Review of feeds and fertilizers for sustainable aquaculture development in sub-Saharan Africa

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SUMMARY

Recent observed changes in production, technological developments and culture practices in sub-Saharan Africa (SSA) have largely been driven by increasing fish prices throughout the region and aquaculture in the region is now poised to increase rapidly. In 2004, Africa as a whole contributed 1.8 percent to world aquaculture fish production, while the SSA region contributed 0.26 percent. Egypt was the largest contributor to African aquaculture (84.5 percent) followed by Nigeria (7.9 percent) and as a whole the SSA region contributed 14.6 percent to African aquaculture output. During the period 2000 to 2004 aquaculture production in SSA increased by 50.8 percent from 54 109 tonnes to 81 598 tonnes. The highest increases in production were recorded in Uganda (575 percent), Cameroon (560 percent) and Kenya (102 percent). Nigeria is the largest producer in the region (43 950 tonnes in 2004), followed by Uganda and Zambia with around 5 000 tonnes each.

This review focuses on seven target countries, namely Cameroon, Ghana, Kenya, Malawi, Nigeria, Uganda and Zambia, and comparative information is provided for other countries in the region. Over 80 percent of fish farmers in the region are small-scale farmers who practise extensive aquaculture on a non-commercial basis to improve household food security. However the bulk of production (~70 percent) is produced by the commercial sector, ranging from small-scale semi-intensive enterprises to industrial scale farming of high value products such as catfish (Nigeria), shrimp (Madagascar and Mozambique) and abalone (South Africa). The most notable developments in the target countries include high density catfish farming in Nigeria, medium and industrial scale cage culture, a switch to commercial aquaculture by previously "non-commercial" farmers (28 percent of farmers in Uganda switched to commercial aquaculture in the last five years), establishment of intensive African catfish hatcheries in Kenya and Uganda, a major expansion of peri-urban aquaculture and dynamic growth in African catfish production.

Between 2000 and 2004 production of clariid catfish had increased by 452% from 5 739 to 31 681 tonnes, contributing 38.8 percent to total SSA production. Over the same period Nile tilapia (*Oreochromis niloticus*) production has increased by 37.2 percent and contributes 25.9 percent to total SSA production. The contribution by common carp (*Cyprinus carpio*) has declined by 11 percent and in 2004 contributed 3.4 percent. The contribution by all other cichlid and non-cichlid species has also declined.

Aquaculture practices are diverse, ranging from single pond subsistence farming to highly intensive pump-ashore abalone farms. The non-commercial sector is characterised largely by the use of "green compost" cribs to enhance pond productivity, irregular application of inadequate quantities of manure and the use of cereal bran, kitchen waste and vegetable matter as feed inputs. Production levels are low (mean = 1.03 tonnes/ha/year) and species choice depends largely on the availability of fingerlings. Commercial, semi-intensive pond culture and intensive cage and tank culture is gaining momentum. Production levels in semi-intensive pond systems are comparable to global averages, ranging from 2.5 to 15 tonnes/ha/year. Polyculture of Nile tilapia and African catfish commonly practised throughout the region, though monoculture is preferred in intensive cage or tank systems. Ornamental fish culture is emerging in several countries.

Except for Uganda and Kenya, the legislative and regulatory environment for aquaculture in the region is weak. It is best developed in Namibia.

There is a clear dichotomy in pond fertilization methods. All non-commercial farmers in the region are constrained either by on-farm availability of manure, price, access, cash resources and transport costs and therefore mainly use compost cribs and some animal manure when available. On the other hand, all commercial farmers, irrespective of scale, use animal manure at appropriate levels and chemical fertilizers where and if necessary, though rarely. Chicken manure is most often used and ranges in price from US$17 to around US$30 per tonne. Animal manure requirement for optimum fish production in

the target countries was estimated based on six possible scenarios. By 2020 total animal manure requirements will be between 257 896 and 754 889 tonnes per annum.

Total animal feed production in the target countries, including South Africa, in 2005 amounted to some 9.0 million tonnes per annum, dominated by South Africa and Nigeria (4.4 and 3.8 million tonnes per annum, respectively). Industrial aquafeeds, manufactured by medium and large scale feed mills, are produced in Cameroon, Kenya, Malawi, Nigeria, South Africa and Zambia, while other countries are on the threshold of commercial aquafeed production. Some 17 000 tonnes of fish pellets and aquafeed mixes were produced in 2005, of which Nigeria produced around 66 percent. The total feed requirement by 2020 was projected based on three growth scenarios of fish production and ranges between 139 000 tonnes and 545 000 tonnes. Only 50–65 percent of the feed milling capacity is utilized and the industry has adequate capacity to provide the needs of the commercial aquaculture sector until 2020.

The general paucity of good quality aquafeeds in the region is generally a factor of scale. In most countries local demand has not reached a critical mass for appropriate attention and investment, though the threshold has now been reached in Nigeria where substantial investments are planned. Only 22 percent of commercial fish production is attributable to industrial aquafeeds. This highlights the pivotal importance of farm-made feeds in the region. Most countries in the region have adequate resources to manufacture appropriate feeds, though the availability and cost of fishmeal and soybean meal or oilseed cake is a major constraint in most countries. The price of feed ingredients, particularly fishmeal, oil seed cakes, soybean meal and maize, is highly variable among countries and varies seasonally within countries. Farm-made feed formulations vary by season, depending on availability and price of ingredients. Some 98 500 tonnes of farm-made feeds are currently produced annually, with reported FCRs ranging from 1.1 to 3.2. In Nigeria some 69.8 percent of fish production is attributable to informal feed manufacturers. There is a good body of knowledge with respect to the proximate composition of locally available feed ingredients and much work has been undertaken on optimal inclusion levels of these ingredients with particular emphasis on fishmeal replacement. The importance of farm-made feeds in the region highlights the urgent and desperate need for further nutritional research in the region.

The principle recommendations emanating from the synthesis include: training of nutritionists and fish feed technologists, developing appropriate manufacturing machinery and bulk storage facilities, evaluating and testing non-conventional feed ingredients, developing databases of available feed and fertilizer resources, developing country specific farm-made feed formulations, effective dissemination of information (availability of ingredients, formulations, manufacturing technologies, feeding schedules), developing country specific animal feed standards and reviewing pertinent legislation to ensure stability, quality and food safety and establishing enabling business environments.

1. INTRODUCTION

In a recent synopsis of sub-Saharan aquaculture the availability, quality, food conversion ratio (FCR) and the high distribution costs of feeds and fertilizers, together with poor quality fingerlings and the general absence of investor friendly regulatory frameworks were singled out as some of the most important issues that constrain the development of commercial and non-commercial aquaculture in the region. It was further concluded that most non-commercial farmers use protein limiting diets, though the use of farm-made feeds is increasing, while locally manufactured feeds, except for isolated cases, are generally of poor quality (Hecht, 2006). This highlights the need for feed quality assurance programmes.

This review focuses, in particular, on the use and availability of feeds and fertilizers for sustainable aquaculture in a select group of sub-Saharan countries and is a sequel to a review undertaken in 2001 (Shipton and Hecht, 2005). The target countries in this instance were Cameroon, Ghana, Kenya, Malawi, Nigeria, Uganda and Zambia. As will be shown later, Cameroon, Uganda and Zambia have recorded the most significant increases in national production while Nigeria remains the giant in the region, though interesting and noteworthy changes have taken place in the other target countries. The most notable changes that have taken place in the last five years are summarized in Table 1. The rapidly escalating price of fish throughout most SSA countries is considered to be the most important driving force of the rapid growth in the sector. For example in Cameroon many previously abandoned ponds have recently been rehabilitated as a consequence of the increasing fish price and this has often been done without technical input from extension services. It was for these reasons that the countries were singled out for this review. For comparison and where appropriate, information on fertilizers and feeds is also presented from elsewhere on the sub continent and from Egypt.

It is currently in vogue to define aquaculture in SSA as being either commercial or non-commercial (Moehl, Halwart and Brummett, 2005). While there is indeed great merit for this distinction these categories are limiting when undertaking a review of feeds and fertilizers for the sustainable development of the sector in the region. In a recent review of SSA aquaculture it was shown that the face of aquaculture throughout the region has and is changing rapidly towards a more commercially orientated activity (Hecht, 2006). "Traditional" low-input/low-output small-holder fish farmers still dominate the scene. However the greater proportion of SSA production is now produced by commercial enterprises that range from small-scale semi-intensive to large industrial scale operations. Therefore, for the purposes of this review, aquaculture in all target countries is categorised by the level of intensity (extensive, semi-intensive, intensive) with respect to culture systems, species cultured, the intensity of management inputs, labour requirements, capital and operational costs, the level of business orientation, the level of integration with other economic on-farm activities such as horticulture or animal husbandry, feeding and fertilization levels. It is not the intention here to define

TABLE 1
Significant developments in sub-Saharan aquaculture since 2000

Uganda	Over 28% of farmers switched to commercial aquaculture in last 5 years. Over 10 intensive African catfish (*Clarias gariepinus*) hatcheries established in last 5 years, now producing around 0.5 million fingerlings per month. Major expansion of African catfish farming.
Kenya	Establishment of six *C. gariepinus* hatcheries, each producing between 10 000 and 50 000 fingerlings per month. Major expansion of catfish farming.
Malawi	Development of a 3 000 tonne cage culture operation in Lake Malawi for production of indigenous chambo *Oreochromis* species (*O. karongae* and *O. shiranus*)
Cameroon	Significant expansion of peri-urban commercial aquaculture
Nigeria	Development of high density clariid catfish culture, rapid expansion of urban aquaculture.
Ghana	Developments in Nile tilapia (*O. niloticus*) cage culture.

Source: Hecht (2006)

TABLE 2
Characteristics of the aquaculture sector in sub-Saharan Africa

CATEGORIES and CHARACTERISTICS	Extensive	Semi-intensive	Intensive
Culture systems	Earthen ponds	Earthen ponds and cages	Cages, raceways, tanks and earthen ponds
Species	Polyculture (various tilapiine species, catfish and carp)	Mainly polyculture (Nile tilapia and African catfish), some monoculture (tilapia)	Mainly monoculture
Management input	Low to medium	Medium to high	High
Labour needs	Family labour to low requirement for external labour	Medium	Low to high (more capital intensive)
Capital costs	Low to medium	Medium	Medium to high
Operational costs	Zero to low	Medium	High
Business orientation	Low to medium	Medium to high	High
Integration with other farm activities	Medium to high	Low to high	Low
Feeding	Zero to supplementary	Scheduled to unscheduled using mainly farm-made feeds	Scheduled intensive feeding using pellets or farm-made feeds
Fertilisation	Zero to medium level	Medium to high level	Zero to high level

Source: Author's data and country reviews

the various categories, but simply to highlight the diverse nature of the sector and to make the point that these categories better facilitate a review of the current situation with respect to feeds and fertilizers. These categories and their general characteristics are summarized in Table 2. Non-commercial farmers as per the definition of Moehl, Halwart and Brummett (2005) would normally, but not exclusively, practice extensive fish farming.

Except for experimental shrimp (*Penaeus* species) culture in Kenya, mariculture is not practiced in any of the maritime countries considered here. Brackish-water aquaculture is practiced only in Nigeria and at a low level. Mariculture in SSA is restricted mainly to shrimp culture in Madagascar, Mozambique and Seychelles and abalone aquaculture in South Africa. Therefore the review focuses mainly on inland freshwater aquaculture. The analysis is based mainly on country reviews for Cameroon (Pouomogne, 2007), Ghana (unpublished reports by Abban, 2005 and Hasan, 2005), Kenya (Nyandat, 2007), Malawi (Chimatiro and Chirwa, 2007), Nigeria (Ayinla, 2007), Uganda (Rutaisire, 2007) and Zambia (author's data) and a review of the primary and grey literature and government reports. For the purposes of this review sub-Saharan Africa includes all continental sub-Saharan countries and Madagascar. Production statistics extracted from Fishstat (FAO, 2006) for comparative purposes and with which to put SSA aquaculture into perspective includes only data for species that depend on feeds and fertilizers.

