Climate-smart Aquaculture for Smallholder Fish Farmers: Integrated Fish and Small Livestock Farming

Mary Lundeba
Netsayi Noris Mudege
Victor Siamudaala

WorldFish
CGIAR | AICCRA
Accelerating Impacts of CGIAR Climate Research for Africa

Acknowledgement

Accelerating Impacts of CGIAR Climate Research for Africa (AICCRA) is a project that helps deliver a climate-smart African future driven by science and innovation in agriculture. It is led by the Alliance of Bioversity International and CIAT and supported by a grant from the International Development Association (IDA) of the World Bank. Explore our work at aiccra.cgiar.org. The work on climate-smart aquaculture is led by the WorldFish and aligns with the aims of CGIAR's Initiative on Aquatic Food, also led by WorldFish. We also acknowledge participants from various stakeholder organizations, including smallholder farmers, small and medium enterprises, the Ministry of Fisheries and Livestock, Ministry of Agriculture and the Department of Fisheries in Zambia, who all participated in a workshop to validate the manual.

Authors

Lundeba M, Mudege N.N, & Siamudaala, V. 2023. Climate-smart Aquaculture for smallholder fish farmers: Integrated fish and small livestock farming. Penang. WorldFish.

Photo credits

Cover page, Henry Kanyembo and Mercy Sichone/ WorldFish (left) and Enock Chanda Chipwepwe/ National Agriculture Information Services (right); Plates 1, 17, 20, Mary Lundeba/WorldFish; Plate 2, Mercy Sichone/WorldFish; Plates 3, 4, Mercy Sichone and Henry Kanyembo/WorldFish; Plate 5-7, Nicholas Mukupa and Derrick Nasando/ Kalahari Media and Office Solutions; Plates 8, 18, 19, Enock Chanda Chipwepwe/National Agriculture Information Services; Plates 9-16, Nicholas Mukupa and Derrick Nasando /Kalahari Media and Office Solutions.

Contents

1. Introduction to climate-smart aquaculture

Climate change and climate shocks are putting the most vulnerable people at risk, as extreme weather events are becoming more and more intense in many regions of the world. Extreme heat, drought, floods and unpredictable farming seasons are harming farmers and their production systems, threatening their livelihoods. In marginalized and vulnerable populations, aquaculture is a key means for sustaining livelihoods because of its contribution to food security and nutrition, but many fish farmers in Zambia endure unfavourable climates for sustainable fish farming.

In Zambia's Northern and Luapula provinces, for example, aquaculture and fisheries are affected by extreme weather events, such as floods, rising temperatures and unpredictable rainfall patterns (Ministry of National Development 2017). These climatic hazards adversely impact food and water security, water quality, and people's livelihoods, especially in rural communities that depend more on aquatic food systems. It is well known that the poorest people are vulnerable to extreme climate events, and Northern and Luapula are among the poorest provinces in Zambia, with 80.5% of people in the two provinces classified as poor and 64.5% as extremely poor as of 2010 (CSO 2010). Southern Zambia, in particular, is designated a climate hot spot. Over the past 30 years, it has experienced the lowest rainfall in the country, and it will continue to experience increased drought and flooding throughout the region, which will affect the aquaculture and the fisheries sector (Kalantary 2010).

With the frequency and intensity of climate events expected to rise in the future, the negative impact on people's livelihoods, food security, nutrition and household income generation are likely to deteriorate if no remediation interventions are proactively implemented. Therefore, it is important to collaborate with farmers to develop and disseminate relevant climate-smart adaptation and mitigation strategies. Such strategies will help farmers increase their resilience and adaptive capacity to climate variability.

1.1 Barriers to climate change resilience among smallholder fish farmers

Several factors hamper efforts to promote resilience to climate change among farmers and fishers:

- Lack of access to quality resilient seed
- Lack of access to quality and locally available nutritious feeds
- Poor management of water resources among farmers
- Lack of knowledge of better management practices (BMPs) in aquaculture that promote resilience to climate change
- Lack of access to meteorological data for farmers to use to make informed decision-making and for planning
- Non-use of climate-smart aquaculture (CSA) practices that promote high productivity and resilience
- Limited access to extension services to promote the skills and knowledge of farmers
- Lack of resources and information needed to adapt to the effects of climate change.

In Zambia, increased awareness and use of climate-smart approaches in aquaculture can enhance food security and ensure sustainable and better livelihoods for smallholder fish farmers. In light of climate change, then, this technical manual aims to help smallholder farmers and other actors get better access to resilience-enhancing knowledge and technologies in aquatic food systems (AFS).

The manual is a guide to aid facilitators in training smallholder farmers on the basics of climate change and CSA under the Accelerating the Impact of CGIAR Climate Research for Africa (AICCRA) project. Although there are many approaches to CSA, this manual focuses on integrated aquaculture-agriculture systems (IAAS). The manual is intended as a companion to the "Better management practices manual for smallholders farming tilapia in pond-based systems in Zambia," because BMPs are key to climate resilience and adaptation.

Interventions around seed, feed and climate-smart information are required to help smallholders increase their productivity and become more resilient to climate change and, ultimately, to improve food and nutritional security and income.

1.2 Alignment with national priorities

Under its intended nationally determined contribution (INDC), Zambia seeks to guarantee food security by diversifying and promoting climate-smart agricultural practices for crop, livestock and fisheries production, including the conservation of germplasm for landraces and their wild relatives. A key activity listed refers to promoting sustainable aquaculture practices through improved water management and feeding regimes and the use of appropriate stocks. Integrated aquaculture-agriculture (IAA) promotes efficient water management and improved feed regimes and increases farmer resilience to climate change, thus contributing significantly to Zambia's INDC.

However, IAA needs assessment for climate change adaptation for Zambia advocated for technologies that promote the sustainable use of land, water and fisheries (Zambia Intended Nationally Determined Contribution (INDC, 2015p:xiii). Under these technologies, proposed adaptation options for agriculture and food security include production systems that integrate small livestock, fish, poultry and vegetables (Zambia Intended Nationally Determined Contribution (INDC, p:xiv). The proposed IAAS technology contributes to the Zambia Climate Change Gender Action Plan (IUCN 2017), as well as to the management of wetlands that women and other poor people depend on for survival.

1.3 Expected results

Beneficiaries should know the following:
- The basics of climate change
- The adaptation and mitigation strategies in the face of climate change risks
- How they can build and maintain resilience of their farming systems
- What is involved in CSA and how they can apply CSA approaches
- How to access information on resilience-enhancing knowledge and technologies in AFS in light of climate change.

2.1 Weather and climate

Climate is often mistaken for weather. However, the two are very different.

Weather can change from day to day or year to year. It describes the current conditions in a specific area or place. For example, if it is currently windy or raining outside, this would describe the prevailing weather. As such, we could say the weather is rainy or windy today.

Climate describes the weather conditions that are expected in a region at a particular time of year, as determined by observing the region's weather over many years. The climate of an area includes seasonal temperature and rainfall averages, as well as wind patterns. Different places have different climates.

The following are examples of climates:
- Desert is an arid climate because it experiences little rain or snow during the year.
- Temperate climates have warm summers and cooler winters.
- Tropical climates are hot and humid.

2.1.1 What is the climate like in Zambia?

Zambia's climate is described as either tropical or subtropical, depending on the altitude of the place. Mid-November to March is Zambia's rainy season, during which it is hot and humid, and April to November is the country's dry season. From mid-May to mid-August, Zambia experiences cold temperatures, and between September to mid-November it is hot and dry.

2.2 What is climate change?

Climate change refers to shifts in average temperatures and weather patterns in a region that occur over a long period. Global climate change refers to the average long-term changes over the entire Earth. These include warming temperatures and changes in precipitation (rainfall or snow) and can be either natural or human-induced. The Earth's climate has constantly been changing, long before humans came into the picture. However, scientists have observed unusual changes recently. For example, the Earth's average temperature has increased much more quickly than expected over the past 150 years. According to the Royal Society, the Earth's average surface air temperature has increased about 1°C since 1900.

Climate change can cause weather patterns to be less predictable. For instance, some areas can experience tropical cyclones that they never have before, leading to higher rainfall, flooding, damaging winds and loss of life. Other areas can become increasingly prone to drought and flooding.

When temperatures and rainfall patterns become unpredictable, it becomes challenging to plan and practice aquaculture and other forms of farming. This uncertainty calls for climate information services (CIS) to facilitate climate-smart innovations to address food security challenges as a result of climate change.

2.2.1 Climate change in Zambia

In Zambia, the alternating occurrences of drought and floods throughout the country will have several effects. They will increase the risks of drowning, climate-sensitive diseases, and outbreaks of infectious plant, zoonotic and human diseases. They will also destroy more agricultural crops, roads, housing, and power and water supply infrastructure, and disrupt the accessibility and delivery of health services and relief assistance, which will then result in food shortages and an increase in malnutrition or starvation. Climate change will likely also displace more of Zambia's population, leading to anxiety, depression and overcrowding.

2.2.2 What causes climate change?

2.2.2.1 Human activities

These are human activities that emit large amounts of greenhouse gases (GHGs) and also those that reduce the amounts of carbon sinks. Many activities contribute to climate change. Here, we highlight only a few. Using fossil fuels (coal, oil and gas) for energy supplies, emits large amounts of greenhouse gases (GHGs) into the atmosphere, such as carbon dioxide and methane. These GHGs deplete the activities that reduce the amount of carbon absorbed from the atmosphere, resulting in a "greenhouse effect" (warming).

Deforestation and land degradation also reduce the amount of carbon sinks. For fisheries and aquaculture, the main pathways of the sector's contribution to GHGs are power inputs, transportation and feed production. However, the sector's contribution is relatively small.

