (around half of growout farmers and one third of nursery farmers), reported that agriculture was their former primary occupation (Figure 33). A little over one third of households reported having no primary occupation before taking up aquaculture, indicating that it was their first occupation upon completion of their education. Nursery operators had the most varied set of previous occupations, including wage labor (12% of respondents) and non-farm enterprise (10%).

Fish-farming is a largely male-dominated activity, but provides some opportunities for women. Among individuals who reported fish farming as their primary occupation, 20% were women. This share was somewhat lower among small-scale farms under 10 acres (17%) and somewhat higher among medium and large farms (23% and 26% respectively). The share of female fish farmers falls somewhat below the share of women among crop farmers (27%) and slightly higher than the share of women non-farm wage laborers (17%). In contrast, 65% of those identifying as government workers and 49% of those identifying as traders, were women.

Members of fish farming households were twice as well-off on average as members of the general population of the aquaculture cluster. The all household average annual consumption expenditure per capita (a proxy for income) in the aquaculture cluster was $718. Annual expenditure per capita for members of households operating growout farms was approximately double this amount ($1525) (Figure 34).

Nurseries had an average per capita consumption expenditure of $971; 35% higher than that of the average household. Interestingly, members of households with small growout farms had a slightly lower average expenditure than members of nursery farming households. Households with large growout farms were 4.2 times wealthier than the cluster population average ($2980).

The social capital that inheres in kinship networks appears to be an important conduit for information and resources that enable households to participate in aquaculture. Households operating growout and nursery farms were two to three times more likely than members of the general population to have a relative who operated a growout or nursery farm, respectively, and were also more likely to be related to hatchery operators and fish traders (Figure 35).

Figure 35. Share of households with relatives engaged in a business related to aquaculture, by type of household

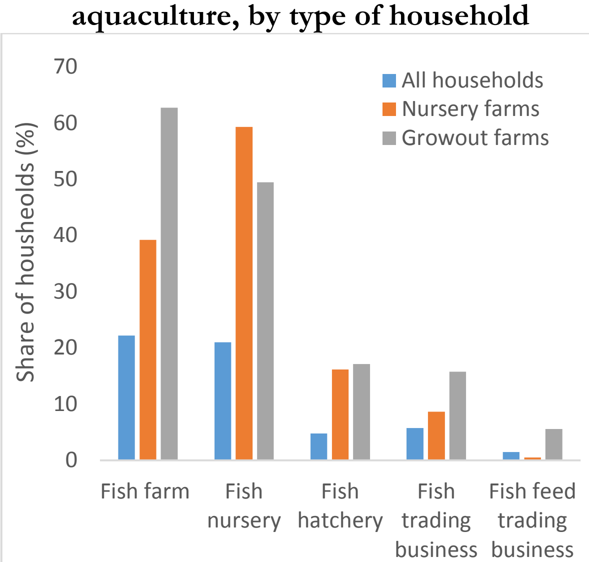
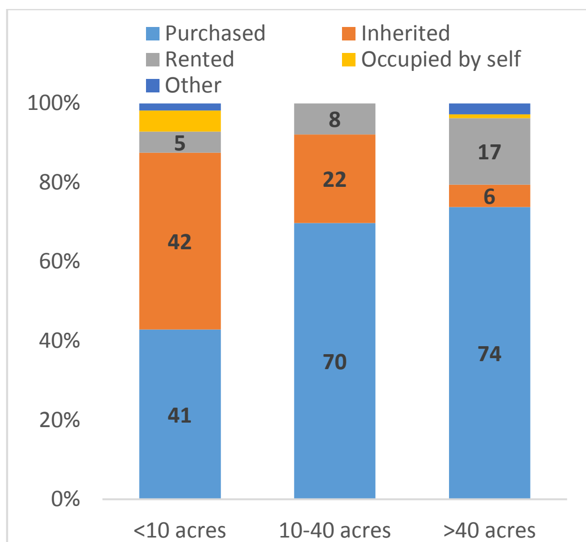


Figure 36. Mode of acquisition of land used for pond construction



6.2. Land acquisition, tenure, use and distribution

Large farm operators tend to establish ponds on land purposefully acquired for this purpose, while smaller farms are more likely make use of land already at their disposal. Growout farms of <10 acres are more likely to be constructed on land inherited by the owners (42% of farms), than those sized 10-40 or >40 acres (22% and 6%). Conversely, the share of ponds constructed on purchased land rises from 41% to 74% across farm categories, from smallest to largest (Figure 36).