2. GENERAL OVERVIEW OF AQUACULTURE, FARMING PRACTICES AND SYSTEMS

Aquaculture in sub-Saharan Africa contributes 0.26 percent and 14.6 percent to total World and African aquaculture production, respectively (FAO, 2006). Nigeria with a production of over 43 950 tonnes per annum in 2004 is by far the largest producer in SSA, though this figure still falls far short of the 471 535 tonnes produced by Egypt in 2004. Nevertheless, since 1990 there have been substantial increases in production in many of the SSA countries (Figure 1). For the SSA region as a whole total production had increased by 434 percent between 1990 and 2004, while in the target countries production had increased by 436 percent. During the last 5 years (2000–2004) production in SSA has increased by 50.8 percent from 54 109 to 81 598 tonnes and in the target countries by 56.4 percent from 36 870 to 57 662 tonnes. In 2994 Nigeria

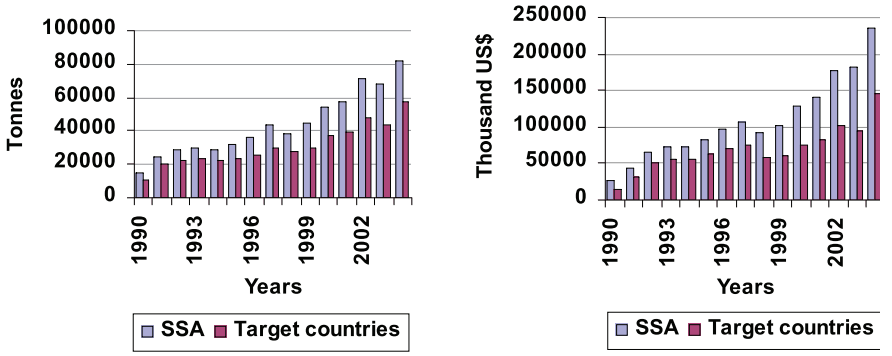
TABLE 3
Total aquaculture production (tonnes) by country

Country	2000	2001	2002	2003	2004	2005	Percent increase
Cameroon	50	150	330	320	330	820	560
Ghana	*	*	*	938	950		
Kenya	512	1 009	798	1 012	1 035		102
Malawi	530	568	642	666	733	800	38
Nigeria	25 718	24 398	30 663	30 677	43 950		71
Uganda	820	2 360	4 915	5 500	5 539		575
Zambia	4 240	4 520	4 630	4 501	5 125		21
Target countries	36 870	39 005	47 978	43 614	57 662		56
SSA	54 109	57 562	71 802	68 121	81 598		51

*Excluded because of questionable data

Source: FAO (2006) and country reviews

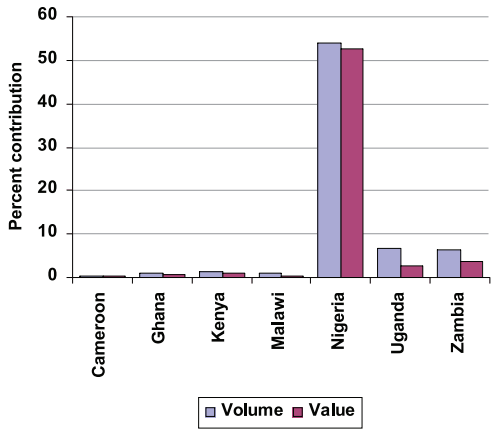
FIGURE 1
Aquaculture production by volume (left) and value (right) in SSA and target countries for the period 1990 – 2004



Source: FAO (2006)

produced approximately 53.9 percent of the SSA total, while Uganda and Zambia each contributed ca. 6.5 percent. Other target countries contributed between 0.4 and 1.2 percent to the 2004 SSA total (Figure 2). In terms of value Nigeria is the only SSA country for which the percent value approximates the value for volume and this is most likely because of the high price of fish in Nigeria (up to US$4.50/kg in urban areas – Hecht, 2006). While Nigeria is clearly the giant in the region, production over the last 5 years had only increased by 71 percent, in comparison to increases of 575 percent, 560 and 102 percent recorded for Uganda, Cameroon and Kenya, respectively (FAO, 2006). However, between 2003 and 2004 production in Nigeria has jumped from 30 677 tonnes to 43 950 tonnes. This clearly illustrates the pace of development of the sector in Nigeria in relation other SSA countries. Despite these impressive increases aquaculture in 2004 only made a measurable contribution to national fish supply (sum of capture fisheries, aquaculture and imports) in Malawi (1.25 percent), Uganda (1.5 percent), Nigeria (4.5 percent) and Zambia (6.7 percent), while in the remainder of the target countries

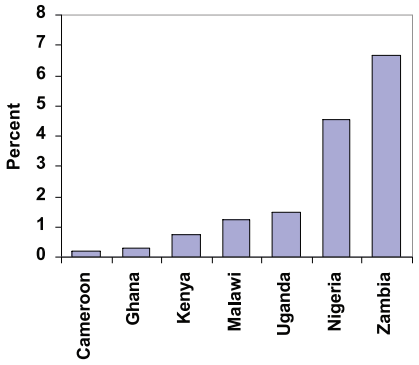
FIGURE 2
Percent contribution by target countries to total SSA production, volume and value



Source: FAO (2006)

the contribution was less than 1 percent (Figure 3). The contribution made by aquaculture to GDP in the target countries is insignificant, ranging from 0.005 percent for Cameroon to 0.154 in Nigeria (Hecht, 2006). However, aquaculture where practiced, makes a significant contribution to food security in rural areas. Table 3 summarizes the most recent production figures for the target countries.

FIGURE 3
Aquaculture production as percent of total fish supply in 2004



Source: FAO (2006) and www.earthtrends.com

Small-scale non-commercial fish farmers vastly outnumber commercial farming enterprises. Using information provided in the NASOs (National Aquaculture Sector Overviews) (FAO Fisheries Global Information System, 2006) of the target countries, which formed the basis of the review of aquaculture in SSA (Hecht, 2006) and the country reviews on feeds and fertilizers it was possible to obtain a rough estimate of the number of non-commercial and commercial farmers and the size of the operations (Table 4). Non-commercial farmers account for around 80 percent of the total number of fish farmers.

However, the bulk of production is produced by the commercial sector (Table 5). The data suggest that 70.5 percent of fish in the target countries was produced by the commercial sector. Of course this estimate is highly skewed by the size and output of the commercial sector in Nigeria. Nevertheless, it shows that commercial aquaculture in SSA, despite the constraints with respect to the availability of commercially produced formulated pellets, is gaining momentum.

TABLE 4
Number of fish farming operations in target countries

Country	Number of Non-commercial farmers	Number and type of commercial enterprises	Size of commercia enterprises	Total area (ha) under culture (commercial and non-commercial)
Cameroon	ca. 3 200	2 large earthen pond farms	Unspecified	270
		400–800 peri-urban earth pond farms	Approx. 0.5 ha	
Ghana*	ca. 800	1 cage culture operation	10 cages (15 m dia x 6 m)	154
		4 earthen pond farms	Pond farms (3.1 to 10 ha)	
Kenya	5 890	1 tilapia tank farm	Unspecified	419
		3 rainbow trout raceway/tank farms	Unspecified	
		Cage farms	Unspecified	
		6 catfish hatcheries		
Malawi	4 050	1 rainbow trout tank farm	0.5 ha	269
		1 cage operation	32 x16 m diameter cages under development	
		1 pond farm	12 ha	
Nigeria	50 000	>2600 earthen pond and tank farms	Unspecified	60 000
Uganda	8 000	11 catfish hatcheries		1 200
		Several pond farms	Unspecified	
Zambia	6 000	4 cage farms	44 cages (6x6x3 m) and 10 pens	260
		10 pond farms	Total pond area = 195 ha	

*Two of these farms (one cage culture and one earthen pond) produce >50% of Ghana's aquaculture output (Hasan, 2005)
Source: Country reviews

TABLE 5
Estimates of commercial production (tonnes) in target countries

COUNTRY	Year	% of fish from commercial farms	Total production	Commercial production
Cameroon	2004	8%	650	52
Ghana	2004	32%	950	304
Kenya	2003	100% of trout, 15% of tilapia 85% of catfish	29 600 319	29 90 271
Malawi	2003	100% of trout 11% of other fish	15 651	15 72
Nigeria	2004	80%	43 950	35 160
Uganda	2003	40% (projected 60% in 2005)	5 500	2 200
Zambia	2003	75%	4 501	3 376
TOTAL			**53 951**	**40 736**

Source: FAO (2005), Hecht (2006) and modified using data provided in country reviews

3. THE SPECIES

Approximately 27 species are farmed in the seven target countries (Table 6). Table 7 provides a summary overview of the most import species groups, with particular reference to Nile tilapia (*Oreochromis niloticus*), African catfish (*Clarias gariepinus*) and common

TABLE 6
Aquaculture species in target countries

SPECIES	Cameroon	Ghana	Kenya	Malawi	Nigeria	Uganda	Zambia
Cichlidae							
Nile tilapia *(Oreochromis niloticus)*	x	x	x		x	x	x
Mozambique tilapia *(O. mossambicus)*				x			
Three spotted tilapia *(O. andersonii)*							x
Longfin tilapia *(O. macrochir)*							x
Chambo *(O. shiranus shiranus)*				x			
Chambo *(O. karongae)*				x			
Banded jewel fish *(Hemichromis fasciatus)*	x						
Redbelly tilapia *(Tilapia zillii)*						x	
Redbreast tilapia *(T. rendalli)*				x			x
T. guineensis		x					
Blackchin tilapia *(Sarotherodon melanotheron melanotheron)*		x					
Mango tilapia *(Sarotherodon galilaeus galilaeus)*	x	x					x
Clariidae							
North African catfish *(Clarias gariepinus)*	x	x	x	x		x	x
Vundu *(Heterobranchus longifilis)*							
Hybrid catfish*							
Cyprinidae							
Common carp *(Cyprinus carpio)*	x	x	x	x	x	x	x
Silver carp *(Hypophthalmychthys molitrix)*					x		x
Grass carp *(Ctenopharyngodon idella)*					x		x
Others							
African bonytongue *(Heterotis niloticus)*	x	x			x		
Snake-head *(Parachanna obscura)*	x				x		
Kafue pike *(Hepsetus odoe)*				x			
Rainbow trout *(Oncorhynchus mykiss)*			x	x			
Squeaker *(Synodontis sp.)*					x		
Nile perch *(Lates niloticus)*					x		
Aba *(Gymnarchus niloticus)*					x		
Distichodus *(Distichodus sp.)*					x		
Moon fish *(Citharinus sp.)*					x		

**Clarias gariepinus x Heterobranchus longifilis (or H. bidorsalis)*

Source: Country reviews, FAO Fisheries Global Information System (2006) and FAO (2006)

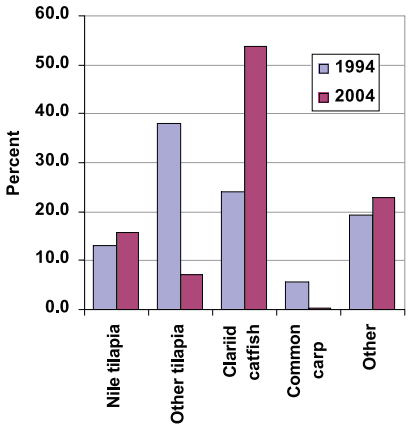
TABLE 7
Production in 2004 by species groups in tonnes and percent contribution

Country	Nile tilapia	Other tilapia	Clariid catfish	Common carp	Others	Total
Cameroon	210		114	6		330
Ghana	760				190	950
Kenya	614		320	67	34	1 035
Malawi		697	17	4	15	733
Nigeria	3 000	1 176	26 750	44	12 980	43 950
Uganda	1 660		3 827	50	2	5 539
Zambia	2 900	2 180		45		5 125
Total	**9 144**	**4 053**	**31 028**	**216**	**13 221**	**57 662**
Percent of total	**15.9**	**7.0**	**53.8**	**0.4**	**22.9**	

Source: FAO (2006)

carp (*Cyprinus carpio*). In most countries except Malawi and Zambia, *O. niloticus* is the dominant cichlid produced in aquaculture. Malawi has managed to exclude *O. niloticus* from its waters and in Zambia greenhead tilapia (*O. machrochir)* accounts for over 41 percent of production, while *O. niloticus* accounts for 35 percent of total production. The farming and production of *Cyprinus carpio* and indigenous cichlids has declined throughout the SSA region during the last decade, while the production of *C. gariepinus*, in particular, as well as *O. niloticus* has increased significantly (Figure 4). Between 1999 and 2004 common carp production throughout SSA has declined by 11 percent. The reasons for the decline are unclear but may be related to consumer preferences and fish price.