2.2.2.2 Natural processes

These are natural variations that alter the composition of the global atmosphere over a long period. Here, we consider three such variations: in solar output, orbital changes and volcanic eruptions. The main source of heat for the Earth is the Sun. As such, fluctuations in solar output in terms of quantity and quality can impact the climate. If a high amount of radiation is emitted, the Earth's temperatures will rise.

The Earth has natural warming and cooling periods caused by variations in the tilt and/or orbit of the Earth around the Sun. When the distance between the Earth and the Sun varies over a long period, there will be frequent variations in the total amount of solar energy reaching the planet, causing climate change.

Volcanoes have a mixed effect on the climate. Eruptions produce aerosol particles that cool the Earth, but they also release carbon dioxide, which warms it. Although volcanic eruptions cause short-term climate changes and contribute to natural climate variability, they are not the leading cause of global warming. Cooling is the dominant effect of volcanic eruptions, not warming.

2.3 Responding to climate change

2.3.1 Climate change adaptation

This refers to "altering our behavior, systems, and—in some cases—ways of life to protect our families, our economies, and the environment in which we live from the impacts of climate change" (WWF, nd). Although reducing GHG emissions can reduce the impacts of climate change in the future and help us adapt better, some climate changes that have already happened cannot be reversed, so it is necessary to adapt to them now. Adaptation entails changes in "processes, practices, and structures to moderate potential damages or to benefit from opportunities associated with climate change" (UNFCCC, nd). Adaptation promotes actions and solutions to address current and future climate change impacts. Cultivating improved fish breeds that are resilient to climate change is one example.

2.3.2 Climate change mitigation

This refers to "making the impacts of climate change less severe by preventing or reducing the emission of greenhouse gases (GHG) into the atmosphere" (EEA, nd). The more we reduce emissions right now, the easier it will be to adapt to the changes we can no longer avoid. If we reduce GHG emissions, we prevent or reduce the rate at which the Earth is warming and avoid extreme temperatures that could be detrimental to life on Earth. "Mitigation is achieved either by reducing the sources of these gases—e.g. by increasing the share of renewable energies, or establishing a cleaner mobility system—or by enhancing the storage of these gases—e.g. by increasing the size of forests. In short, mitigation is a human intervention that reduces the sources of GHG emissions and/or enhances the sinks" (EEA, nd).

As an example, planting trees and stopping deforestation are considered mitigation measures, because they allow trees to capture GHGs instead of them being released into the atmosphere. Mitigation activities for aquaculture, meanwhile, can include environmentally friendly technologies and practices as well as the use of BMPs for aquaculture, including genetic improvement programs and also better water management, which would improve water use efficiency and minimize water pollution.

2.3.3 Climate resilience

This refers to "the ability to prepare for, recover from, and adapt to the impacts of climate change" (C2ES 2019). To effectively plan for resilience, you need to understand the contexts and risks to develop effective resilience plans. A system that is not resilient is unable to recover from climate shocks. When individuals, households, communities and systems cannot address climate-related shocks and stresses, their development trajectory could cause them to sink deeper into poverty, as illustrated in Figure 1.

Figure 1. *A system that is not resilient to shocks.*

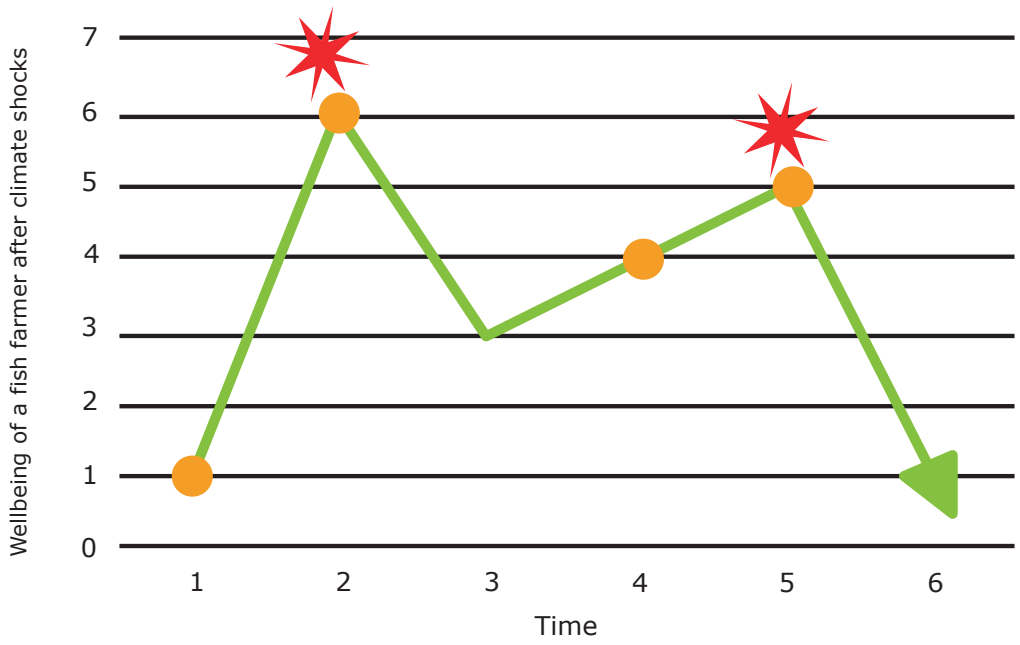
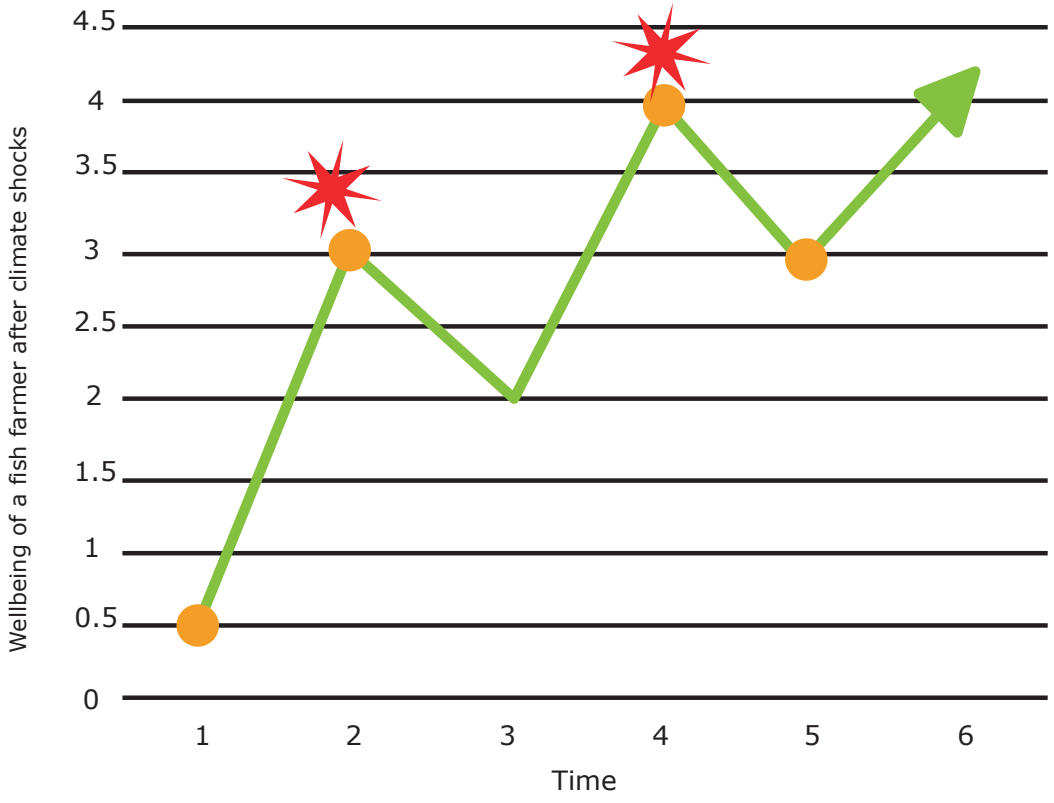


Figure 2 illustrates what climate resilience could look like. Communities and households are able to bounce back or maintain and even increase their progress even when facing shocks and stresses.

Figure 2. *A system that is resilient to shocks.*



2.3.5 Impacts of climate change on aquaculture

The aquaculture value chain is vulnerable to the impacts of climate change, the effects and implications of which can be both negative and positive. For aquaculture, warmer temperatures within species tolerance would promote tilapia production and other warmer water species, while flooding of low areas could increase the land available for pond water aquaculture. Prolonged warmer periods could also promote longer growing seasons for some fish species, such as tilapia, as well as increase the demand for cultured fish as a result of the collapse of capture fisheries.

However, the negative effects of climate change far outweigh the positive ones for aquaculture. The higher costs of inputs would severely impact small-scale fish farmers because they have no support system, such as insurance products.