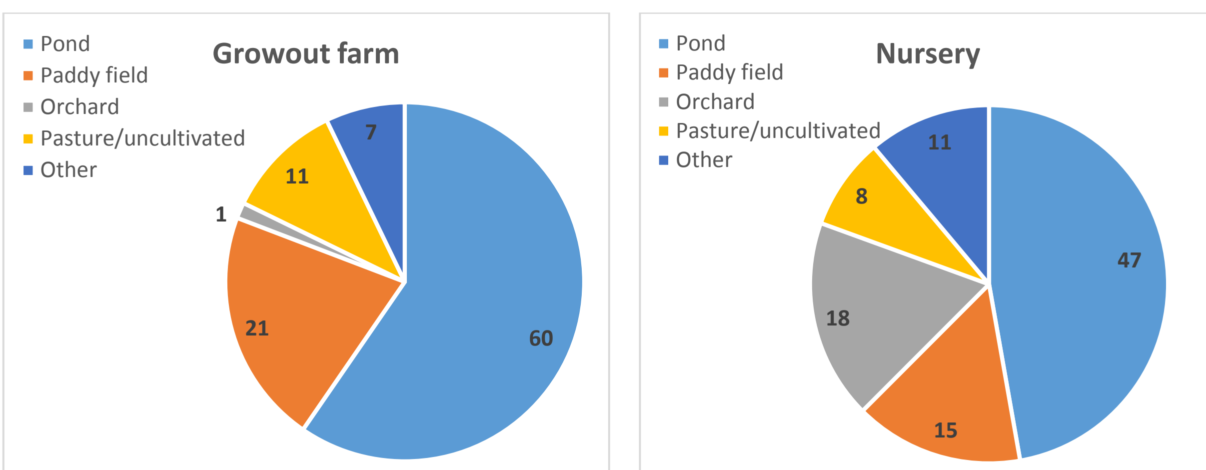
Land rentals play a minor role in enabling access to land for ponds, likely reflecting high levels of tenure insecurity. Leasing accounts for only 5% of pond area among the smallest category of growout farm, rising to 17% of farms over 40 acres.

Interestingly, land rented in accounts for the same share of total nursery area (17%) are as that of large growout farms. Nursery tenure is otherwise similar to that of growout farms under 10 acres (46% purchased, 36% inherited).

Contrary to the belief that it is almost impossible to convert paddy land to non-agricultural uses, our results show that paddy land is an important precursor to ponds. We also find that a wider variety of land than is commonly recognized is converted to ponds, particularly by nurseries and farms under 10 acres (Figure 37).

The most common use of land presently utilized for fish ponds at its time of acquisition differed markedly between growout farms and specialized nurseries. Sixty percent of land parcels utilized as growout ponds at the time of the survey were already converted to ponds at the time when they were acquired. It is not possible to know the original use of these parcels prior to their conversion into ponds. Interestingly, the share of land acquired as ponds was greater for large farms (66%), than for small farms (41%). The next largest former land use category was paddy land (21%), followed by pasture or uncultivated land.

Figure 37. Use of pond land at time of acquisition, by farm type



Just under half (47%) of parcels utilized as nurseries at the time of the survey were ponds at the time of acquisition. Fifteen percent of parcels had been utilized for paddy cultivation, while more than one third had been under other uses, the most important of which was orchards (18% of all parcels; the second largest share among nurseries).