FIGURE 4
The change in percent contribution to total production by species groups in the target countries between 1994 and 2004



4. AQUACULTURE PRACTICES AND THE FARMING SYSTEMS

The diversity of farming systems in the region varies according to the motivation and circumstances of the farmers. Non-commercial fish farmers in all target countries practise extensive aquaculture and normally own between 1 and 5 small ponds (average = 2 ponds), ranging from 100 to 350m^2. Ponds are either situated on the farmers own land or are clustered in fish farming "clubs" (Figure 5).

Diversion ponds are most commonly used, though in some instances (Malawi, Cameroon, Ghana) ground water seepage ponds are also often used by small-holder fish farmers. Production technologies are characterised typically by the low level of inputs resulting in low yield. Annual production by non commercial farmers in the target countries ranges from 0.5 to 2.5 tonnes/ha/year and averages around 1.2 tonnes/ha/year. Most of the fish produced on non-commercial farms is internalised, used for

FIGURE 5
Typical small-holder farm pond (left) and club ponds (right)

barter and cash income and plays a significant role in food security at the household level. Most farmers in this category use "green compost" cribs and occasionally use animal manure when available (chicken, goat, rabbit and cattle manure) to enhance natural pond productivity and use cereal bran (maize, rice and wheat), kitchen waste, green leaves and non-conventional animal protein products as feed, when available. Substantial proportions of farmers in all target countries do not provide any pond inputs and rely only on natural pond productivity. In Cameroon the cribs comprise around 10 percent of pond surface area, though in other countries may comprise less than 1 percent of the pond surface. Most farmers practise some form of arbitrary polyculture, which is largely dependent on the availability of fingerlings. Because of higher yields, polyculture of *O.niloticus* (or other Tilapia species (e.g. *O.shiranus* and *O.mossambicus* in Malawi and *O.andersonii* in Zambia) with *C.gariepinus* or other clariid species, such as *Heterobranchus* spp. is becoming the most preferred practice even by non-commercial farmers, particularly in Nigeria as well as in Cameroon, Ghana, and Uganda.

Stocking densities remain low, at an average of 1–4 fingerlings/m^2. Fishponds are usually stocked using fingerlings left over at harvest or purchased from neighbours. More often than not, this means that small mature fish (stunted) that have no or very little scope for growth are stocked as fingerlings. Some farmers stock their ponds with fingerlings captured from rivers, lakes or wetlands and this leads to higher yields (ADiM, 2005).

Management practices by the majority of non-commercial farmers in all target countries, with respect to scheduled stocking, fertilization, feeding and harvesting is rudimentary, except where farmers work in collaboration with development projects. Labour on most non-commercial fish farms is provided by the family, though hired labour is used where this is affordable. Many small-scale farmers do not have the cash or other resources to hire labour and this is a major constraint on small-holder farms. In Cameroon, Kenya, Malawi, Uganda and Zambia most small-scale fish farmers have integrated their fish farming activities with agriculture in one or several ways. Though not mentioned in the country reports it is assumed that the same holds true for Ghana and Nigeria.

Semi-intensive and intensive commercial aquaculture except in Nigeria and Zambia, where it is relatively well established, is a rapidly emerging activity in all target countries. The sub-sector has gained particular momentum in the last five years. As mentioned previously these developments are principally ascribed to the rapidly escalating fish price in peri-urban and urban areas as well as to progressive changes in government policy and support for the private sector, particularly in Kenya and Uganda (Hecht, 2006 and see SSA country reports). In 2004 the average price of fish in peri-urban and urban markets was US$2.5/kg (US$1.6 in Kenya to US$4.5/kg in Nigeria). The adoption and implementation of strategic aquaculture development plans also act as enabling tools for the development of the sector (Hecht, 2006). Strategic plans have now been adopted in Cameroon, Zambia and Malawi, awaiting adoption in Nigeria and in a preparatory phase in Ghana. Most importantly, these developments have improved investor confidence in the sector in all target countries. Nevertheless, as suggested by Hecht (2006), there is an urgent need to educate financial institutions in all SSA countries as to the potential, risks and benefits of commercial aquaculture, such that they are better equipped to assist the development of the sector.

There is a wide spectrum of commercial fish farms in SSA that range from small to medium scale operations in peri-urban areas, to large pond and or cage farming operations. The level of intensification in each of these categories ranges widely from semi-intensive pond culture, to small and large cage culture operations to high density tank culture of African catfish, using water recirculation technology (Figures 6–10). It is clear from the country reviews that each system has evolved and is driven by market

needs. For instance, limited by space, urban and peri-urban farmers in Nigeria are using recirculation technology (Figures 9 and 10), while farmers in Uganda and Kenya have recognized the opportunities provided by the Nile perch longline fishery in Lake Victoria for the supply of live African catfish fingerlings as livebait and have therefore become full-time fingerling producers (Figure 11).

Except for Uganda and Kenya, the legislative and regulatory environment in the other countries remains weak and does not actively promote investment in the sector. Where these shortcomings exist (Cameroon, Ghana, Malawi, Nigeria and Zambia) the problem has been recognized and is being addressed through the development of strategic sector development plans (Hecht, 2006).

Production by commercial enterprises is variable and depends on the systems employed and the level of intensification. Cage culture production levels in Ghana, Zimbabwe and Zambia with *O.niloticus* range from 2 to 4 tonnes/100 m^3. Cages range from small locally made cages to medium size square cages (6x6x3m), to 796 m^3 in Ghana to 1 200 m^3 circular cages (Malawi). The largest cage culture operation in SSA is Lake Harvest (Pty) Ltd (Lake Kariba, Zimbabwe), producing around 2 500 to 3 000 tonnes per annum, most of which is exported to the European Union (EU). A similar operation is now being established in Malawi. The Malawian operation intends to produce 3 000 tonnes of chambo, *O. karongae* or

FIGURE 6
Emerging small-scale commercial farmers specialising in fingerling production (left) and table fish production (right)

FIGURE 7
Large scale polyculture pond farming of *C. carpio, C. gariepinus* and *O. mossambicus*

FIGURE 8
Small Nile tilapia **cages in Lake Kanyaboli in Kenya (left) and large *chambo* cages in Lake Malawi (right)**

COURTESY OF M. MBUGUA

FIGURE 9
Trickle filter tower (left) and high density indoor rearing tank (right) at an African catfish farm in Nigeria

COURTESY OF MOHAMMAD R.HASAN

FIGURE 10
African catfish broodstock and recirculating hatchery in Nigeria

COURTESY OF K.J. RANA

FIGURE 11
***Clarias gariepinus* hatchery in Uganda**

COURTESY OF J. RUTAISIRE

FIGURE 12
Circular and D-ended *O. niloticus* tank farm in Kenya

O. shiranus in 32 cages in Lake Malawi. Initial stocking density ranges from 65 to 75 fingerlings (30g average weight) per m^3. Final biomass at harvest ranges from 21 to 40 kg/m^3 after growth cycles of 6 to 9 months.

Commercial aquaculture in earthen ponds is well developed in Nigeria and Zambia. In many of the target countries polyculture of *O. niloticus* and *C. gariepinus* is currently the most popular practice, though some farmers use other combinations. While polyculture is practised in all countries commercial farmers in several countries also produce *O. niloticus* (Zambia and Kenya) and *C. gariepinus* (Nigeria) under monoculture farming conditions. Production levels range from 2.5 to 15 tonnes/ha/year for *O. niloticus* (monoculture) and *O. niloticus*/*C. gariepinus* polyculture and up to 10–30 tonnes/ha/year for *C. gariepinus* monoculture in Nigeria. The size of production ponds ranges from 500 m^2 to 1.5 ha. Stocking densities in earthen ponds average around 5 to 8 fingerlings per square meter.

High density mono-culture of *C. gariepinus* in tanks (using water recirculation) is expanding rapidly in Nigeria, particularly in urban and peri-urban areas. Final densities as high as 100 kg/m^3 have been reported and initial stocking densities may be as high as 50 fingerlings/m^2. Some of the high density farms in Nigeria now produce in the region of 3 tonnes of catfish per week. In response to the demand by the Nile perch long line fishery in Lake Victoria, farmers in Uganda and Kenya have developed intensive hatchery and fingerling rearing technologies. In Kenya there are six and in Uganda there are eleven commercial catfish hatcheries. These hatcheries supply the Nile perch fishery with live fingerlings of around 10 g and also supply other farmers with catfish fingerlings for grow-out. The capacity of the Ugandan and Kenyan catfish hatchery operators ranges from 10 000 to 30 000 fingerlings per month. It is not known how many catfish hatcheries there are in Nigeria, nor is there an accurate figure for the number of high density catfish farms.

Concrete raceways are the preferred mode of rainbow trout production in Malawi and Kenya. Circular and D-ended concrete tanks are also used for the production of *O. niloticus* in Kenya (Figure 12) and Zambia.

Cameroon, Uganda, Kenya, Malawi and Zambia also boast an emerging ornamental fish farming sector, which produces fish for the local as well as the export market. Ornamentals are produced in concrete tanks and earthen ponds. The volumes and or numbers produced are not known.

5. REVIEW AND ANALYSIS OF FERTILIZER USE IN POND AQUACULTURE

Pond fertilization practices and the use of different commodities to enhance pond productivity in the region are very diverse and depend to a large extent on the scale of operation. Table 8 summarizes the types of fertilizers used by commercial and non-commercial farmers in the target countries. Compost cribs are not used by commercial farmers and chemical fertilizers are only used by commercial farmers and then only when these are available. Similarly, manure is only used intermittently by non-commercial farmers, when available.

The vast majority of small-scale, non-commercial farmers use "green compost cribs" to fertilize their ponds. In many instances this is supplemented by animal manure, though there is no evidence to suggest that farmers adhere to any fixed fertilization regimen. Depending on the resource base of the farmer some only fertilize their ponds at irregular intervals and do not provide supplementary feeds. This practice has been recorded in Kenya, Zambia, Malawi and Uganda and no doubt also occurs in the other target countries. The size of the compost crib varies substantially. In Cameroon the cribs comprise an average of 10 percent of pond surface area to less than 1 percent (personal observations in Malawi and Zambia). Kitchen wastes and other agricultural by-products are also often dumped into the cribs. The general recommendation throughout the region is that the contents of the crib should be turned once every one to two weeks (Figure13). It is however not known to what extent this is practiced.

Emerging commercial farmers in Cameroon, Ghana, Nigeria and Uganda often still use a combination of crib and animal manure fertilization. However, as soon as they can afford adequate quantities of animal manure they no longer use the crib technique.