The following are direct impacts of climate change on aquaculture:

- Higher temperatures, beyond tolerance levels, could increase mortality for some fish species.
- Changes in temperature increase bacterial, parasitic, viral and fungal diseases (Maulu et al. 2021), so fish could become more susceptible to these diseases as temperatures rise. Higher temperatures could also lead to the emergence of epizootic diseases.
- Changes in temperature could increase algae blooms, which can be toxic to fish, resulting in poor growth and underperformance.
- Limited fish seeds from the wild could threaten fishmeal and fish oil supplies and hamper fish breeding programs. "Generally, the projected impact of climate change on agriculture and capture fisheries is expected to lower the availability and increase the cost of the inputs, such as fish seed and feed ingredients required for aquaculture production" (Maulu et al. 2021:8).
- Heavy rainfall and flooding is a production risk in low lying areas. This can damage ponds and lead to fish escaping from ponds, and unwanted fish species invading ponds. A flooding event on a fish farm can easily introduce an invasive fish species into the wild.
- Changes in rainfall patterns affect water availability, ranging from droughts and shortages to floods, thereby reducing water quality for aquaculture. Increased run-off could bring in nutrients from agricultural fertilizers and cause algal blooms. This would lead to reduced levels of dissolved oxygen, which can be lethal to fish (Plate 1). Rising temperatures also reduce the level of dissolved oxygen, with similar results.
- Indirect effects of climate change can occur because of alterations to primary and secondary productivity, which could affect the prices of input supplies. For example, if the price of fishmeal increases, this would translate into higher feed costs.
- Increased occurrence of strong winds that force fish out of ponds would result in losses for aquaculture farmers.

The negative impacts of climate change are already being felt in form of more frequent extreme weather events. Plate 1 shows the negative effects of a shift in the 2021–2022 rainfall pattern in Mporokoso District, Northern Province, related to climate change, which resulted in lower fish production for smallholder farmers. Excessive rains promoted excessive inflow of nutrients into ponds, leading to greater algae bloom, which is harmful to fish.

Plate 1. Development of excessive algae bloom in Mporokoso District because of greater inflow of nutrients.

Changes in rainfall patterns also affect fish production in Northern and Luapula provinces, as farmers often abandon their ponds when they dry out during prolonged dry spells.

Plate 2. A drying pond in Samfya District (left) and a completely dried out and abandoned pond in Mpulungu District (right), both as a result of the late onset of rains.

Plate 3. Broken pond walls and fingerling holding tanks in Luwingu District because of excess water from the rains.

Damaged pond walls and tanks resulting in fish escaping

The vulnerability of aquaculture-based communities is primarily a function of their exposure to extreme weather events and the impact of climate change on the natural resources required to undertake aquaculture, such as good water, land, seed and feed.

2.3.6 Vulnerability

All smallholder farmers are vulnerable to the negative impacts of climate change. In Zambia, women depend on wetlands, which are also used for fish farming (IUCN 2017). When wetlands are mismanaged or become dry because of climate-related weather variability, this affects the women who depend on them. When water quality is affected, households become prone to waterborne diseases and suffer losses of income. Using water efficiently, such as adopting CSA technologies, will benefit women who depend on these wetlands. Such climate change mitigation and adaptation measures need to be mainstreamed to promote well-being. This includes better health through increased production of nutritious food (including fish) and higher incomes while at the same time reducing environmental risks.

Increases in feed prices also affect smallholder farmers, who often cannot afford feed. Climate-smart approaches are those that reduce reliance on fishmeal and fish-oil inputs. According to the Food and Agriculture Organization, "Aquaculture systems, which are less or non-reliant on fishmeal and fish oil inputs (e.g. bivalves and macroalgae), have better scope for expansion than production systems dependent on capture fisheries commodities (such as fishmeal)" (2009:4).

Smallholder fish farmers face several challenges in this regard, including inadequate access to quality seed (fingerlings), resilient fish species, feed, and unpredictable weather patterns (Kakwasha and Mudege et al. 2020). As a result, these farmers often have low fish production levels. Overall, they make up 26% of total national fish supply/production, which puts pressure on capture fisheries. Interventions around seed, feed and climate-smart information are needed to help smallholders increase their productivity, become more resilient to climate change and, ultimately, increase their food and nutrition security and income.

3. Climate-smart aquaculture (CSA)

CSA promotes efficient use of water as well as adaptation to climate change. It is an integrated approach that combines adaptation and mitigation in a way that enhances sustainable aquaculture production and food security in the face of climate change. CSA addresses the challenges of building synergies between the related objectives of climate change mitigation, adaptation and productivity, as well as increases in income. Climate-smart fisheries and aquaculture require improved efficiency when using natural resources to produce fish and aquatic foods. This maintains the resilience of aquatic systems and the communities that depend on them to allow the sector to continue contributing to sustainable development. CSA also requires gaining an understanding of the ways to effectively reduce the vulnerability of those most likely to be negatively impacted by climate change (Ahmed and Solomon 2017).

CSA encompasses various aquaculture practices and technologies. These includes integrating aquaculture and agriculture as a sustainable practice to adapt to climate change effects, enabling more efficient use of resources and improving farm productivity. The use of BMPs for aquaculture on farms is also an integral part of CSA.

3.1 Climate-smart adaptation and mitigation strategies

Climate-smart adaptation and mitigation strategies can help increase the resilience and adaptive capacity of smallholder farming communities as well as the ecosystems. CSA approaches and technologies include, but are not limited to, the following:

- Using IAA as an adaptive measure
- Digging boreholes or wells to supply water during dry weather
- Using tank ponds to reduce water infiltration during dry weather
- Using pond liners to help retain water
- Reusing waste water to use water more efficiently as a scarce resource
- Adopting water harvesting technologies
- Adjusting stocking time in line with CIS delivery
- Building well-designed drainage systems and pond dikes or walls to guard against floods
- Using fish species that can better adapt to climate change impacts, such as catfish, which can tolerate low levels of water and dissolved oxygen
- Implementing BMPs for aquaculture in farming systems
- Using gas or electricity rather than charcoal during fish smoking
- Treating waste water from aquaculture.

In addition to technical adaptation strategies, other strategies call for institutional and policy changes to ensure that smallholder farmers are fully supported and are able to manage climate related shocks and recover. Such strategies include creating insurance products for smallholder fish farmers, ensuring the availability and accessibility of climate-smart information for decision-making, and investing in human capital and resources to support farmers with relevant extension services.

4. Integrated aquaculture-agriculture systems as a climate-smart aquaculture technology

This manual focuses on IAAS or fish farming as a CSA technology in the face of climate change related-risks. IAA is not a new strategy or technology. It was first developed in China over 2000 years ago and has long been used in parts of Southeast Asia. IAA is common in both extensive and semi-intensive culture systems.

The manual focuses on integrating aquaculture with small livestock, such as chicken and goats. Most smallholder farmers are engaged in small-scale aquaculture, but the shortage and high cost of commercial feeds for their fishponds often hinders their operations. Most smallholder farmers traditionally raise chickens, but more and more of them are now raising goats because of the high demand for goat meat within Zambia and in neighboring countries, especially in the Democratic Republic of Congo. Smallholder farmers should, therefore, integrate aquaculture with livestock and crop production to establish a sustainable and resilient farming system that is aimed at maximizing profitability and minimizing operational costs.

4.1 What is integrated aquaculture-agriculture?

IAA is a system of producing fish and other aquatic organisms in combination with other agricultural activities, such as farming crops and rearing livestock, to promote synergistic effects. It is a circular approach that reduces waste and increases production and productivity.

Farmers can use manure from livestock to fertilize fishponds to propagate plankton, which is natural food for fish. They can also use farm residues as supplemental feed for livestock, and some species of fish, such as redbreast tilapia (Coptodon rendalli), can feed on crop by-products. Farmers can use pond sediments as fertilizer for crops or orchards and use nutrient-rich pond water to irrigate them. In addition, they can also use pond mud as fertilizer for crops on land.

Examples common types of aquaculture integration include poultry with fish (such as chickens or ducks), pigs with fish and rice with fish.

4.2 Why practice integrated aquaculture-agriculture?

There are many reasons to practice IAA:

- IAA is a sustainable and resilient strategy to increase food security and cash flow.
- It is a key livelihood strategy for smallholder farmers to diversify their income, spread the risk, stabilize production and increase resource efficiency.
- It increases production efficiency and investment profitability because of its capacity to generate synergies between farm enterprises.
- It conserves the environment since because it uses small amounts of land to produce a variety of aquatic and terrestrial products.
- Multiple uses of water and land make the overall system more stable and resilient than using water and land for one single purpose.
- It spreads out both biological and economic risks since several subsystems are involved, as opposed to one in a single commodity farming system.
- It uses an ecosystem-based management approach because of interconnected interactions within an ecosystem. One example is rice-fish integration, where nutrient-rich water from fish waste fertilizes rice plants in the same aquatic system.
- Adopting IAA as a strategy not only increases output productivity and efficiency in a sustainable manner, but it also plays a role in reducing the aquaculture sector's vulnerability and in increasing its resilience to climate change.
- It allows double cropping, leading to diversification and improved incomes and rural livelihoods.

4.3 Why integrate aquaculture and small livestock?

Small livestock play an important role in food and nutrition security and in the live livelihoods of many smallholder farmers, for the following reasons:

- Small livestock can help families diversify and be resilient in the event that one farm enterprise is adversely impacted by weather variability.
- Poultry droppings are good organic manure for pond fertilization.
- Small livestock increases the consumption of meat, milk and eggs, which are a source of protein, vitamins and minerals.
- Integrating chickens with aquaculture results in sustainable land management, food and nutrition security, resilience and poverty reduction.
- Household livelihoods improve, because small livestock give birth more frequently than large livestock and grow faster and reach maturity age earlier.
- Small livestock require less maintenance than large livestock and need less land, water and feed.
- They can use forage, foliage and crop residues.
- They tend to be more tolerant and resistant to diseases and drought conditions.
- They are easier to handle and transport.
- They can use a small area unsuitable for farming crops.
- Farmer can use their manure in home gardens and fishponds.

4.4 What are the links for integrated agriculture-aquaculture?

IAA links with plant crop and livestock farming systems in several ways.