Pond construction costs can be substantial, representing a barrier to entry for low income households. The average cost of constructing a pond within the past five years was $1235/ha (MMK 0.6 million/acre). The average cost over the past 50 years (accounting for inflation), was about double that ($2676/ha; MMK 1.3 million/acre), indicating that pond construction has become cheaper over time. Occasional maintenance can be necessary, and overall the average farm spends a yearly $62/ha (MMK 30,000/acre) on pond construction and repair ($1441, or MMK 0.7 million per farm).

In contrast, the cost of acquiring a pond through purchase has remained roughly stable in real terms, at $4135/ha (MMK 2 million/acre). The cost of pond rental currently stands at $371/ha (0.18 million MMK) per acre annually.

Figure 38. Share of ponds with license and La Na 39, by farm type

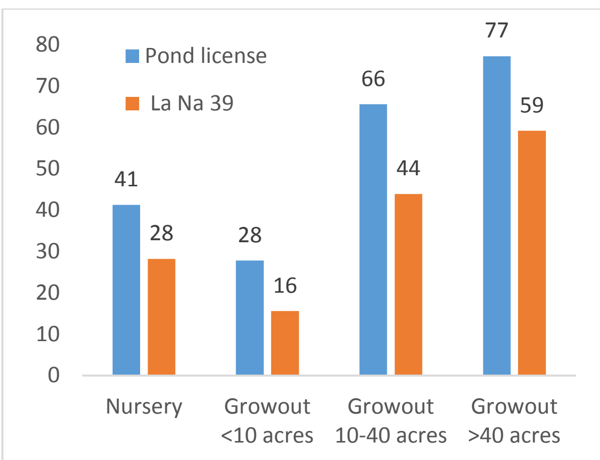
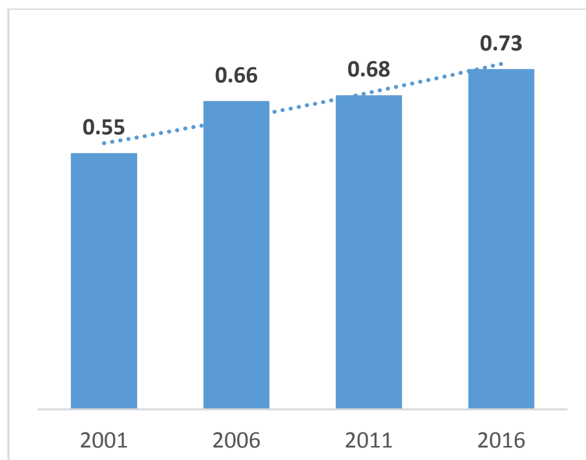


Figure 39. Gini coefficient of land utilized for ponds in 2001, 2006, 2011 and 2016



Larger farms have more formalized status and more secure tenure than small fish farms, but levels of pond registration and tenure security are low. Just over half (54%) of all ponds were reported to have a license (issued by the Department of Fisheries to fish pond operators), and 39% had La Na 39 (the certificate permitting a change in title from agricultural to non-agricultural land) (Figure 38).

Small farms are least likely to possess either document (28% and 16% of ponds reported to have either a pond license or La Na 39 respectively), and have the weakest tenure security on average. The respective shares of ponds with licenses and La Na 39 rise to 77% and 60% on farms over 40 acres.

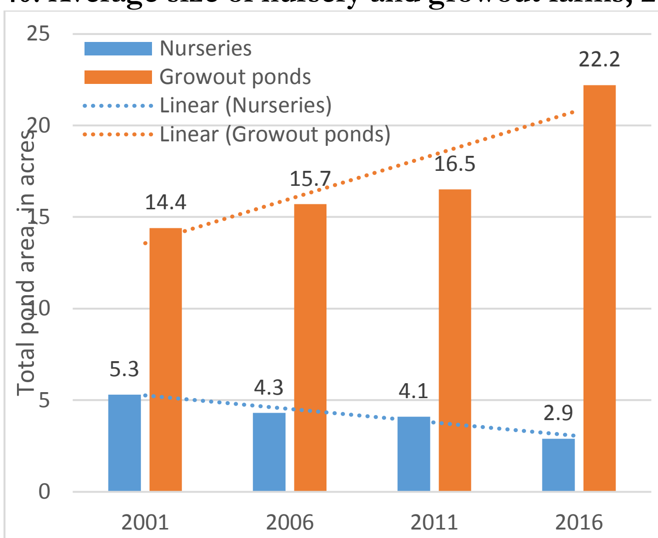
Land used for aquaculture is less equitably distributed than land used for agriculture. The weighted Gini coefficients[11] of pond land owned and agricultural land owned are 0.73 and 0.59, respectively.