The most commonly used manures are chicken, pig (depending on the religious persuasion of the region and of the market) and cattle manure, though the prevalence of use varies among countries. For example in Uganda most farmers (58 percent) use cattle manure, while chicken manure was least used. In Malawi, Nigeria, Ghana and Cameroon chicken manure is most commonly used. Other less often used manures include goat, sheep, duck and rabbit manure. Chicken manure appears to be readily available in all countries. In Cameroon, Ghana, Malawi and Uganda it is either available free of charge or at a minimum cost from industrial broiler farms. However, the cost of bagging and transport is often such that non-commercial farmers cannot afford

TABLE 8
Use of compost, manure and inorganic fertilizers by non-commercial (NC) and commercial (C) fish farmers in target countries

Country	Compost		Manure		Fertilizers	
	NC	C	NC	C	NC	C
Cameroon	Yes	No	Yes	Yes	No	NPK (20:10:10), though rarely used
Ghana	Yes	No	Yes	Yes	No	NPK though rarely used
Kenya	Yes	No	Yes	Yes	No	NPK, under semi-intensive conditions
Malawi	Yes	No	Yes	Yes	No	TSP, NPK, urea (used only occasionally and in combination with animal manure)
Nigeria	Yes	No	Yes	Yes	No	SP, TSP, NPK used only occasionally and in combination with manure.
Uganda	Yes	No	Yes	Yes	No	DAP, NPK, urea and phosphoric acid used mainly to start plankton blooms in catfish fingerling ponds.
Zambia	Yes	No	Yes	Yes	No	TSP, NPK

NPK = nitrogen, phosphorus and potassium; TSP = triple super phosphate; SSP = single super phosphate; DAP = di-ammonium phosphate.

Source: country reviews

the commodity. Moreover, in most countries there is considerable competition from vegetable farmers for chicken manure. Pig and cattle manure is apparently only used in instances where the animals are kept in a kraal (enclosure) during the night to facilitate collection. The practice of holding animals in pens above the ponds or in enclosures adjacent to the pond is also increasing. The average density at which chickens and pigs are kept for fish pond fertilization is 1 to 2 pigs (>25 kg) or 50 mature birds per 100 m^2. It is well known that semi-intensive duck cum fish farming has been promoted by development partners and is practiced in several countries in SSA. It was however not mentioned in any of the country reports. This may indicate that the practice is not popular, practical or profitable.

There is no doubt that adequate quantities of manure are produced in each country to satisfy the requirements of agriculture and aquaculture. For instance, total manure production in Cameroon and Kenya amounts to 30 000 and 18 788 tonnes per annum, respectively (Pouomogne, 2007 and Nyandat (2007). Similar calculations using livestock production figures from the various target countries would undoubtedly also show that manure is available in adequate quantities. However, the costs involved in collecting, bagging and transport prohibits its ready use by fish farmers. In summary, it can be concluded that on a national basis adequate quantities of manure are available in all countries. However, the low livestock holdings of small-holder farmers, or alternatively the high cost of acquisition limits its use in non-commercial aquaculture throughout the region.

The use of animal manure in small-holder aquaculture is further constrained by free range farming practices and the limited number of livestock kept by farmers. For example, in Malawi the average number of livestock per fish farming household is around 4 chickens and 1 goat. Using on-farm livestock population estimates it was calculated that small-holder farmers in Malawi have access to about 2.6 tonnes of wet manure or 1.62 tonne of dry manure per annum. This quantity is not sufficient for the production of the main food crop (maize), which requires about 12.5 tonnes/ha, hence very little if any is left for fish production. In Uganda it was estimated that more than 80 percent of fish farmers have access to fertilizers (all types) all year round but not in sufficient quantities. No doubt the same holds true for small-holder, non-commercial farmers in other target countries.

Manure is either spread directly over the water or is incorporated into the crib or is allowed to leach from grain bags that are tied to a stake in the centre or the side of the pond. All of the target countries have aquaculture extension services of one kind or another (Hecht, 2006), which for many years have been promoting basic aquaculture and pond management techniques to small-holder farmers. Hence, while farmers may understand the need for drying out their ponds after harvest and fertilization with animal manure prior to filling and stocking, very few farmers actually practice these basic techniques. The reasons for this are manifold but are also clearly related to on-farm labour requirements for other economic activities and the need to adhere to the agricultural calendar. Many small scale fish farmers in Malawi, Uganda, Kenya, Cameroon and Ghana consider fish as a "free extra" and many farmers rely solely on natural productivity to obtain a small but welcome intermittent harvest. In other words, aquaculture is of a lower priority than staple food production.

Recommended initial manure application rates in the target countries are similar and range from an initial start up fertilization regimen of 50–60 kg for chicken manure, 50–65 kg for pig manure and 70–150 kg/100m^2 for cattle manure, with follow up rates of 6, 7 and 8–9 kg for chicken, pig and cattle manure respectively per 100 m^2 every 10–14 days. However, in Cameroon (Pouomogne, 2007) and Ghana (Abban, 2005), and no doubt elsewhere actual application rates are far below (<30 percent) the recommended rates. In Malawi, Brummett (1994) calculated that only 27 percent of the nitrogen requirements of ponds are met by the average fertilization rates, which is reflected by the low yields.

FIGURE 13
Mixing of compost crib in Cameroon (left) and mechanical application of cattle manure in Zambia (right)

COURTESY OF V. POUOMOGNE

It is clear from the country reviews and Hecht (2006) that commercial fish farmers follow more rigid pond management regimens, with respect to drying, liming and adequate fertilization throughout the production cycle. Crude Secchi disks are now quite commonly used by emerging commercial farmers to gauge the need for fertilization in Cameroon, Ghana, Uganda and Malawi. The most commonly used manures by commercial farmers are chicken, cattle and pig manure (depending on availability and cost). Many of the larger commercial fish farms have integrated fish production with other forms of animal husbandry. For example, one of the larger fish farms in Zambia relies on manure from the farms cattle herd (Figure 13) and some larger chicken farmers in Uganda, Zambia and Nigeria have expanded their activities to include fish farming.

Inorganic fertilizer is used only by some commercial farmers and then mostly to "kick start" pond productivity, which is thereafter maintained by the application of animal manure. Several catfish fingerling producers in Uganda use only chemical fertilizer (phosphoric acid and urea) with which to enhance pond productivity. The price of inorganic and organic fertilizers in the target countries in 2004/5 is illustrated in Table 9.

The data show that the average farm gate price of animal manure is substantially lower than the average price of chemical fertilizers. However, while animal manure is significantly cheaper per tonne than inorganic fertilizer, the quantities required and the cost of transport makes it unaffordable to most small-holder farmers. In Malawi and Uganda (for which data were available) the cost of transport ranges from US$0.5 to 1.11 km/tonne. If a farmer is located 50 km form the nearest chicken farm effectively trebles the cost, unless purchased and transported in bulk (7 to 10 tonnes per trip). Using the price of chicken manure and the average price of chemical fertilizers in Uganda and Malawi and the theoretical quantities of manure required to 1 ha of fish ponds on a yearly basis in relation to super phosphate makes the former three times more expensive than the latter. The Malawi report revealed that 75 percent of small-holder farmers cannot afford to purchase adequate quantities of fertilizer for their annual maize crop. It stands to reason therefore that they would be even less able to

TABLE 9
Price of fertilizers and manure in target countries in 2004/5 (US$ per tonne)

Chemical fertilizers	Cameroon	Ghana	Kenya	Malawi	Nigeria	Uganda	Zambia
Triple super phosphate			470				
NPK		402		340	600		
Urea		468	440				
Di-ammonium phosphate			500				
CAN			400				
Average chemical fertilizer price	272–400	435	452.5	368.7	-	430–500	383
Manure							
Chicken manure	74	11*–22	54	26.9	29	16.6	22
Cattle manure	45		130	4	18		10
Pig manure	45		60				

* Poultry farm gate price

Source: Country reviews, Hasan (2005) and B. Thiga, Sagana Aquaculture Centre, Kenya, (pers. comm.)

afford the cost of adequate manure (if they have to purchase it) for the fertilization of fish ponds. In a survey conducted in 2004 it was found that only 9 percent of farmers applied adequate amounts of fertilizer to their ponds and over 63 percent did not apply any fertilizer at all. The picture with respect to manuring of crops was very similar, with only 9 percent of farmers applying adequate quantities, 56 percent under applying and 21 percent not applying any fertilizer at all (Singa, 2004). Similarly, in Uganda farmers are all aware of the value of animal manure and many purchase some quantities but cannot afford adequate amounts.

From this we may conclude that the cost of adequate quantities of manure to effectively boost fish production is too high for the average non-commercial fish farmer in the region. This conclusion is corroborated by the fact that the majority of small-holder, non-commercial fish farmers use green compost cribs as the primary method of fertilization. Unless there is a change in this dynamic it will not be possible for small-holder farmers to make meaningful contributions to national fish supply. However, the important contribution by fish ponds to household protein supply should not be underestimated in rural areas.

6. REVIEW AND ANALYSIS OF FEEDS AND FEEDING

Analysis of the country reports revealed that commercial aquafeeds in 2005 were only manufactured in Cameroon, Kenya, Malawi (non pelleted feed mix), Nigeria and Zambia, though initiatives are now also underway to produce fish pellets in Ghana and Uganda. Approximately 12 000 tonnes of commercial fish feed was manufactured in the five target countries, of which the bulk (88 percent) was produced in Nigeria. The types of feeds produced are shown in Table 10. Perhaps most importantly the summarized information in Table 9 illustrates the pivotal role of farm-made feeds[1]. Given the total volume of fish produced and the proportion produced by commercial farmers (see Table 4) it is fair to conclude that the aquaculture sector relies almost entirely on farm-made feeds. On the assumption that country production statistics are realistic crude calculations using a food conversion ratio of 1.8:1, suggests that the commercial aquafeed produced by the formal industry accounts for a maximum of 15.6 percent of total fish production in the target countries or 22 percent of fish produced by the commercial aquaculture sector.

A wide range of ingredients are available for feeding fish and or for the manufacture of fish feeds in the region. Table 11 lists some of the ingredients commonly used by feed manufacturers (formal and informal) and based on information provided in the

TABLE 10
Species and use of commercial and or farm-made feeds in sub-Saharan Africa

FEEDS	Cameroon	Ghana	Kenya	Malawi	Nigeria	Uganda*	Zambia
Trout							
Commercial			√				
Farm-made			√	√			
Tilapia							
Commercial	√		√		√		√
Farm-made	√	√	√	√	√	√	√
Catfish							
Commercial					√ and**	**	
Farm-made	√	√	√	√	√	√	√
Common carp							
Commercial							
Farm-made	√	√	√	√	√	√	√
Ornamental							
Commercial			√				
Farm-made	√		√	√		√	√

*Two firms are currently undertaking fish feed manufacturing trials; **Imports from Aquanutro (Pty) Ltd, South Africa and elsewhere

[1] Farm-made feeds collectively describes fish feeds made by farmers as well as by informal small-scale feed manufacturers.