4.4.1 Semi-integration

This is where farming activities are all integrated on the same farm but are set independently. For example, both crops and livestock (poultry, goats, pigs) houses are placed away from fishponds, but benefit from each other in several ways (Plate 4):

- Manure is collected from the livestock houses and used as fertilizer in fishponds to propagate natural food for fish and also on crop land to fertilize crops.
- Crop-by products are fed to livestock and herbivorous fish species. Banana stalks can also be used to feed pigs.
- After harvesting fish, the pond bottom, which is rich in nutrients, can be used as fertilizer in gardens and orchards and on other crop land.
- Depending on the layout of the farm, a furrow could water gardens with nutrient-rich pond water.

Plate 4. On-farm integration at Mr. Manfred Bwalya's farm in Samfya District.

In Plate 5, a farmer in Samfya District only brings his ducks to the ponds when he feeds them to allow their droppings to fertilize the water directly.

Plate 5. On-farm integration using poultry droppings.

4.4.2 Complete integration

Complete integration, also known as vertical integration, is a system in which farmers build livestock houses on pond dikes or over the ponds to so that the droppings fall directly into the water.

4.4.2.1 Chicken and fish integration

Chickens can be integrated with fish to reduce the cost of fertilizer and fish feeds to maximize benefits. Chickens can be raised either over or adjacent to the ponds.

Raising chickens over a pond has the following advantages:
- It maximizes the use of space.
- It saves labor in transporting manure from the poultry house to the ponds because it drops directly into the pond.
- It makes the poultry house more hygienic (for aesthetic purposes).
- There is no need to feed the fish because the feed that the chickens spill also falls directly into the pond for the fish to eat.
- No fertilizer is needed because the chicken manure fertilizes the pond.

When a plankton bloom occurs, pond water turns deep green and dissolved oxygen levels drop, resulting in fish deaths. When this happens, farmers must put mats or plastic sheets under the poultry house, or inside it, to catch the chicken droppings and leftover feed. They can then use this excess manure for other farming systems.

To facilitate and maximize the collection of chicken manure, farmers raising local chickens should house their chickens instead of raising them free range.

Plates 6 and 7 show the preparation of a poultry house over a fishpond for direct integration of fish and chickens.

Plate 6. Preparation of a poultry house over a fishpond. **Plate 7.** Direct integration of fish and chickens.

Pigs can also be integrated with fish farming. Plate 8 shows direct integration of pigs and fish. The system uses pipes to wash pig droppings directly into the fishpond.

Plate 8. Direct integration of fish and pigs at Hopeways in Mansa District.

4.4.3 Indirect integration

Indirect integration uses off-farm by-products as inputs into aquaculture systems.

4.4.3.1 Goat-fish integration

In the northern region of Zambia, most smallholder farmers raise goats instead of cattle and pigs. With goat manure readily available in the region, there is great potential for goat-fish integration, as goat manure is an excellent fertilizer for fishponds. Using goat manure directly in fishponds is considered a good practice that increases the efficiency of both goat and fish production.

5. Using integrated agriculture-aquaculture to help farmers mitigate and adapt to the effects of climate change

Diversifying food systems and integrated agriculture production systems can be important climate change adaptation measures (Mbow et al.2019). IAA can reduce some emissions. Traditional IAA systems are semi-intensive, with limited feed and nutrient inputs and minimal use of electricity, so their GHG emissions are negligible. Additionally, in livestock-fish systems, where the manure of farm animals, such as chickens, is converted into nutrients for fish, the methane and nitrous oxide emissions that decomposing animal waste produce are avoided.

Table 1. Examples of IAA methods and their potential for adaptation and mitigation.

Method	Description	Adaptation	Mitigation
Integrated fish, pond and livestock	This is a traditional low-input agricultural method that consists of three integrated components: a garden, a pond and a livestock pen.	- The pond water can be used for irrigation, making farms more resilient to changes in rainfall, and in situations of water scarcity, making more efficient use of a limited resource. - This method maximizes land use by enabling several production systems at the same time.	- The garden can add to carbon sinks, and using animal waste as fertilizer and fish feed avoids emissions from the decomposing waste. - It avoids emissions associated with fertilizer and fish feed production.
Fish-livestock systems	Individually, intensive agriculture and aquaculture systems can create large amounts of waste, as well as pollution. For example, when manure is used as fertilizer on land, any excess can leach into waterways. In integrated fish-	- This method recycles excess waste and provides added nutrients, particularly nitrogen and phosphorus, for fish production. - It reduces pressure on natural aquatic resources, making farm systems more resilient.	- Proper manure management can decrease GHG emissions. - It avoids emissions associated with fish feed production.
	livestock systems, farm effluents and wastes are recycled in fishponds and contribute to the production of animal protein.		
Rice-fish systems	Rice-fish systems maximize land and water resources while providing carbohydrates and protein. This method of rice production might need cash investment, but the fish production generates additional income and reduces labor and material inputs.	- Rice-fish systems can improve on-farm water management and allow for diversification. - They can also increase the outputs of both rice and fish and reduce the need for fertilizer.	- Certain species of fish can be fed with manure from livestock, which avoids emissions from decomposed animal waste. - Emissions associated with fertilizer and fish feed production are avoided.

Method	Description	Adaptation	Mitigation
Fish-vegetable/ horticulture culture	This refers to the integration of fish farming with vegetables, horticultural crops and fruit trees, such as bananas. Vegetables can be grown on pond dikes using water from the fishpond to maximize land and water sources. Vegetables can also be grown in separate fields, like fruit trees, and irrigated with pond water.	- Fish-vegetable/ horticulture systems can improve on-farm water and land use and allow for diversification. - Pond water can be used for irrigation, making farms more resilient to changes in rainfall patterns. - This method can deliver expected products at a lower cost of inputs because of the reduced need for fertilizer.	- The vegetables, banana trees and other fruit trees can add to carbon sinks. - Nutrient-rich water from the fishpond and the mud from the bottom of the pond can be used as fertilizer on vegetable and horticultural crops. - Emissions associated with fertilizer production are avoided.
Aquaponics	Aquaponics is a hydroponics system that uses aquaculture to grow plants in a closed and controlled system. It is suitable for multiple species of fish and several types of vegetables.	- Fish waste is converted into nutrients for vegetables using bacteria. The entire process is environmentally friendly, saves water and creates no waste. - The system promotes efficiency in the use of water, nutrients and space.	Nutrients like nitrates and oxygen are recycled between fish and vegetables, which eliminates the need for fertilizers. - Emissions associated with fertilizer production are avoided.
Integrated multitrophic aquaculture (IMTA	This is similar to polyculture, where different organisms from different trophic levels can be farmed together. In IMTA, multiple aquatic species from different trophic levels are farmed in an integrated fashion to improve efficiency, reduce waste and provide ecosystem services, such as bio-remediation. Lower trophic fish species or aquatic plants should be able to absorb metabolic by-products of the main organisms and, in the case of fish, feed on natural food.	- Species at the lower trophic level use waste products such as feces and uneaten feed from the higher trophic species (typically fish) as nutrients. - This system recycles wastes and provides nutrients for the lower trophic organisms.	- Nutrients are recycled between fish and other aquatic organisms, eliminating the need for fertilizer. - Emissions associated with fertilizer production are avoided.

In summary, integrated systems reduce waste and increase productivity by using by-products from crops, livestock and fish systems, and also other waste as inputs for other subsystems. As such, IAAS make farmers less dependent on agro-industrial products such as commercial inorganic fertilizers and formulated pelleted feed, which contribute to emissions.

6. Integrating aquaculture with poultry

This involves integrating fish with poultry, such as chickens, ducks and geese. One can integrate broilers, layers or dual-purpose chickens. According to Agrifarming (nd), "The best suitable fishes for integrated fish and poultry farming are those fishes that can filter and feed on phytoplankton, zooplankton and bacteria. From pond water per ha".

If a farmer does not keep many birds, integration might not be cost-effective. To be cost-effective, a farm needs 500–6000 poultry birds for a 1 ha fishpond (Ramanathan et al. 2020). On average, 50 to 60 kg of manure is required daily per ha (Agrifarming, nd).

6.1 Chickens and ducks

Fast-growing birds like broilers and layers are best for integrated chicken and fish farming. However, farmers can also use village or local chickens and ducks, which are the most common type of livestock in many rural areas of Zambia and the most common source of animal protein in Zambian villages, especially in the northern region. They are also resistant to disease and easier to feed.

In rural communities of Zambia, village chickens and ducks are mainly kept under an extensive low input-low output management systems where they are left to fend for themselves in terms of feeding and shelter (free range). To use village chickens and ducks in IAA, however, farmers need to change their management regime so that they provide enough of the best quality waste products for fishponds.

Ducks, specifically, are hardy and resistant to most poultry diseases. They also produce reasonably well even when kept under low management. For people living in rural areas, ducks are easy to rear, and when kept intensively they can outpace chickens in both growth rate and egg production.

6.1.1 Village chickens

There are several types of village chickens in Zambia.

Table 2. Types of village chickens.

Type	Characteristics
Naked neck	• No feathers on the neck • Normal to large in size • Lay up to 18 eggs per batch • Up to 100% of eggs can hatch • Recommended for use in natural egg incubation and natural chick brooding • Good resistance to diseases
Short-legged	• Raised feathers on the head that look like a hat • Good laying and hatching abilities • Lay 18 or more eggs per batch • Generally large in size
Guinea fowl	• Black-and-white spotted feathers like a guinea fowl • Brown and black spots • Generally large in size • Lay about 10–14 eggs per batch
Frizzle	• Frizzled feathers • High mortalities because low resistance to disease

Type	Characteristics
Feathered shanks	• Feathers on the shanks that make the chickens look like they are wearing pants • Generally very small
Dwarf	• Raised feathers on the head that look like a hat • Good laying and hatching abilities • Lay 18 or more eggs per batch • Generally large in size
Guinea fowl	• Generally very small • Tend to be resistant to diseases • Low market value because of their small size • Lay 12–18 eggs per batch

Source: Modified from MAL 2013.