[11] The Gini coefficient is a measure of inequality, on a scale from zero to one, with zero representing perfect equality (everyone

Rental markets and sharecropping arrangements can alter the distribution, but while they slightly reduce the Gini coefficient for agricultural land, they do not alter the distribution for aquaculture significantly. The Gini coefficient for operated ponds is 0.75; that of operated agircultral plots is 0.50.

Land ownership within the fish farm sector appears to be coming increasingly concentrated over time (Figure 39). The weighted Gini coefficient for land used for aquaculture increased from 0.55 in 2001, to 0.73 in 2016. It is not possible to determine whether this has occurred because large farms have grown more quickly than small farms, or because smaller farms have been subsumed by larger ones.

Figure 40. Average size of nursery and growout farms, 2001-2016



Average growout farm size grew by 53% from 2001 to 2011, increasing particularly between quickly 2011 and 2016. However, the average size of specialized nurseries fell by 48%, as numbers grew rapidly (Figure 40).

has the same amount) one representing and perfect inequality (one person has everything).

7. CONCLUSION

The findings presented above have a number of important implications for the design of policies and interventions aimed at promoting the growth of aquaculture in Myanmar. These are summarized below:

1. Aquaculture should be recognized and promoted as a mechanism for stimulating rural development and growth in Myanmar. Average returns are four times higher than those from crop farming. In addition, aquaculture creates rural growth linkages by generating demand for labor, goods (e.g. fish seed from nurseries) and services (e.g. transport).

2. Small commercial farms and nurseries should be the principal target of policy and technical interventions. Considered together, nurseries and small growout farms account for 70% of all fish farms. Small farms create greater relative demand for labor and many goods and services than large farms. However, they remain disadvantaged with respect to tenure security, access to credit, and capacity to invest in adequate levels of feed inputs. Overcoming these constraints would help boost small farm productivity and profitability and bring their performance closer to that of large farms.

3. Smaller farms have a competitive advantage in the production of non-carp species – especially tilapia, pacu and freshwater prawn, as indicated by high yields compared to medium and large farms. These species should be priority investments. Even though tilapia and pacu have a lower market value than carps in Myanmar, their rapid growth rates and robustness make them highly suitable culture species. In particular, efforts should be made to deliver research to overcome bottlenecks in the hatchery production of freshwater prawn, and to support the establishment of privately operated mono-sex tilapia hatcheries.

4. Research and outreach is needed on the use of fertilizers for aquaculture. Pond fertilization is a simple low cost technique, widely adopted by fish farmers elsewhere in Asia, which can significantly improve production efficiency. Research is needed to understand farmers' attitudes toward and use of fertilizers, identify management protocols for optimal use under Myanmar conditions through field trials, and disseminate results and recommendations to users. This support could be provided by projects in the short to medium term while government research and extension capacity is developed.

5. Small farms, nurseries and SMEs in aquaculture value chains all confront high operating costs, but have limited options for accessing credit to fund investments in their enterprises. Identifying mechanisms to enable the provision of commercial loans tailored to the needs of actors in the farmed fish value chain could help to overcome this constraint.

6. The market for pelleted feed is extremely highly concentrated. Pelleted feed prices are high, obtaining credit usually commits farms to selling their product back to the feed supplier. As a result, levels of pelleted feed adoption are low, limiting potential for intensification and higher productivity. Encouraging new investment in the feed sector could increase its competitiveness, lower feed prices, and improve the ease and terms of access to pelleted fish feeds. Obstacles that may need to be overcome include access to suitable factory sites and access to startup and operating capital.