TABLE 11
Availability of the most common ingredients for the manufacture of animal feeds in sub-Saharan Africa

Commodity	Cameroon	Ghana	Kenya	Malawi	Nigeria	Uganda	Zambia
PLANT ORIGIN							
Coffee pulp	++		++	+	+		++
Cacao husks	+++		-	-	++		-
Rice ban	+	++	++	++	+++	+++	++
Wheat bran	++	+	++	+	++	++	++
Maize bran	+++	++	++	+++	+++	+++	+++
Groundnut bran	?	++	?	?	?	?	?
Wheat pollard	?	?	++	?	?	?	?
Maize	++	+	+	++	++	++	++
Millet	+		+	+	+		+
Soybean	?	+	+	+	+	+	+
Wheat	+		+	+	++	+	+
Oil seed cakes							
Cotton	++	++	+		+++	++	+
Groundnut	+	++	++	+	++		+
Sunflower	?		++	++	+	++	++
Palm kernel	++		-	-	++		-
Soybean	+++		+	+	+	+	+
Copra	?	++	+	-	?		-
Sesame	?		+	-	+		-
Other seed cakes		++				++	
Brewery waste	++	++	++	++	++	++	++
Vegetable oils	+++	++	+	++	+++	++	+++
ANIMAL ORIGIN							
Fishmeal (local)	+	+	+		+	+	+
Fishmeal (imported)	+	++	+		++		++
Blood meal	+		+		+++	++	-
Hydrolyzed feather meal			?		++		-
Carcass & bone meal	+		++		+++		-
Crayfish meal	+		?		?		-
Shrimp waste	?		+		++		-
Chicken layer dropping meal	++						
Fish oil	+		?		+		-
Rendered poultry oil	?		?		+		-
Vitamin and mineral premix*	++	++	++	++	++	++	++

* = Imported; + = limited supply, ++ = readily available, +++ = abundant supply

Source: Bentley and Bentley (2005), Fagbenro and Adebayo (2005), Hasan (2005); Radull, (2005), C. Mudenda, Dept. Fisheries, Zambia (pers. comm.),

country reviews and Hasan (2005), provides a qualitative indication of availability. From the information provided in the country reviews it would appear that the animal feed industry in Kenya in particularly is severely constrained by shortages of suitable ingredients. Table 12 provides an insight into the availability and use of non-conventional ingredients as fish feeds by small-holder non-commercial fish farmers in the region. The proximate composition of the various ingredients (crude protein, lipid, fibre and ash) is provided in the country reviews.

The price of ingredients in the target countries is shown in Table 13. Prices vary significantly between countries and this affects the formulations used by feed manufacturers and farmers. For example, the price of fishmeal ranges from US$1 500 per tonne in Nigeria to US$370 per tonne in Kenya. Both Kenya and Uganda produce substantial quantities of fishmeal from the *Rastrineabola argentea* fishery in Lake Victoria, while the other target countries produce limited quantities of fishmeal (e.g. 9 000 tonnes in Nigeria in 2004). Uganda currently does not permit the import of fishmeal and until recently Nigeria also imposed restrictions on the importation of fishmeal. While some fishmeal is made by small-scale producers in several target

TABLE 12
Non-conventional commodities used by small-scale, non-commercial farmers

Commodity	Cameroon	Ghana	Kenya	Malawi	Nigeria	Uganda	Zambia
Napier & other grasses	Common	Common	Common	Common	Common	Common	Common
Cacao husks	Common	Common	No	No	?	No	No
Cassava leaves	Common	Common	Common	Common	Common	Common	Common
Cassava peels	Common	Common	?	Common	?	?	?
Other vegetable peels	Common	Common	Common	Common	Common	Common	Common
Vegetable leaves	Common	Common	Common	Common	Common	Common	Common
Banana & other fruit leaves	Common	Common	Common	Common	Common	Common	Common
Over ripe fruit	Common	Common	?	Common	?	Common	Common
Dead farm animals	Rarely	Rarely	?	No	?	?	?
Animal viscera	Rarely	?	?	No	Rarely	?	?
Termites	Common	Common	Common	Common	Common	Common	Common
Maggots	Rarely	Rarely	?	Rarely	Rarely	?	?
Rice bran	Common	Common	Common	Common	Common	Common	Common
Wheat bran	If available	?	If available	Rarely	?	If available	If available
Maize bran	Common	Common	Common	Common	Common	Common	Common
Kitchen waste	Common	Common	Common	Common	Common	Common	Common
Trash fish	Rarely	No	Rarely	No	Rarely	Rarely	No

? = No information.

Source: Country reviews

TABLE 13
A comparison of prices (US $ per tonne) of common feed ingredients used in the manufacture of animal and aquafeeds in sub-Saharan Africa

Commodity	Cameroon	Ghana	Kenya	Malawi	Nigeria	Uganda	Zambia
Year	2005	2005	2005	2006	2005/6	2005	2006
Fishmeal	1 132	453–1 031	360–990	750	870–1 500	470–670	750
Carcass meal	1 132		450				
Blood meal	1 320				320	420	
Bone meal						190	
Lake shrimp meal			200–400				
Crayfish meal	1 320						
Soya seedcake	679			483		500	694
Sunflower seedcake						160	
Cotton seedcake	301		260	192	305	140	442
Groundnut seedcake	471	544	300		330	170	
Palm kernel oilcake	75	125					
Dry layer droppings	94						
Rice bran	91		90	27			
Maize bran		68	90	30		80	70
Wheat bran	109	68	90				91
Brewery waste	28	2.3	30	150		11	**
Maize	264		191	210–230	345	280	205–240
Millet	283						
Soybean		544		350	460		
Vegetable oils				1 600	1 100		
Fish oil					3 800		
Chicken mash			240	305	800		568
Dairy mash			220				
Pig finisher mash			190		500		470
Mineral mix*/kg						2.8	
Vitamin & mineral premix /kg		8.5	7	6.6		20	

* Made in some countries and consists mainly of cattle horns, freshwater snail shells and oyster shells
** Brewery waste is normally obtained free of charge at the factory gate

Source: Country reviews

countries it is not known what quantities are produced. Given the high price of fishmeal it is fair to conclude that the use of alternative protein sources for fish feed in the region is a priority. The price of oilseed cakes, though readily available, is high and also varies significantly among countries. Soya oil seedcake is the most expensive throughout the region, while cotton oil seedcake is generally available at a lower price.

Moreover, the price of feed commodities also varies seasonally and this also determines the composition of feeds. Many of the smaller commercial farmers in Nigeria (and probably elsewhere) purchase the cheapest feed ingredients on the market irrespective of the nutritional value of the commodity. The majority of small-holder, non-commercial farmers rely largely on enhanced pond productivity (green compost cribs) and supplementary feeding using cereal bran, as and when available. For example, in Kenya over 99 percent of farmers are reliant on this practice.

Trash fish and factory offal is recognised as a possible fish feed in Nigeria, Ghana and Cameroon. However, very little if any, is used as most of it is sold as food for human consumption.

A comparison of prices of some common feed ingredients used in the manufacture of animal and aquafeeds is provided in Table 13.

7. THE ANIMAL FEED INDUSTRY

The animal feed industry in SSA consists of a formal and an informal sector. The formal sector is embedded within the industrial sectors of the countries, while the informal sector consists of small-scale feed manufacturers using less sophisticated machinery and farm-based feed mills that may produce anything from a few kilogram's to several tonnes of feed per day. On the whole the animal feed industry is focused primarily on the production of chicken feed and the formal or commercial feed industry in the group of target countries is best developed in Nigeria.

The total production of animal feeds in the target countries is shown in Table 14. Nigeria, after South Africa (which produced over 4.4 million tonnes in 2005), is the biggest producer of animal feeds in SSA (Shipton and Hecht, 2005). Nigeria produces around 3.8 million tonnes per annum. Kenya with 450 000 tonnes is the third largest producer of animal feeds. Production by the other countries in 2005 ranged from 80 000 to 148 000 tonnes. It should be noted that the data for all countries is not for 2005. The most recent available information for Nigeria for example was for 2000/1. In 2000/1 Fagbenro and Adebayo (2005) estimated that there were some 620 feed manufacturers in Nigeria of which 59 percent were small operators with a capacity of between 0.5 and 5 tonnes/hour. They also calculated that only 51 percent of the production capacity of the formal feed mills was being used. Currently there are 32 industrial scale feed manufacturers in Nigeria (see Table 14 for more details).

TABLE 14
Commercial animal feed* production (tonnes) in target countries

	Cameroon	Ghana	Kenya	Malawi	Nigeria **	Uganda	Zambia
Year	**2004**		**2004/5**	**2005**	**2001**	**2005**	**2001**
Poultry	52 910	>28 000	256 440		2 591 732	68 000	
Pig	15 120		32 630		1 084 214		
Aquafeed	<100		104	620	10 760	√	450
Ornamental fish	√		√			√	√
Unspecified	7 524						
Other			177 081				
Total production	75 594		466 255	>65 000	3 799 925	80 000	>120 000
Production capacity	150 000		?		7 000 000	?	
Number of feed mills: formal and (informal)	8		17 (63)	12 (2)	32 (500+)	27	2 (?)

* Produced by the formal animal feed industry

** Of the 54 large feed mills operating in 2001, only 32 industrial scale feed mills were functional in late 2005. Since early 2006 bird flu has had a serious impact on animal feed production (O. Fagbenro, pers. comm., 2005). The other 500+ feed producers are small-scale private operators and medium scale cooperatives. Over 78 percent of Nigeria's animal feed is made by the informal sector and 81.4 percent of aquafeeds is made by the informal sector. On a total combined basis aquafeed production by the formal and informal sectors only account for about 30 percent of the total estimated annual use. The rest is farm-made

Source: Shipton and Hecht (2005), country reviews and C. Mudenda, Dept. of Fisheries, Zambia (pers. comm.)

8. AQUAFEEDS

Formulated aquafeeds are produced commercially only in Nigeria, Cameroon, Kenya, Zambia, Malawi and Uganda. However, the country reviews reveal that the bulk of the aquafeeds are made on farm or by informal small-scale feed manufacturers (Table 15). In Nigeria it has been estimated that approximately 70 percent of fish feeds are farm-made (Fagbenro and Adebayo 2005). Similarly, while some aquafeeds are made by the formal sector in Cameroon, Ghana, Uganda and Malawi, most of the feeds used are compounded and manufactured on farms and made by small-scale producers. Formal and informal feed manufacturers in all countries have the capacity to make pellets of some sort, although extruded floating pellets are only manufactured in South Africa and Nigeria.

Formulated feeds for *O. niloticus* and/or *C. gariepinus* are manufactured in Cameroon, Nigeria, Kenya and Uganda, and Zambia produces a formulated pellet for *O. niloticus*. No specific feeds for *C. carpio* are compounded. Given the general decline in the popularity and production of common carp throughout the region this is not surprising. Cameroon, Uganda and Kenya also produce small quantities of flake feeds for ornamental fish, which is used by hobbyists. Ornamental fish farmers all use farm-made feeds. Despite better FCR's commercial formulated pellets in most instances are uneconomical to most small-holder fish farmers because of the high unit cost, transport costs and the small-scale nature of their enterprises, hence are used only by medium and large scale operations.

The formulations in most countries vary according to seasonal availability and price of ingredients. The cost of tilapia feeds (20–25 percent crude protein) range from US$225 to 599 per tonne (Table 16).

Both Nigeria and Uganda import feeds for rearing of juvenile clariid catfish from South Africa, the Netherlands and the United States of America. However, it was not possible to obtain sufficiently accurate estimates of imported volumes.

The country reports and the data above suggest that the status of the formal animal feed industry in the target countries ranges from "just established" to "well established". In Nigeria it is comparatively well established, though unregulated, while in Uganda it is in a nascent phase. Fish feeds have only been made since around 1999–2000 in the target countries and the formal aquafeeds industry is currently still in a formative phase and only reasonably well developed in Nigeria and to some extent in Zambia. Except for Nigeria and South Africa, fish feeds in other countries are manufactured by the formal animal feed industry on request. The reports however revealed that the informal aquafeed

TABLE 15
Production of aquafeeds (tonnes) used by the commercial aquaculture sector in target countries

	Year	Formal	Informal and farm-made feeds*
Cameroon	2004	<100 (estimated demand for 2005 = >300 tonnes)	
Ghana	2005	Small pilot scale quantity produced by one company (2 tonnes /month)	547
Kenya	2004		558
Tilapia		59	
Trout		45	
Malawi	2005	620	156
Nigeria	2000/1		
Tilapia		6 554	14 258
Catfish		4 206 (plus 4 000 tonnes of imported feed)	10 552
Uganda	2005	<50 (plus and unknown quantity of catfish starter feed)	3 870
Zambia	2005	450	5 400
South Africa	2004/5	3 864	?

* Except for Nigeria, informal and farm-made feed production in the other countries are calculated estimates, based on commercial production estimates and using a FCR of 1.3 for compounded pellets and 1.8 for farm-made feeds.