6.1.2 Ducks

There are four main duck breeds in Zambia: Aylesbury, Pekin, Khaki Campbell and Muscovy, which is the most common breed in the country.

Table 3. Common duck breeds in Zambia.

Breed	Characteristics
Muscovy	• Males (drakes) weigh up to 7 kg and females (ducks) 3.6 kg • Many colors, including black, white, black-and-white • Drakes have puffs of red skin around the eyes and on the bill • Lays up to 80 eggs per year • - Lays 8–16 eggs per batch, incubate eggs and look after their young for 10–12 weeks • Non-broody • 35-day incubation period
Aylesbury	• Originated from England • Large ducks raised for meat and appearance • White plumage, pink bill, orange legs and feet • Body parallel to the ground • Fattens quickly to 2.3 kg at 8 weeks of age, large enough to eat but still young and extremely tender • Males weigh 4.5–5.5 kg and females 4–5 kg • Lays 40 to 100 eggs per year • 28-day incubation period
Pekin	• Originated from China • Reared for egg and meat production • Mature ducks weigh 3.5–5 kg • White feathers, light-orange legs and beak • Non-broody • Lays up to 200 eggs per year • 28-day incubation period

Source: Modified from MAL 2013.

Ducks typically begin to lay eggs at about 6 months of age. The females (ducks) mature at 5 months and the males (drakes) at 8, with a mating ratio of one drake for every four ducks. Muscovies can cross with other breeds, but the offspring are sterile. Muscovies incubate eggs and look after their young, but other breeds are non-broody, so their eggs need to be incubated artificially. The incubation period is 4 weeks for most breeds, except for Muscovy, which is 5. Muscovy ducks can incubate and hatch up to 30, while other breeds usually hatch 15–20. Hens can be used to incubate duck eggs.

In Zambia, smallholder and commercial farmers keep ducks for meat and eggs. Ducks are hardy and resistant to most poultry diseases, and they produce reasonably well even when kept under low management. For people living in rural areas, they are easy to rear and, when kept intensively, can beat chickens in both growth rate and egg production.

Ducks can be raised under intensive, semi-intensive and free-range management systems. In intensive systems, duck houses, which are similar to those used for chickens, are built over fishponds so that their droppings fertilize the water. The houses can also be built on pond dikes, where the ducks can graze on green forage around the pond and have easy access to the water. Plate 9 shows how to integrate ducks into fish farming.

In free-range systems, specifically, ducks can access dambo areas or recently cultivated rice fields and live on forage, small fish and insects. Under this system, ducks can take up to 6 months to reach market weight.

Plate 9. Integrating ducks with fish.

6.2 Rearing chickens

In Zambia, smallholder farmers commonly raise village chickens using an extensive system such as free range. Table 4 shows a comparison of the characteristics, advantages and disadvantages of the three rearing systems.

Table 4. Chicken rearing systems and their advantages and disadvantages.

	Extensive (free range)	Semi-intensive	Intensive
Characteristics	• Chickens have no fixed house. • Chickens move freely everywhere on grassland and around homesteads. • Chickens find their own food, such as grasshoppers, worms, termites and grain.	• Chickens have a fixed house with an enclosed area around. • Chickens move around on enclosed grassland during the day and housed at night.	• - Chickens are kept in poultry houses. • - Chicken houses are fully equipped with relevant facilities, such as feeders, drinkers, lights and nest boxes.

	Extensive (free range)	Semi-intensive	Intensive
Characteristics	• - Chickens get valuable minerals from the grass and the soil. • Chickens are provided with a shelter at night or a perch in trees. • Hens generally make their own nests to lay eggs • Hens and cocks run together all the time. • Brooding hens care for their chicks. • Water is provided.	• Chickens are provided with feeders, drinkers and laying nests. • Chickens are provided with water and supplementary feed. • Hens and cocks run together.	• Chickens are fed complete feed and watered. • Chickens are not allowed to brood, as eggs are collected for artificial incubation. • Alternatively, chicks are weaned at 2 weeks of age and brooded artificially.
Advantages for aquaculture	• When a farmer wants to integrate chickens with fish, a free-range system is discouraged because it has limited or no advantages.	• Chickens can be fed • Supplementary feeds, which can improve the quality of droppings. • More droppings can be collected than in free-range systems.	• Droppings are considered high quality for integration into fishponds because chickens are provided with complete feed and water. • Droppings are easy to collect. • A large amount of droppings can be collected with minimum waste.
Disadvantages	• Less manure means less fertilizer for fish. • The system is inefficient and not cost-effective to integrate with fish farming. • Poor quality manure can be produced, especially during lean months of the year, so fish fed on this manure will not be able to grow and thrive.	• Moderate labor is required to collect droppings, and it can take long to get the amount needed. • Droppings can be of poor quality, depending on the quality of supplementary feeds.	• Investment costs, such as housing and feeds, are high. • It is labor-intensive in terms of taking care of the chickens.

Source: Modified from MAL 2013.

Plate 10. A female farmer adopting a semi intensive chicken rearing system where she provides feed to her chickens.

6.3 Why integrate fish with poultry?

According to Agrifarming, "Poultry excreta is an excellent feed for fishes. The manure contains highly soluble organic salts, more 'N' and 'P'. You can integrate both broilers, layer, or dual purpose chickens" (Agrifarming, nd). Poultry manure also has a better conversion rate in aquaculture than agriculture, and chicken manure, especially, helps with the development of zooplankton. Zooplankton also comes with bacteria that does well on the organic component of poultry dung and can be consumed by the chickens. As Agrifarming puts it, "There is a high production of detritus at the pond bottom, which provides the substance for colonization of micro-organism and other benthic fauna particularly the chironomid larvae" (Agrifarming, nd)

Integrated poultry-fish farming produces few effluents, and according to Little and Satapornvani, "one hectare of static water fish ponds can 'process' the wastes of up to 1500 poultry, producing fish in quantities of up to 10 MT/ha without other feeds or fertilizers" (1997:426).

Ducks use the pond for their daily intake of water and also aerate the pond (AQAI 2021). They also increase pond productivity by releasing nutrients from the pond bed and get 50%–75% of their total feed requirement from the pond itself in the form of aquatic weeds, insects, mollusks, etc., which do not form the food of the fish (AQAI 2021).

6.3.1 What are the ideal conditions for integrated poultry-fish farming and better management practices?

According to Little and Satapornvani, integrated poultry-fish farming requires a "high water temperature and sunlight ensure year-round growth of both fish and natural

feeds" (1997:428). The authors also state that low temperatures reduce the amount of waste that can be processed by a given area of fishponds and that the ideal temperature for culturing fish with poultry waste products is 25°C (1997). The tolerance levels of fish to poultry manure also differs. Species that breathe air, such as catfish, can tolerate high input levels.

In Thailand, the optimal amount of poultry manure in ponds fertilized with high levels of inorganic fertilizer (5 kg of nitrogen/ha per day) is about 75 kg/ha per week for a monoculture of Nile tilapia (Knud-Hansen et al. 1991). These low levels reflect the subtle balance of dissolved oxygen and food production in a highly eutrophic pond (Edward et al. 1983). Green et al. (1994) recorded similar daily high yields of more than 20 kg/ha of Nile tilapia using higher levels of chicken manure in combination with inorganic fertilizer. According to Little and Satapornvani, "In contrast, the microphagous Nile tilapia is more sensitive to low dissolved oxygen in the early morning but thrives at numbers of poultry between 1000 and 1500 egg-laying ducks/ha without other inputs. Using poultry manure alone, net extrapolated yields of up to 12 MT, or standing stocks of 5-6 MT/ha, appear possible in monocultures of tilapia" (1997:439)

6.3.2 How to integrate poultry in ponds?

There are two methods to integrate poultry into aquaculture: building a poultry house over the ponds (vertical integration) or confining the poultry closer to the pond.

6.3.2.1 Vertical integration

Vertical integration systems that house poultry directly over ponds are used for both broiler and layer chickens, while pens that give poultry access to ponds stocked with fish for drinking and/or bathing are generally used only for ducks and geese (Little and Satapornvani 1997). According to Little and Satapornvani, "Construction of the poultry house over the pond allows wastes to drop directly in, saving labour costs" (1997:438). When building a chicken house over a pond, use concrete pillars or posts that are 2.4 m long, with half in the ground and half above it so that they lift the cages above the pond to allow people to work under them. The bottom of the cage can be made with wire mesh to allow the poultry waste to fall directly into the pond (Ramanathan et al. 2020).

The main disadvantage of this system is that there is a danger of overloading the ponds with chicken waste, which could affect water quality and dissolved oxygen levels. However, overloading can be avoided by housing poultry over concrete or earthen floors rather than directly over ponds, and then regularly manually or mechanically add manure to the pond. This option can reduce construction costs considerably and also enables farmers to sell surplus manure to their requirements (Little and Satapornvani 1997). In addition, replacing the water regularly to reduce phytoplankton biomass can alleviate water quality problems from overloading. This is avoided in a well-designed system, as effluents reflect inefficient nutrient reuse and negative impacts on the surrounding environment (Little and Satapornvani 1997).

6.3.2.2 Confining poultry closer to ponds

Farmers must collect manure from the poultry house and store it in a safe place. It should be applied to the pond every morning after sunrise at a rate of 50 to 60 kg per hectare.

This system has two main advantages. Evaporative cooling can reduce heat stress in broilers (Theimsiri 1992; Little and Satapornvani 1997), and access to water improves the quality of feathers in ducks, though growth might suffer (Edwards 1986).