ANNEX 1: SURVEY METHODOLOGY

MAAS adopted a two stage sampling strategy to facilitate comparison of the rural economy and livelihoods in groups of village tracts with high concentrations of fish farms (referred to as the 'aquaculture cluster'), and in areas where paddy cultivation was the main farming activity (the 'agriculture cluster').

For first stage sampling, four townships—Kayan and Twantay in Yangon Region, and Maubin and Nyaungdon in Ayeyarwady Region— were identified as the main fish farming areas using a digital database of ponds, created during the previous phase of research using satellite images and ground-truthed in the field.

From these four townships, the 25 village tracts estimated to hold the highest concentrations of ponds (calculated as the ratio of pond surface area to total land area) were identified using ArcGIS software. These were selected as the 'aquaculture cluster'. Fifty seven percent of the area of inland fish ponds in the delta is estimated to fall within these village tracts.

A total of 15 village tracts (three separate groups of five village tracts each in Kayan, Twantay, and Maubin townships) were selected to form the agriculture cluster. 'Agriculture cluster' village tracts were selected based on interviews conducted in the same four townships with staff of the General Administrative Department (GAD). The three main agricultural crops grown in each of the village tracts in the townships were listed and ranked in order of importance. Village tracts where cultivation of paddy and pulses were the predominant forms of agriculture were prioritized for selection. All village tracts in Nyaungdon Township were found to contain significant areas of fish ponds, and were excluded from selection as part of the agriculture cluster.

Second stage sampling was designed to ensure that the entire populations of both the aquaculture and agriculture clusters (including non-farm households), were represented. This approach was taken in order to facilitate the estimation of the economic multiplier effects of aquaculture and agriculture.

Enumeration areas (EAs) were selected by probability proportional to size sampling from within the 40 (25 + 15) aquaculture and agriculture cluster village tracts, using the national population census of 2014 as the sampling frame. This procedure yielded a sample comprised of 78 EAs: 49 in the aquaculture cluster and 29 in the agriculture cluster. A listing (census) of households was conducted in every selected EA to serve as the final sample frame for randomized selection of respondent households.

In each aquaculture cluster EA, eight fish farming households and seven non-fish farming households were selected for interview. Non-fish farming households included both those engaged exclusively in non-farm work and those engaged in crop farming. Households operating fish farms of 40 acres or more were selected with 100% probability, to ensure a sufficient sample of large farms to support statistically valid analysis.

In EAs in the agriculture cluster, a sample of eight agricultural households (households engaged in farming paddy and/or pulses), and seven non-agricultural households were drawn at random from the listing data. Large farms were not oversampled.

Respondents from a total of 1,102 households, representing a population of 37,390 households, were interviewed, one on one in the privacy of their own homes.

The survey instrument was comprised of three elements:

1) A household section, containing modules on household composition, migration, employment, land and asset ownership, production of non-field crops, and consumption expenditures. This was administered to all 1,102 households.

2) An aquaculture section, administered to households operating specialized nurseries (producing juvenile fish for sale to other farms), and 'growout farms' (producing food fish for human consumption). The survey instrument was comprised of modules on: pond acquisition and tenure status; input utilization and costs (including labor); harvesting and marketing; trends in production over the preceding 10 years; and credit utilization. This section of the questionnaire was answered by 224 households in the aquaculture cluster.

3) An agriculture section, divided into two sub-sections on monsoon season and dry season field crop cultivation. The instrument incorporated modules on: land ownership and tenure; irrigation; agricultural machinery and draft animal use; input application; marketing practices and costs; changes in production practices over the last decade; and access and utilization of agricultural credit from Myanmar Agricultural Development Bank (MADB) and informal sources. This section of the questionnaire was administered to 329 households (216 in the agriculture cluster and 113 in the aquaculture cluster).

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