Source: Shipton and Hecht (2005), country reviews and www.afma.co.za for South Africa

TABLE 16
Retail price of fish pellets in target countries in US$ per tonne

COUNTRY	Year	Trout	Nile tilapia	African catfish
Cameroon	2006		381–424	943 (starter diet for catfish and tilapia)
Ghana			520	
Kenya	2005	542	225	
Malawi		NA	NA	NA
Nigeria	2005			1 100* to 3 500 for imported catfish starter feed
Uganda	2006		250	300 (35% crude protein, CP) to 6 100 for imported catfish starter feed
Zambia	2006		599	
South Africa**	2006	Pre-starter crumble 48% CP = 2 016 Pre-starter 2mm 48% CP = 1 532 Starter 45% CP = 1 035 Grower 38% CP = 877 Finisher 38% CP = 1 012	Starter 41% CP = 879 Grower 32% CP = 771 Semi-intensive 25% CP = 645	Pre-starter 52% CP = 2016 Starter 41% CP = 879 Grower 35% CP = 715

* = local grow out sinking pellet, ** = Aquanutro (Pty) Ltd. pricelist Feb 2006, NA=Not Applicable

Source: country reviews

sector, consisting of small-scale feed manufacturers as well as on-farm facilities, provides the bulk (60 percent and above) of the requirements of commercial farms. This situation is simply a reflection of economies of scale. The demand for formulated aquafeeds in the target countries (except Nigeria) is relatively small and hence it is not economically viable for the formal sector to invest in dedicated aquafeed lines. The presently available information for Cameroon, Nigeria and Zambia suggests that only between 50 and 65 percent of the formal industry's total capacity is being utilized, which means that the industry could and probably would be able to provide for the needs of the industry if and when the demand reaches critical mass. For example, within the South African economic realm a feed mill would only invest in a dedicated feed line and associated costs (quality control, personnel etc) if the demand for a specific feed exceeds 5 000 tonnes per annum (L. de Wet, Aquanutro (Pty) Ltd, 2006, pers. comm.).

It is clear from the country reports that the formal aquafeed industry, in general, is still in a developing phase. In Nigeria the aquafeed industry only emerged in 1999/2000 as a consequence of the upsurge of African catfish production and the resulting demand for feed. In all countries were aquafeeds are produced there are problems with consistency of supply and quality. The percentage of fines may be as high as 50 percent (personal observation). In the absence of information on capacity within the industry it is probably correct to assume, given the low demand for aquafeeds, that manufacturers do not pay much attention to aquafeed quality control. It is perhaps for this reason that farmers in Nigeria, and elsewhere, still prefer to deal with small-scale feed producers, with whom they have established a feedback system with respect to fish performance and food conversion ratios. For example, in Nigeria 69.75 percent of the 35 570 tonnes of fish feed produced in 2001 was "farm-made" feed. Catfish farmers in Nigeria and Uganda now also import a starter diet for African catfish from South Africa, the Netherlands and the United States of America. Nigeria imported just over 4 000 tonnes of catfish feed in 2004. It would appear that rapid steps, inclusive of foreign investment, are being taken in Nigeria to supply the 27 000 tonne demand for catfish feeds.

9. FARM-MADE FEED FORMULATIONS AND MANUFACTURING TECHNOLOGY

The emergence of informal small-scale fish feed manufacturers in most target countries is extremely encouraging and suggests that commercial aquaculture in the region is expanding. Several farm-made feed formulations as used in the region are shown in

Table 17. It was not possible to obtain specific feed formulations from the formal sector. Three basic feeds are manufactured, namely a starter diet for African catfish and tilapia with a protein content of between 40 and 45 percent, grower formulations for tilapia (also used for carp and other species) with a protein content ranging from 20 to 28 percent and a grower formulation for African catfish with 32–40 percent CP. Several of the formulations are based on research undertaken at local universities or research institutes or have been formulated by farmers based on the nutritional requirements of the dominant species.

TABLE 17

Some typical formulations (percent), proximate composition and price of feeds made by small-scale feed producers and/or manufactured on-farm

Diet	1	2	3	4	5	6	7	8	9	10	11	12	13
Ingredient composition													
Fishmeal		20	55		50	25	15	16		30	2	11	30
Blood meal						10					48	13.5	5
Carcass meal													15
Bone meal	1		4										
Lake shrimp meal									34				
Soya meal						35	45						15
Soya oilcake	13	15	5									3	
Cotton oilcake	15	15	5		9						2	4	
Groundnut oilcake	12	5	4					17					
Sunflower oilcake				30									
Copra cake								17					
Brewery waste	10	15	10										
Rice or wheat bran	20	15	2						66			8	
Wheat bran					25			50					22
Maize bran				50						70	48	7	10.5
Cocoa husk / Coffee pulp	10												
Layer dropping meal	15												
Maize		8	3			15	25					49	
Maize germ					15								
Pigeon pea meal				20									
Cassava flour												4	
Palm oil	2	2	5										
Vegetable oil						4	6						
Fish oil						6	4						
Starch/binder						2	2						
Vitamin & mineral premix	2	5	5		1	3	3					0.5	2.5
Proximate analysis													
Crude protein (%)	28.5	34.5	43.3	20		40	38	25					37
Crude lipid (%)	8	9	11				9	5					9.4
Energy (kJ/g)	?	19.2	20.4										
Cost per tonne (US$)	381		943	148			547	227	153	176	270	425	600
Retail price (US$/ tonnes)												519	

1 = Grower formulation (CP 31%) for *O. niloticus* farming in fertilised ponds (Cameroon).
2 = Grower formulation for intensive *O. niloticus* farming (Cameroon).
3 = Starter formulation (CP 45%) for *C. gariepinus* and *O. niloticus* (Cameroon).
4 = Grower formulation for *C.carpio* and *O. mossambicus* in fertilised ponds (Malawi).
5 = Grower pellet for *C. gariepinus* (Kenya).
6 = Grower pellet for *C. gariepinus* (Nigeria).
7 = Grower pellet for *O. niloticus* (Nigeria).
8 = Tilapia grower pellets (Kenya).
9 = Grower pellet for *C. gariepinus* (Kenya).
10 = Farm-made grower formulation 1 (Uganda).
11 = Farmer made *C. gariepinus* grower formulation (Uganda)
12 = Industrial pellet formulation for *O. niloticus* and *C. gariepinus* polyculture (Cameroon)
13 = Catfish, carp and tilapia fingerling and broodstock formulation (Malawi)

Source: country reviews

Several different kinds of farm-made feeds are produced, ranging from formulated mixes fed to the fish in punctured bags (adapted from India) as practised in Malawi, to moist feed cakes and dry pellets. Preparation and manufacturing technologies are simple. The raw materials are milled and mixed at predetermined ratios. Ingredients are mixed by hand or mechanical devices such as cement mixers. Some of the ingredients such as soybean meal and maize meal are precooked (to eliminate anti-nutritional factors where these exist, to improve digestibility and to improve binding capacity). Warm or hot water is added to the final mixture to make a firm dough. Pellets are hand made by extruding the dough through a meat-mincer or pasta maker (hand or electrically operated). The "spaghetti's" are then sun dried or dried in locally manufactured driers and cut or crumbled into appropriate sizes. In some instances farmers order their preferred formulation in milled form and extrude their own pellets on-farm. Figures 14 to 17 illustrate some of the on-farm feed manufacturing technologies and products.

There are several common problems in the production of farm-made feeds. Many small-scale manufacturers throughout the region do not use an anti-oxidant, except in Nigeria were producers add Sodium propionate at an inclusion level of 0.1 percent as an anti-mould agent. Storage time is therefore reduced and the incidence of spoilage is high. However, the main problem associated with pellets produced by small-scale producers, is the high percentage of fines resulting in a high degree of wastage and poor FCRs. Catfish farmers in Nigeria report FCRs between 2 and 3:1 and above in comparison to 0.95 using imported floating pellets. However, the cost of the

FIGURE 14
Cooking feed ingredients in Malawi (left) and locally made feed in mixer in Kenya (right)

COURTESY OF M. UOMIZO AND M. MBUGUA

FIGURE 15
On farm pelleting in Nigeria (left) and pellet plunger and handful of dried pellets (right)

COURTESY OF O.A. AYINLA

FIGURE 16
Sun drying fish pellets (left) and (right) wind tunnel feed dryer

COURTESY OF V. POUOMOGNE AND R. BRUMMETT

FIGURE 17
Home made aquarium fish flakes in Cameroon (left) and (right) farm-made pellets in Nigeria

COURTESY OF T. MBONGO AND OF O.A. AYINLA

TABLE 18
Maximum recommended inclusion rates of unconventional feed ingredients

Ingredient	Maximum inclusion rate (%)	Replacement	Species
Groundnut cake	25		
Palm kernel cake	10–15		
Cottonseed cake	20–30		
Jackbean	10–30	Soybean meal	*C. gariepinus*
Winged bean	50	Fishmeal	*C. gariepinus*
Poultry offal	10		
Sorghum	50		
Cassava	40		
Sweet potato	20		
Fish silage	40	Fishmeal	*C. gariepinus*
Shrimp head meal	10	Fishmeal	*C. gariepinus*
Macadamia presscake	50	Protein source	*O. niloticus*
Poultry by-product silage	15–30	Protein source	*C. gariepinus*
Duckweed	15	Any carbohydrate source	*Tilapia*
Corn oil	10		
Soybean	10		
Palm oil	10		
Periwinkle shell	7.5		
Limestone	5		
Malt dust	2		
Coffee bean pulp	20		
Cacao husk	20		

Source: see Ayinla (2007) and Pouomogne (2007) for detail and data sources

imported floating pellets for grow-out is uneconomical and farmers now only use the imported starter pellets for a short period before switching to farm-made feeds.

Moreover, small-scale feed producers and commercial fish farms most often do not have adequately sized and pest proof storage facility. This prohibits bulk purchase of raw material when prices are low.

The price of farm-made feeds is generally lower than the products from the formal sector (e.g. US$154 to 750 per tonne for farm-made feeds vs. US$227 to 1 110 per tonne for industrially made pellets (excluding imported pellets) (see Tables 16 and 17). Depending on feeding practices FCRs of 1.1:1 have been reported for some farm-made feeds in Uganda and Kenya. Moreover, as mentioned above, farmers who make their own feeds are normally also in a position to purchase raw materials directly from producers, so that the middleman is cut out, which results in significant savings. The reported average FCR for farm-made feeds is around 2:1 (range 0.95 to 3.8:1), although upper level estimates by the author are in the region of 8:1.

There has been an intense research focus on the use of alternative ingredients and agricultural by-products to replace fishmeal in fish feeds, optimal inclusion rates and feed formulation, particularly in Nigeria, and to some extent in Cameroon and Malawi (see country reports). Moreover, there is an excellent body of knowledge with respect to the proximate composition of most non-conventional ingredients that may be used in fish feeds (see country reports). Table 18 summarizes the recommended maximum inclusion rates for some of these ingredients. For many years this research was considered to have little impact on the development of commercial aquaculture in the region. However, with a growing need for fish and a rapidly developing commercial aquaculture sector this has changed and many non-conventional ingredients, depending on price, are now used by small and medium scale informal feed producers.

10. FEEDING PRACTICES

Feeding practices are as diverse as the feeds used in the region. The most commonly used feed by non-commercial farmers is maize or rice bran, which is spread over the water surface. This practise is wasteful as any breeze will blow the feed into the

grassy verges of the ponds, where it is unavailable. Some farmers have realised this and use floating rings made of grass that are attached to a stake. The bran is placed into the rings to contain it and to ensure that feeding is optimised. Some farmers also place grass ropes over the water surface area in a square pattern and depending on wind direction will place the feed (bran or vegetable leaves) into a pre-selected square (Figure 18). Vegetable matter (where reported in the country reviews) is generally not chopped prior to feeding.