The disadvantages are that having ducks free-range over ponds in large numbers can damage dikes and cause water quality problems, though restricting ducks to the water and pen prevents this problem (Edwards et al. 1983; Little and Satapornvani 1997). Edwards et al. (1983) also found that problems associated with marketing duck eggs, coupled with high feed costs, prevented small-scale farmers from maintaining even 30 ducks over small ponds (200 m2) as

feedlots. Farmers with limited numbers of poultry for their pond area need additional nutrient inputs to optimize productivity (Little and Satapornvani 1997)

6.3.2.3 Using poultry manure

Poultry manure can be used fresh, or after processing, to enhance the production of natural food production in sunlit tropical ponds (Little and Satapornvani 1997). It is necessary to monitor dissolved oxygen, because as Little and Satapornvani put it, "Input levels in excess of 75 kg DM/ha/ day typically 'overload' the system over a typical fish culture cycle (4-8 months), causing early morning deficits of oxygen. Balancing the production of wastes from poultry and the requirement of the fishpond is a key aspect of management" (1997:448).

Generally, larger birds produce more waste than small birds. As a result, the waste production increases rapidly over the rearing period of modern broilers. Layers produce more calcium and phosphorus-rich excreta than broilers, and the waste of replacement birds fed restricted diets high in fiber is correspondingly poorer than laying birds (Little and Satapornvani 1997).

For example, using egg-laying poultry that are of constant weight and produce fairly constant levels of waste are easier to manage than broilers in which waste is cyclical (Hopkins and Cruz 1982). The timely availability of replacement stock, veterinary support and market demand can be critical to maintaining poultry and the waste they produce (Little and Satapornvani 1997).

6.3.2.3.1 Application rates for poultry manure

Example #1
If 50 kg of manure is required daily per hectare, how many birds would be needed?

Guideline: on average, a chicken produces 0.1 kg of excreta daily.

Answer:
50 kg = 10,000 m^2 (1 ha); how much manure would we need for 1 m2?
50 kg = 10,000 m^2
x = 1 m^2
10,000x = 50kg
10,000x/10,000 = 50/10,000
x = 50/10,000
= 0.005 kg/m^2

To find the number of chickens for a particular pond, multiply the pond size (m2) by 0.005 to find the kilograms of manure per day and then divide that by 0.1 kg of manure daily per chicken to get the number of chickens for that particular pond size.

Example #2
How much manure and how many chickens are needed for a 600 m2 pond?

Answer:
600 m2 * 0.005 = 3 kg manure daily
1 chicken = 0.1 kg manure daily
x chickens for 600 m2 = 3 kg/0.1kg = 30 chickens

6.3.3 Better management practices for integrating fish and chickens

Farmers should follow these BMPs to improve chicken and fish integration:
- Control algae blooms and sample fish frequently to check on their growth.
- Monitor the health of the fish frequently.
- Use an intensive poultry system that confines birds to a poultry house or a shed.
- Select chickens that grow fast or are best at laying eggs.

- Note that poor quality supplementary feeds and lack of confinement results in "less and poorer quality manure being available for use in fish culture" (Little and Satapornvani 1997:431).
- "Manure derived from maize-fed ducks was high in nitrogen, sorghum was intermediate and rice bran low, reflecting the composition of the feeds themselves" (Little and Satapornvani 1997:431)
- "Poultry raised on a balanced ration produce a higher quality, more nutrient dense waste than those fed a supplementary feed" (Little and Satapornvani 1997:431).
- Use nutritional feeds for the chickens, as the type of feed affects the quality of droppings that the chickens produce. Poor quality waste results in poor fish growth.

6.3.3.1 Feeding regimes

Chickens need adequate feed to move around, renew their feathers, fight diseases, grow, and produce eggs. Like humans, their diet should have carbohydrates, proteins, fats, vitamins, minerals, crude fiber, and water. Properly fed chickens produce good quality droppings that can be integrated into aquaculture.

Proper feed and nutrition increases meat and egg production and results in better chick growth rates and flock sizes. Without supplementary feed, chickens usually starve during certain periods of the year if left to find feed by scavenging or fed only leftovers. It also boosts their immune system and results in high quality droppings.

Nutrition plays an important role in the performance of chickens. It promotes good health, good reproduction, high-quality meat and eggs, fast growth rate and high-quality droppings

Table 5. Effects of nutrition on village chickens.

Effects of poor nutrition	Effects of good nutrition
• Slow growth in young stock • Susceptibility to diseases and parasites • Low fertility in breeding cocks and hens • Low production of meat or eggs • Sexually weak cocks and hens • Increased mortalities	• Fast growth and early maturing of young stock • Bigger chickens means more droppings • Increased resistance to diseases among healthy chickens • Increased egg laying • Increased egg hatchability • Generally sexually active hens and cocks • High-quality droppings that can be integrated into aquaculture

It is good practice for a farmer to make sure their chickens have adequate nutrition. This enhances year-round production performance despite seasonal feed quantity and the variability in quality. As such, farmers should plan ahead to ensure feed is available throughout the year. They should save cereals, cassava and high protein seeds for supplementation, and use plants from their vegetable gardens (weeds or waste pruning) and along streams or wet areas, ensuring that only edible and nonpoisonous plants are fed to chickens. Feedstuffs must be pounded or ground coarsely so that the chickens can pick, eat and digest it easily.

6.3.3.2 Feed formulation

If rearing broilers and layers, farmers can buy commercial feeds that are available. However, as shown in Table 6–8, they can also make their own simple feed as a supplement. The feed formulation depends on the cost and availability of ingredients. However, 5 kg of formulated feed should produce 2.5 kg of chicken flesh.

Table 6. Feed ingredients that farmers can use to make their own feed.

Ingredients	Nutrient
Maize/maize bran, millet, cassava, sorghum, rice bran	Carbohydrates
Sunflower, groundnut cake, soybean cake, fishmeal	Protein
Vitamin premix	Vitamins
Edible vegetables/weeds	Vitamins (pounded and put in drinking water)
Mineral premix	Minerals
Salt	Minerals

Table 7. Simple feed ratio for raising village chickens.

Ingredient	Quantity
Maize bran	1.485 kg
Soybean	495 g
Fishmeal	4 g
Salt	8 g

Source: Chazya 2009.

Table 8. Simple feed ratio for supplementing local chicks up to 6 weeks of age.

Ingredient	Quantity
Crushed maize bran	1 kg
Wheat bran, sorghum bran or millet bran	1 kg
Sunflower oil cake	2 matchboxes
Seashell/bone meal/salt mix	1 matchbox (1 match box of salt to 13 match boxes of bone meal)
Fish or blood meal	2 matchboxes
Sesbania leaves	2 matchboxes

Source: Chibinga 2016.

Methionine and lysine need to be supplemented because animals cannot get them in adequate amounts from soybeans, especially if they are not well treated. These elements are locked because of the inhibitor in soybeans makes them unavailable to animals. Chickens are monogastric, like humans, and untreated soybeans could be poisonous to them, so it is essential to roast or cook the soybeans to make sure they are bioavailable for better growth.

A good source of protein for chickens is maggots, such as soldier flies, which have a protein content of 40%. If soybeans are not available, feeding chickens maggots will give them all the protein they need.

The Zambia Agriculture Research Institute in Misamfu, Kasama, has a laboratory that offers services to farmers who would like to test their farm-made feed to know whether it is balanced.

6.3.3.2.1 Simple feed formulations

The following are other examples of simple feed formulations (MAL 2013):

- Formulation for chicks and laying hens: Mix one part (one Meda container) energy feedstuff to one part (one Meda container) protein feedstuff. This will have a 22% crude protein content.

- Formulation for growing birds: Mix two parts (two Meda containers) energy feedstuff to one part (one Meda container) protein feedstuff. Provide vitamins in drinking water in the form of pounded vegetables or edible weeds soaked in water.
- Formulation for growing birds: Mix two parts (two Meda containers) energy feedstuff to one part (one Meda container) protein feedstuff. Provide vitamins in drinking water in the form of pounded vegetables or edible weeds soaked in water.

6.3.3.2.2 Complete feed formulation

A good formulation for chickens must contain a good source of energy, mainly from cereal grains, as well as protein, as birds need high-quality protein from both animal and plant sources. It must also contain vital minerals and vitamins, especially calcium, salt and phosphorus. Putting chickens on grass or a high-quality pasture can provide them with most vitamins, especially vitamin A.

6.3.3.2.3 How much feed is needed to raise local chickens in a semi-intensive system?

Table 9 shows the amount of feed that local chickens need at different ages, the total amount that the average chicken eats at a particular age, and the combined amount from supplementary feed and scavenging.

Table 9. Feeding table for chickens according to age.

Age (weeks)	Amount of supplementary feed for each bird per day (grams of dry weight)	Approximate total amount eaten per bird per day (grams of dry weight)
1	10–15 g	12–15 g
2	15–20 g	15–21 g
3	21–30 g	21–35 g
4–6	30–40 g	35–50 g
8	30–40 g	55–60 g
16–27 (grower)	30–50 g	65–80 g
28 (adult)	30–50 g	100 g

Source: Chibinga 2016.

6.3.3.3 Village chicken housing and shelter

Rearing chickens requires housing, and the design and construction of chicken houses demands careful planning. Chicken houses allow farmers to carry out routine operations efficiently while giving chickens a favorable environment for them to grow and for hens to lay eggs. The design must meet the specific management needs of the three types of flocks: hens with chicks up to 8 weeks old, young growing cockerels and pullets, and adult breeding hens and cocks.

Housing chickens protects them from rain, cold, theft and predators, such as rats, dogs and snakes. Housed birds are also easier to catch if you need to inspect them for signs of illness or injury or to vaccinate them against disease.

6.3.3.3.1 Siting the poultry house

A good chicken house must be built on well-drained, level land to avoid water logging around the house and dampness inside it, as this spreads diseases and parasites and weakens the foundation of the house. There must also be a good source of water nearby so that the chickens can drink clean water all the time, and the house must be clean as well. The chicken house should be constructed near the homestead for easier supervision and to ensure security, but it is important to leave enough space between the chicken house and the farmer's home to avoid the spread of disease.

A good chicken house should have a good flow of fresh air at all times and allow for enough sunlight. It must be solid enough to protect the chickens from rain, cold weather, winds and excess heat and to keep out predators, such as cats, dogs and thieves. It should also provide them with sufficient space for comfort and rest and be easy to clean and disinfect.

6.3.3.3.2 Materials for construction

The materials required depend on the type of house being built.

A simple poultry house is made of debarked wooden poles, chicken wire, mud or burnt bricks, grass for thatching and anthill soil for floors. This type of house needs a lot of litter on the floor, and sanitation is a challenge. Depending on the stocking rate, the litter needs to be changed frequently.

A standard poultry house, meanwhile, uses burnt bricks or concrete blocks, chicken wire, treated timber or metal poles, iron sheets for the roof and cement for floors. However, it is also possible to convert an old garage into a good poultry house, as long as there is adequate ventilation and sufficient protection from bad weather and it is easy to clean.

6.3.3.3.3. Night shelter

To build an ideal night shelter for growers and chickens, follow these steps:

- Construct a shelter with readily available local materials, such as wooden poles or bamboo.
- To collect the manure easily, make sure the shelter is built at least 1.5m above the ground, leaving gaps in the floor between the poles for droppings to fall to the ground.
- House no more than seven chickens per square meter to avoid overcrowding.
- If using iron for the roof, provide an overlap of 0.8m on all sides to keep out rainwater.
- Allow at least 0.5m between the roof and the perch on the slanted lower sides for good ventilation.
- If possible, construct a new structure on a new site at least every 3 years. Changing sites for chicken structures helps prevent the build-up of disease-causing organisms and parasites.

6.3.3.3.4 Types of housing

- Adult birds and growers are often provided with elevated night housing. Chicken houses built close to the ground are suitable for hens with young chicks that cannot enter an elevated house, but it might be necessary to dig a drain around the house or to raise the floor so that it will stay dry during the rainy season. A chicken house that is about 4m long, 1 m wide and 1.5 m high can hold 8–10 adult birds if they are kept enclosed all day, or about 20 for overnight housing. The house can be completely covered with wooden slats or be left partly open with netting or woven bamboo.

6.3.3.3.5 Building a chicken house

- To construct a proper chicken house, follow these guidelines:
- Clear grass and bush about 3 m on all sides of the planned site of house to keep snakes and rats away from the chickens.
- To decrease costs, use local materials such as trees and bush branches or reeds and thatch grass.
- The size of the house depends on how many birds the farmer has (or plans to have) and if they are to be kept in the house overnight or for extended periods.
- Do not keep too many birds together because they will start to peck each other, which could lead to injury and disease.
- Always remove the bark from timber used to build the house so that pests and parasites, such as ticks and mites, have nowhere to hide.
- Ensure the house has enough protection from rain and wind but enough ventilation to provide birds with fresh, clean air.
- Make the opening wide enough so that it is easy to clean the inside of the house, and fit it

with a door or other means of closure.

- Because many infectious diseases affecting chickens are transmitted through their droppings, ensure the floor of the house has openings to allow the droppings to pass through to the ground.
- The spaces between the slats depend on the age and size of the chickens. They must be close enough to provide adequate foot support but wide enough that droppings can pass through them.
- If the chicken house is built on poles, it should be at least 1m above the ground but not so high that the farmer cannot reach inside.

Plate 11. A raised chicken house made from local materials.

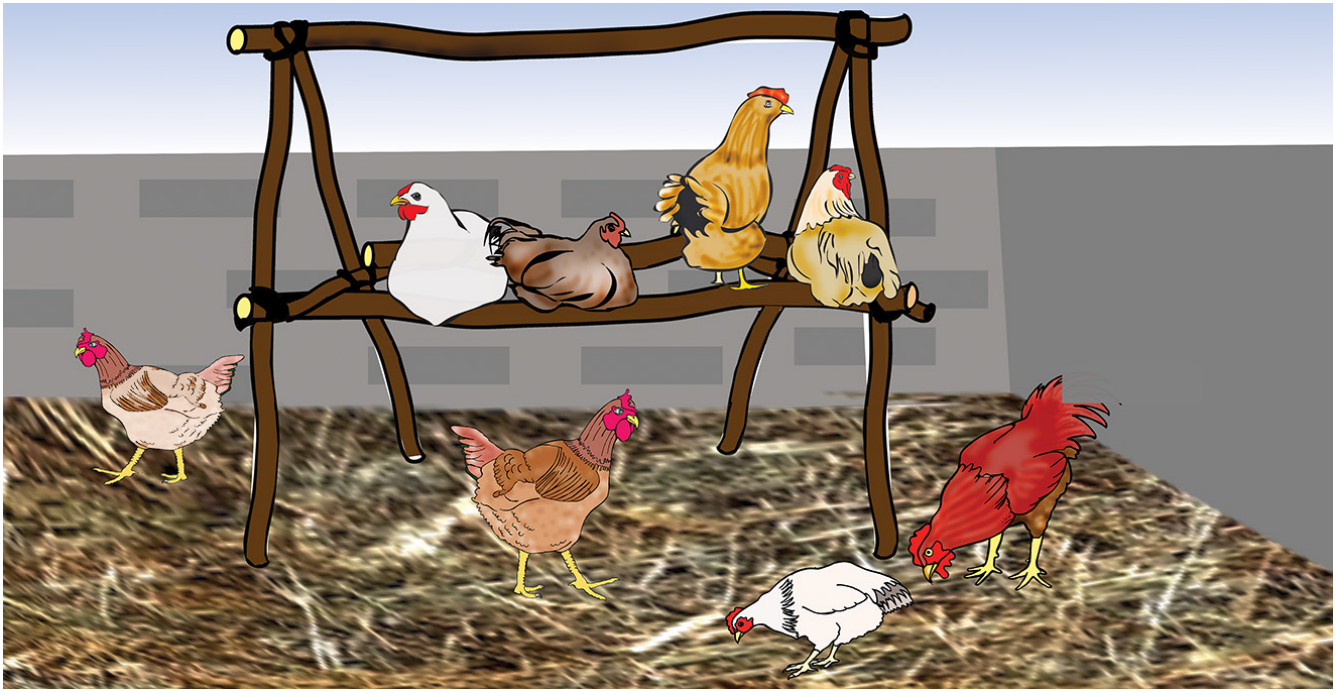
Chicken house facilities

6.3.3.3.6.1 Perches

Chickens like perches, as they prefer to sleep above the floor. Roosting on perches minimizes contact between the birds and their droppings to help prevent diseases, as chickens kept on floors are prone to parasites. The roosts can be made from bamboo or straight tree branches, at about 3 cm in diameter, but be sure to remove the bark from the branches.

Each adult chicken requires about 20 cm of perch space. If more than one perch is needed, they should be about 50 cm apart and at the same level. If they are at different levels, the birds will fight to reach the highest perch when they come in to roost in the evening, causing them unnecessary stress.
ckeep away most external parasites.

Plate 12. Chicken house with perches

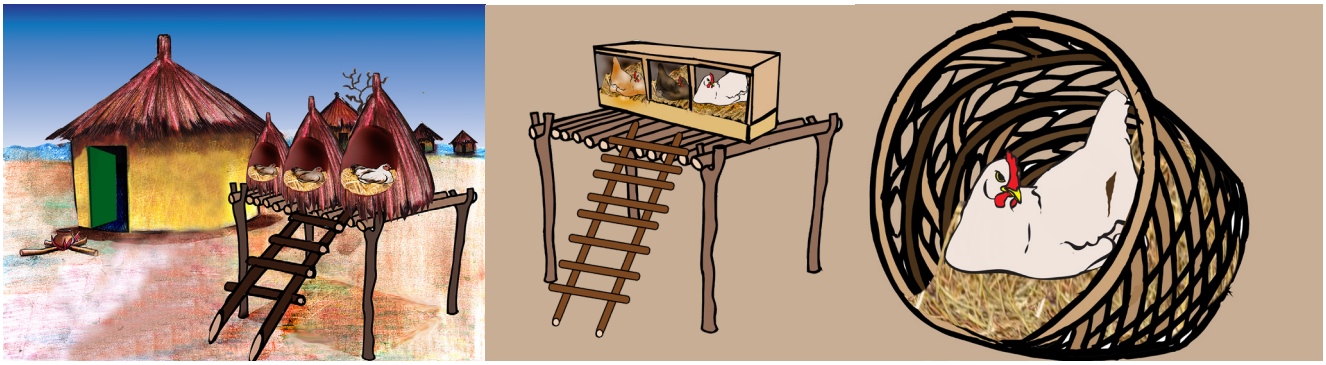


6.3.3.3.6.2 Laying nests

To ensure that eggs are laid and incubated safely, follow these nesting guidelines for brooding hens:

- Ensure that nests are free from germs and parasites. External parasites in nests can reduce egg hatchability, as infected hens tend to leave their nests and spend a lot of energy cleaning and scratching their body.
- Place laying nests in shady places.
- Use sun-sterilized, dry, clean and soft grass as nest bedding.
- Raise nests at least 1.5m above the ground for protection.
- Mix ash, tobacco leaves or other antiparasitic substances in the nest bedding to help keep away most external parasites.