FIGURE 18
Floating grass pond divisions for improved feeding with leaves or bran

Though farmers are aware of the importance of feeding their fish (Hecht, 2006), it would appear that non-commercial farmers feed their fish less than once a day and with an inadequate ration and many rely entirely on natural pond productivity. To a great extent this is a consequence of the financial circumstances of the farmer.

In all instances fish on commercial farms are fed regularly at fixed rations and schedules that are adjusted according to average fish weight. Feeding frequencies range from 2 times per day in earthen ponds to 6 times per day for juvenile African catfish under high density tank culture conditions, to 1 or 2 times daily during grow-out. Feeding is done mainly by hand, except for some experimental trials using automatic feeders or demand feeders in high density catfish culture in tanks (Nigeria) and tilapia cage culture (Ghana and Malawi).

Most farmers feed dry pellets or a formulated mash to juvenile tilapia. However, several farmers use formulated wet dough, in some instances bound with sugar cane molasses. The dough is offered to the juvenile fish in baseball size portions on submerged feeding trays. According to one of these farmers this method allows for better visual inspection and observation of feeding intensity and fish health and reduces feed wastage (S. Pala, Aquafarms, Malawi, pers. comm.). The feed balls are made every second day.

11. PROBLEMS AND CONSTRAINTS

Some of the problems and constraints facing feed manufacturers in general and the farmers in particular have already been mentioned briefly in the preceding sections. The following bullets summarize the general constraints as expressed in the country reviews:

- variable ingredient quality and proximate composition;
- general shortage of fishmeal and within country variability in supply;
- inter-annual variability in supply of raw materials;
- competition for raw materials for human nutrition (e.g. *Rastrineobola argentea* fishmeal in Uganda and Kenya) and the chicken feed industry (e.g. maize, brans, fishmeal, oilseed cake);
- farmers in rural areas have poor access to feeds and fertilizers (cost of transport increases price beyond their means);
- small scale feed manufacturers are limited by their ability to store raw materials (pest control and warehouse space);
- poor and careless packaging of manufactured feeds;
- seasonal fluctuations in commodity prices (related to agricultural calendar);
- high level of fines in dry pellets;
- poor feed conversion ratios of some farm-made feeds (>4:1);
- high rate of spoilage of raw materials and feeds (mould, insects and rodent faeces);

- high transport costs (US$0.35 to US$1.00 per km for small loads less than 1 tonne) (e.g. transport adds minimum of 25–30 percent to cost of all imported goods in landlocked countries);
- high duty on imported feeds and raw materials;
- lengthy customs clearance of raw material;
- lack of affordable industrially manufactured feeds;
- poor quality of industrially manufactured feeds and lack of quality control;
- lack of adequate feed manufacturing equipment (symptom of low demand and investor hesitancy);
- limited and inadequate funding for research;
- operating within poor governance structures; and
- lack of expertise in feed manufacturing technologies.

While several of the constraints are uncontrollable factors (e.g. inter annual variability in supply and price of raw materials) many of them are typical of poor quality control in an unregulated industry, where the end user is to a large extent at the mercy of the supplier. The upswing in the number of small-scale feed producers in Nigeria and Cameroon is therefore not entirely surprising since it allows for better quality control and feedback. In most countries, except perhaps in Nigeria, the commercial aquaculture sector will for the foreseeable future be dependent on small-scale feed producers and farm-made feeds. The situation will only change if and when there is a critical mass of demand for high quality industrially manufactured feeds such that industry would risk the initially high investment costs. The situation however provides competitive advantages to small-scale operators to gear up and grow with the aquaculture sector. Given the growth of the aquaculture sector in many SSA countries governments must be sensitised as to the potential of aquaculture and the need for incentives to stimulate the aquafeed industry and of the need for quality control measures. Moreover, the high cost of imported feeds may in fact be inhibiting the growth and development of the catfish farming sector.

Many of the constraints listed above are issues related to economies of scale. For example, small-scale feed producers will only invest in improved and larger storage facility if and when the demand for feed exceeds a certain threshold. Governments in all countries should and must play a more facilitating role, such as reducing or abolishing import duty on raw materials and improving the efficiency of customs and excise for speedy release of perishable goods. Policy on these issues is being revised in Cameroon, Nigeria, Malawi, Kenya and Uganda.

There is no doubt that there is lack of capacity in feed technology throughout the region. Many, if not most, donor funded projects in the past have focused on fish nutrition in some or other way. However, to our knowledge there has not been one project that has focused specifically on feed technology. There is a serious need to address this shortcoming by the provision of training opportunities and most importantly by the inclusion of feed technologists in donor funded aquaculture development programmes. In essence, aquaculture in SSA has now developed to stage where it is no longer appropriate for donor countries to send general aquaculture practitioners to partner countries. The time has arrived for deploying specialists to foster the growth of the sector.

12. LABOUR COST

Labour requirements are dictated by the size of the farm, intensity of production and the level of management employed. The average daily wage in the target countries is US$1.10 per day (Range US$0.75 to US$2.70). From the data presented in Table 19 it can be concluded that the cost of labour in all countries is low in comparison to the rest of the world. It was unfortunately not possible to calculate a realistic figure for labour cost as a proportion of total production cost per tonne of fish produced.

However, as mentioned elsewhere the cost of labour, despite the low daily wage structure, is prohibitive to most small-holder farmers and restricts their on-farm activities.

TABLE 19
Labour requirements

Farm size/number of ponds (Max. pond surface area)	Scale of intensity	Labour units required
1–4 ponds (0.1ha)	Extensive	1
1–2 ponds (0.2ha)	Semi-intensive	2
3–10 ponds (1ha)	Semi-intensive	4–8
Tank or raceway (25 tonnes/year)	Intensive	8
Tank or raceway (50 tonnes/year)	Intensive	12

Source: Country reviews and interviews with farmers

13. COMMENTS ON RESOURCE AVAILABILITY AND EXPANSION OF THE AQUACULTURE INDUSTRY

In a reassessment of Kapetsky's (1994) strategic assessment of warm water fish farming in Africa, Aguilar Manjarrez and Nath (1998) showed that 50–76 percent of Africa's land, despite several constraints, has the highest pond culture yield range potential for Nile tilapia, African catfish and common carp. Because of environmental tolerances the spatial distribution of carp culture potential was found to be greater than for Nile tilapia and African catfish. However, carp culture throughout the region is declining, probably as a consequence of consumer preference and higher returns with the other two species. All countries, except Malawi, Uganda and Zambia were shown to have adequate resources for the expansion of pond based aquaculture. The potential in Zambia is theoretically constrained by the high proportion of land incorporated as protected areas (>30 percent of surface area), while the potential for pond aquaculture in Malawi and Uganda is constrained by lacustrine environments and in the case of Malawi the high population density in the most suitable areas. The potential of cage culture was however not explored by Aguilar Manjarrez and Nath (1998). Given the success of Nile tilapia cage culture in Lake Kariba highlights the opportunities presented by the African Great Lakes in Uganda, Kenya, Zambia and Malawi, as well as in other lakes and large man-made impoundments. Aguilar Manjarrez and Nath (op cit.) also considered urban areas as a constraint for aquaculture development. However, the notion that urban areas constrain aquaculture development has recently been challenged by Costa-Pierce *et al.* (2005) and indeed urban and peri-urban aquaculture is perhaps the most rapidly expanding sector in Cameroon, Ghana, Nigeria and Uganda (Rana *et al.,* 2005). Moreover, Aguilar Manjarrez and Nath (1998) suggest that all the countries considered in this review (see country reviews for details) have the required environmental conditions, livestock waste and agricultural by-products for the expansion of the sector. Aguilar Manjarrez and Nath's (1998) general conclusions are discussed below in relation to current observations and the projected expansion of the sector.

It is clear from the country reviews that there are sufficient gross quantities of animal manure in each of the target countries to satisfy the needs of aquaculture. However, as mentioned previously, an increase in production by small-scale farmers will continue to be constrained in most instances by the small number of farm animals and the cost of transporting manure from source to farm. The problem of manure availability facing small-holder fish farmers cannot and should not be considered on a country basis. The problem can only be addressed at the district level, where the requirements can be realistically quantified by the responsible lead agency or by NGOs and for them to then devise the most appropriate and cost effective manner of delivering manure to communities in conjunction with farmers.

The commercial sector in all target countries appears to be split, in various proportions, between stand alone fish farms and those in which aquaculture is integrated with other animal husbandry or agricultural activities, e.g. cattle, chicken, pig or grain farming. Under such conditions the availability of manure is obviously not a problem. However, commercial stand-alone pond fish farms of whatever scale that have to source manure from chicken producers or cattle farms may face competition

from other users of manure. However, the current average price of chicken and cattle manure is low particularly in Malawi, Nigeria, Uganda and Zambia, suggesting that access to the resource should not be problematic in the short to medium term.

Inorganic fertilizers are rarely used to enhance pond productivity in the target countries. This may be related to the high price and the general scarcity of fertilizers in all countries.

During the last five years (see Table 3) aquaculture production has increased significantly in most target countries and as mentioned previously approximately 70 percent is produced by the commercial sector. Because the vast majority of "non-commercial" fish farmers use farm by-products and / or rely on natural pond productivity for fish production, the projected future requirements for fish feeds has been calculated for the commercial sector only. The projections are illustrated in Table 20 and are discussed on a per country basis below. The estimation procedures did not consider the impacts of future commodity prices (particularly fishmeal and oil seed cakes) as well as factors that could have a negatively impact on production cost (e.g. international oil prices, inflation and cost of electricity) on the demand for feeds.

According to FAO statistics the aquaculture sector in Cameroon over the last five years has grown by over 112 percent per annum. Clearly, the sector is making rapid advances and examples set by some commercial farmers are being copied in increasing numbers by others, particularly in peri-urban areas. The manufacture of aquafeeds is a recent initiative in Cameroon and only 80–90 tonnes were produced in 2005. The current animal feed production capacity is around 150 000 tonnes and only 50 percent of this capacity is presently utilized. At the moment most commercial farmers use farm-made feeds. Agricultural products and by-products used for the manufacture of animal feeds, except fishmeal, are readily available and the formal feed industry has the capacity to provide feeds under any one of the three growth scenarios.

In Ghana the sector has not shown the same high growth rate as in Cameroon. Commercial aquaculture has only emerged during the last five years but is already contributing between 30 and 35 percent of total production. Only small quantities of fish feeds are made on a pilot scale level. (ca. 2 tonnes per month). The country has a seemingly well established animal feed industry (though no quantitative data were provided). Fishmeal is mainly imported. The report by Abban (2005) suggests that Ghana has adequate oilseed cake resources to supply and future demand by aquaculture. As in other countries most commercial farmers at this stage use farm-made feeds and their feed production capacity exceeds their requirements.

In 2005, Kenya produced just over 100 tonnes of compounded fish feed for trout and tilapia. The country's feed industry is, within the group of countries examined, the second largest after Nigeria, producing over 450 000 tonnes. The animal feed industry in Kenya is relatively new, having been developed during the past 10 years. As elsewhere, most commercial farmers use farm-made feeds or feeds produced by small-scale feed producers. Kenya has adequate agricultural by-product resources though the competition for locally produced fishmeal is intense, as it is also used for human consumption and other animal feeds. Fishmeal supply, currently standing at around 30 000 tonnes per annum, is considered to be the major constraint facing the animal feed industry as a whole. Even if aquaculture grows from its current base at 15 percent per annum until 2020 the industry would require just under 2 percent of the current animal feed production capacity. The Association of Kenya Feed Manufacturers was formed in 2003 and functions as the industry's voice to government.

After many false starts, commercial aquaculture in Malawi emerged in 2003. The largest cage culture operation in the SSA region is currently being developed in Lake Malawi, using indigenous tilapia, *O. karongae* and *O.shiranus* The company will probably reach its production target of 3 000 tonnes in 3–5 years. At a conservative FCR of 1.5:1 this single operation (excluding the requirements for broodstock

maintenance and fingerling production) will require some 4 500 tonnes of feed per annum. If this venture is successful then others will most certainly follow, which will increase the demand for pelleted feeds substantially. The farm has installed a feed mill and pelletizer but will probably not be able to, or want to, manufacture its own feeds at full production. The Malawian scenario is different from that in other countries in that the establishment of a single operation within a short time will create a demand for a substantial quantity of formulated pellets. Though there are about 12 animal feed producers the animal feed industry in Malawi is small, though fairly well established. As elsewhere it is heavily reliant on imports (maize, oilseed cake and all fishmeal) and as in the other target countries produces mainly poultry feed. In 2005 the industry produced approximately 600 tonnes of formulated milled product for fish pellets. Amongst other variables, the success of the cage culture operation in Malawi therefore also hinges on co-operation with the formal feed industry. There is no animal feed association in Malawi and all companies operate independently of each other, however the Malawi Bureau of Standards regulates feed quality in the country. A call has recently been made to improve the regulatory environment of the animal feed industry in Malawi.

Nigeria has shown the most dramatic increase in fish production, from 30 677 tonnes in 2003 to 43 950 tonnes in 2004, mainly as a result of significant increases in African catfish and Nile tilapia production. Nigeria has the largest animal feed industry in SSA after South Africa, producing around 4 million tonnes per annum. Currently there are 32 functional commercial scale animal feed mills (O. Fagbenro, pers. comm. 2006). Over 35 000 tonnes of aquafeed was produced in 2003, of which approximately 60–80 percent was farm-made or produced by small-scale feed producers. Oilseed cake and other primary agricultural products and by-products for animal feeds in Nigeria are in short supply and the country is reliant on imports of oilseed cake, soybean and fishmeal. An adequate supply of fishmeal is recognised as the major current and future constraint, unless the country's unexploited lanternfish resources are utilized. Only 13 percent of its annual fishmeal consumption was produced locally in 2004, while the bulk of the 2004 demand (67 500 tonnes) was imported. All feed additives in Nigeria (as well as in other countries) are imported. However, Nigeria has the capacity and expertise to produce the required quantity of feed under any of the projected growth scenarios. Several foreign companies are currently investing in aquafeed mills. Nigeria and Uganda are currently the only countries that import fish feeds, mainly from South Africa and specifically for early juvenile rearing of African catfish under intensive farming conditions. There is no animal feed manufacturing association in Nigeria and the industry is unregulated and not controlled by any organ of state with respect to quality and bio-safety. Given that the animal feed industry is only operating at 56 percent efficiency (Fagbenro and Adebayo 2005) it is well placed to provide the needs of the aquaculture sector in future, though its participation in meeting the aquafeed requirements, as in other countries, depends entirely on the quality of the product it can produce.

Aquaculture in Uganda is growing at a rapid rate. The animal feed industry in Uganda was started around 1994 and currently produces around 80 000 tonnes. The country is well endowed with natural resources and except for soybean produces adequate quantities of produce and by-products that are readily available to the feed industry. It has a reduction fishery of some 50 000 tonnes and fishmeal is also made from the offal of the Nile perch fishery in Lake Victoria. However, because no fishmeal is imported the competition for this commodity is intense and has serious negative social implications in that the fish previously used for human consumption is now used mainly for fishmeal. Aquafeed production is sporadic and is only produced on request and the quality is poor. Most commercial farmers make their own feeds or purchase it from informal feed producers. Uganda has developed a policy for animal feeds as well as a draft bill to safeguard consumers and to ensure feed quality.

Total fish production in Zambia is around 5 000 tonnes of which around 75 percent is produced by the commercial sector. The animal feed industry is well established and produces over 120 000 tonnes per annum. In 2005 some 450 tonnes of fish feed was produced and until 2004 an unknown quantity of fish feed was imported from Zimbabwe. Most of the commercial farmers produce their own feeds. Agricultural by-products and other feed ingredients are readily available in Zambia though fishmeal is scarce and is imported, mainly from Namibia. The formal feed sector has the capacity to increase fish feed production

A common denominator throughout the region is that many, if not most, commercial farmers rely more on farm-made feeds and feeds produced by the informal sector than on the formal animal feed sector. This scenario will probably continue until such time as the demand in the various countries reaches a critical mass. All countries have established animal feed industries, which are capable of accommodating the demand of the commercial aquaculture sector. However, at this stage the common complaint is poor feed quality, particularly with respect to the high percent of fines, water stability and poor FCRs. Unless there is a certain minimum demand it is highly unlikely that the formal feed industry, with its focus on poultry feeds, would gear up in any of the countries to manufacture high quality, competitively priced fish feeds. Hence the small-scale aquafeed producers have a competitive advantage. The synergistic growth of the commercial aquaculture and small-scale feed producing sectors should therefore be strongly encouraged and supported. The projected demand for aquafeed under three different growth scenarios of 5, 10 and 15 percent per annum (Table 20) is substantial and certainly provides opportunity for some of the current cadre of small-scale feed producers to carve a profitable niche for themselves. Overall, commodities for inclusion into fish feeds in the target countries are readily available, though seasonal price fluctuations can be significant. This has a serious impact on small-scale producers who generally do not have adequate storage facility to purchase product when prices are low (usually immediately after harvest). Fishmeal throughout the region is a constraint, with respect to quality and quantity and most countries are largely dependent on imports.

14. RECOMMENDATIONS

Recommendations for improved utilization of fertilizer and feed resources including suggested policy guidelines emanating from the country reports can be grouped into four major categories, viz. (i) Technological; (ii) Research and Development; (iii) Outreach; (iv) Policy and legal.

i) Technology

The country reviews reveal that there is a serious lack of capacity and knowledge with respect to feed technology. It is therefore necessary to;

- train private and public sector nutritionists and fish feed technologists (formulation, pelleting, on-farm feed formulation and manufacture, small-scale feed manufacturing);
- design, adapt and develop appropriate low-cost machinery for milling, mixing and feed manufacture;
- adapt and improve low cost feed drying technologies; and
- design, develop and test appropriate bulk storage facilities to prevent spoilage as a mitigating measure against seasonal price fluctuations.

ii) Research and development

It is necessary to:

- evaluate alternate feed ingredients and determine optimum inclusion rates;
- quantify the demand for animal manure in aquaculture at district level and devise low-cost distribution plans;

TABLE 20
Projections of aquaculture production and aquafeed requirements in target countries for 2010 and 2015*

Periods	Cameroon			Ghana			Kenya			Malawi			Nigeria			Uganda			Zambia		
2003/04/05	2005			2004			2004			2005			2004			2003			2003		
Aquaculture production (tonnes)		820			950			1035			800			43 950			5500			4490	
Contribution of commercial aquaculture (%)		8			30			41			12			80			40			75	
Aquafeed production (tonnes)		90			<50			104			720			>35 570			<50			>750	
Growth rate (% per annum)	5	10	15	5	10	15	5	10	15	5	10	15	5	10	15	5	10	15	5	10	15
2010																					
Projected aquaculture production (tonnes)	1 046	1 320	1 649	1 212	1 529	1 687	1 320	1 666	2 081	1 021	1 288	1 609	56 092	70 781	88 399	6 752	8 857	11 062	5 730	7 231	9 030
Projected contribution of commercial aquaculture (%)	15	15	15	35	35	35	45	45	45	55	55	55	80	80	80	40	40	40	75	75	75
Projected commercial aquaculture (tonnes)	156	198	247	424	535	590	594	749	936	561	708	884	44 873	56 624	70 719	2 700	3 542	4 424	4 297	5 423	6 772
Aquafeed demand (tonnes)	234	297	371	636	802	885	891	1 124	1 404	842	1 062	1 327	67 310	84 937	106 078	4 051	5 314	6 637	6 446	8 134	10 158
2015																					
Projected aquaculture production (tonnes)	1 335	2 126	3 317	1 547	2 464	3 395	1 685	2 684	4 187	1 303	2 074	3 236	71 589	113 994	177 802	8 617	14 265	22 250	7 313	11 645	18 164
Projected contribution of commercial aquaculture (%)	30	30	30	45	45	45	55	55	55	65	65	65	80	80	80	55	55	55	75	75	75
Projected commercial aquaculture (tonnes)	400	637	995	696	1 108	1 527	926	1 476	2 302	846	1 348	2 103	57 271	91 195	142 241	4 739	7 845	12 237	5 484	87 337	13 623
Aquafeed demand (tonnes)	600	955	1 492	1 044	1 663	2 291	1 390	2 214	3 454	1 270	2 022	3 155	85 906	136 793	213 361	7 109	11 768	18 356	8 227	13 100	20 434
2020																					
Projected aquaculture production (tonnes)	1 704	3 428	6 672	1 974	3 968	6 828	2 151	4 323	8 421	1 663	3 341	6 509	91 368	183 590	357 623	10 998	22 974	44 753	9 334	18 755	36 535
Projected contribution of commercial aquaculture (%)	60	60	60	60	60	60	70	70	70	70	70	70	80	80	80	70	70	70	75	75	75
Projected commercial aquaculture (tonnes)	1 022	2 056	4 003	1 184	2 380	4 096	1 505	3 026	5 894	1 164	2 338	4 556	73 094	146 872	286 098	7 698	16 081	31 274	7 000	14 066	27 401
Aquafeed demand (tonnes)	1 533	3 084	6 004	1 776	3 571	6 145	2 258	4 539	8 842	1 746	3 508	6 834	109 641	220 308	429 147	11 547	24 122	46 990	10500	21 099	41 101

*Data and assumptions: Baseline fish production data obtained from country reviews, except for Uganda and Zambia for which the FAO Fishstat estimates for 2003 were used. Estimates of current commercial production as a percent of total production obtained from Hecht (2006). Increase in commercial aquaculture contributions estimated from percent increases in total production over last 5 years. Estimates of aquafeed requirements calculated on basis of commercial production at an FCR of 1.5, which is below the current average FCR of 2.0 obtained by commercial fish farmers in the region. The projections are based on three growth scenario's of 5, 10 and 15 % per annum.

Source: Shipton and Hecht (2005), FAO (2006) and author's calculations

- develop appropriate agro-ecological fertilization regimens;
- undertake surveys and develop databases of available feed resources at district or provincial basis;
- develop and test country specific "farm-made" feed formulations;
- develop and test appropriate feeding table; and
- develop and test appropriate feeding methods to reduce waste and improve FCR.

iii) Outreach

For maximum impact the outreach listed below should focus specifically on districts or regions with high aquaculture potential; mainly to:

- train farmers, NGOs and extension staff in food storage methods;
- disseminate information on availability of ingredients suitable for fish feeds;
- disseminate information on "farm-made" feed formulations to fish farmer associations, farmers, NGOs and extension staff;
- disseminate information on manufacturing technology for "farm-made" feeds to fish farmer associations, farmers, NGOs and extension staff;
- disseminate information on feeding schedules and improved feeding practices to fish farmer associations, farmers, NGOs and extension staff; and
- provide support services to small-scale feed producers to fine tune their production processes and technologies to achieve optimum results.

iv) Policy and legal

It would appear from the country reviews that the animal feed industry in most countries is inadequately regulated. Hence the relevant legislation, where this exists, should be reviewed and amended to support the development of the industry. Cameroon and Kenya are in the process of reviewing their legislation with respect to the feed industry. The most pertinent recommendations are listed below:

- governments and financial institutions must be sensitized with respect to business opportunities offered by the aquaculture sector;
- governments in all countries should provide incentives for the development of the animal feed industry (including aquafeeds);
- the feed industry must be encouraged and assisted in lobbying governments to change the legislation on import duty of raw materials and feeds (e.g. Ugandan farmers have to pay holding tax at 6 percent, value added tax at 18 percent and import duty at 10 percent for catfish feed from South Africa). and
- governments must be made aware of the need to regulate the formal and informal animal feed industry, particularly in terms of quality assurance and certification.

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