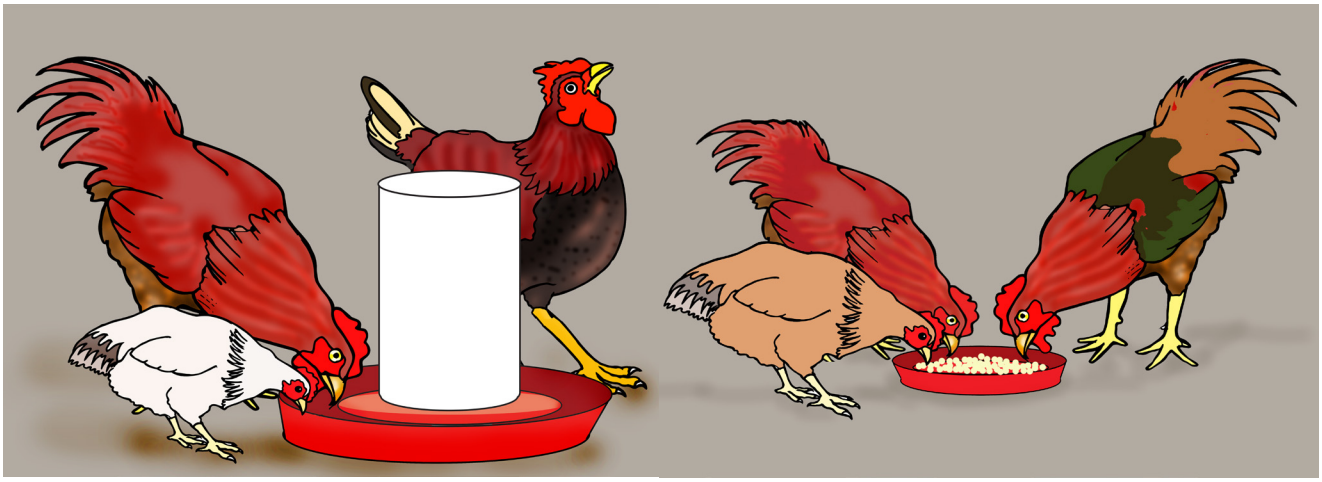
Plate 13. Types of chicken nests



6.3.3.3.6.3 Feeders and drinkers

Chickens require clean drinking water all the time. There must be enough feeders and drinkers for chicks and chickens, and they should be made of plastic, wooden or metal.

Plate 14. An illustration of a drinker and a feeder.



6.3.3.3.6.4 Maintaining a chicken house

Cleaning the chicken house helps prevent and control diseases, especially external parasites such as fleas and mites. For proper cleaning, follow these guidelines:

- Remove droppings and litter from inside the house weekly or, if the house is portable, move it to a new area.
- To control external parasites, fumigate the chicken house every 6 months with smoke by lighting a fire under the house, which should be elevated. It might be necessary to remove the birds before fumigating the house.
- Keep the area around the house clear of grass and bush to keep out snakes and rats.
- Do not overcrowd the chicken house.
- If the house has any sick birds, empty the house and then either clean it or even burn it and build a new one.
- Remove the droppings from underneath the chicken house regularly.
- Place wood ash or lime on the floor and walls to repel external parasites and to make it easier to remove manure when cleaning.
- Tobacco leaves are also effective at controlling pests.

6.4 Poultry health

6.4.1 Disease and health management

6.4.1.1 Use of antibiotics in chickens

Antibiotics can control and treat diseases and bacterial infections in livestock. However, misuse and high usage of antibiotics must be avoided to reduce the occurrence of antimicrobial-resistant bacteria. Antimicrobial resistance (AMR) means that the bacteria causing the infection become resistant to the antibiotic used to treat them. AMR is a global threat to public health. If there is high misuse of antibiotics on chickens integrated with fish when the chicken droppings enter into ponds and are consumed by fish, which humans then eat, it can also increase the occurrence of antimicrobial-resistant bacteria in human beings leading to diseases and death. Misuse of antibiotics in livestock rearing is one of the most significant causes of AMR development in humans (Okon et al., 2022).

Farmers integrating chickens and fish should use antibiotics only where appropriate and should seek advice from their extension officers. Additionally, farmers must implement better management practices for livestock and maintain better farm biosecurity to prevent the emergence and spread of diseases that may require antibiotic treatment. Non-drug alternatives to preventing the occurrence and spread of diseases and infections are essential (Selaledi et al., 2020; Lojewska and Sakowicz, 2021) to stop the spread of AMR. Additionally, farmers that integrate chicken-fish farming may need to monitor their farms and routinely take samples of chicken droppings to the labs to test for AMR.

Table 10. Factors that influence the health of chicken.

Factor	Causes/comments
Stress	• Stress predisposes village chickens to New Castle Disease (NCD), especially during the cold months of June and July and the hot months of September and October. • High or low temperatures, a prolonged rainy season, dampness and poor nutrition all induce the production of stress hormones in chickens that causes them to excessively break down body protein for energy for them to cope. • - Stress reduces the immunity of chickens and the effectiveness of medicines used to treat diseases.
Poor nutrition	Lack of nutrition from either underfeeding or poor quality feed weakens chickens, making them more susceptible and less resistant to disease.
Poor ventilation	Lack of proper air circulation can spread respiratory diseases rapidly.
Overcrowding	Too many chickens in a small area make the transfer of diseases, especially NCD, between birds much easier.

Source: Modified from MAL 2013.

6.4.2 Common diseases

Table 11. Diseases in village chickens.

Disease	Symptoms/Cause	Control and prevention
Newcastle disease	• Birds that breathe through their mouth and make a rattling noise are having difficulty breathing because of the accumulation of mucus dripping from their mouth and nostrils. • Bird display signs of nervousness, such as twisting their head, circling their neck, shivering and paralysis of legs and wings. Birds can become drowsy and sleep most of the time with their heads turned backward or drawn toward their body. • The crop (part of the bird's food pipe, at the base of the neck) becomes swollen. • Birds have yellowish diarrhoea. • Eggs shells are soft or rough. • Birds eat less food but drink plenty of water. • Egg production is low. • Many birds die within a day. In severe cases, healthy birds die in the nest or on the floor before showing any symptoms. The mortality rate is between 90% and 100%.	• Vaccinate all chickens, including chicks, from 2 weeks of age. • Remove dead birds from the house immediately and dispose of them by either burning them or burying them deep in the ground. • During an outbreak, control the movement of birds between pens/areas. • NOTE: Specimens should be sent for laboratory diagnosis. • After an outbreak, and before restocking birds: • Remove bedding from the house and burn it. • Clean and disinfect the house and all equipment. • Leave the house empty for 3–4 weeks before introducing new stock.
Bumblefoot	• Germs enter the feet of birds through wounds or bruises from sharp nails, thorns or coarse litter, causing the feet to swell.	• Remove nails, sharp stones and coarse litter from the house. • Put sufficient litter in the house so that birds do not scratch themselves on the floor, which could be rough. • Treatment • Open the wound with a clean, sharp knife or razor blade to remove the pus. • Clean the inside of the wound after removing the pus. • Disinfect the wound with iodine. • Isolate the bird and confine it to a small space while it is being treated.

Chronic respiratory disease (CRD)	• CRD is one of the most common diseases in poultry. It is caused by bad management practices in the poultry house, including poor ventilation, overcrowding and dust, as well as cold temperatures.	• Do not put too many hens in a house. • Feed the birds well to keep them healthy. • Do not introduce diseased chickens into the flock. • Do not rear chicks with adult birds. • Keep the house well ventilated and free of dust to maintain hygienic conditions. • Keep ammonia emissions at minimum levels by maintaining dry conditions in the house, as wet conditions encourage the decomposition of faeces. This releases ammonia gases that irritate the respiratory system and cause the eyes to itch. • Maintain the correct temperature in the house.
Bumble foot	• Germs enter the feet of birds through wounds or bruises from sharp nails, thorns or coarse litter, causing the feet to swell.	• Remove nails, sharp stones and coarse litter from the house. • Put sufficient litter in the house so that birds do not scratch themselves on the floor, which could be rough. **Treatment** • Open the wound with a clean, sharp knife or razor blade to remove the pus. • Clean the inside of the wound after removing the pus. • Disinfect the wound with iodine. • Isolate the bird and confine it to a small space while it is being treated.
Chronic respiratory disease (CRD)	• CRD is one of the most common diseases in poultry. It is caused by bad management practices in the poultry house, including poor ventilation, overcrowding and dust, as well as cold temperatures.	• Do not put too many hens in a house. • Feed the birds well to keep them healthy. • Do not introduce diseased chickens into the flock. • Do not rear chicks with adult birds. • Keep the house well ventilated and free of dust to maintain hygienic conditions. • Keep ammonia emissions at minimum levels by maintaining dry conditions in the house, as wet conditions encourage the decomposition of faeces. This releases ammonia gases that irritate the respiratory system and cause the eyes to itch.

		• Maintain the correct temperature in the house.
Coccidiosis	• Signs of coccidiosis include blood-stained diarrhea/feces, • Droopy wings, ruffled feathers and closed eyes. • Chicks eat less and lose weight. • Most chicks die after 6–10 days, and the death rate can be very high. **Spread of disease** • Birds eat food or drink water contaminated with coccidiosis germs, which often occurs with dirty troughs. • Bedding is contaminated with coccidiosis germs. • Chicks are mixed with older chickens, which are often carriers disease.	• Feed chicks mash containing a coccidiostat, a substance that helps prevent the growth of coccidiosis parasites. • Keep the litter dry at all time. Remove wet patches. • Turn the litter regularly to keep it dry. • Clean the house thoroughly before placing chicks in it. • Do not reuse old litter. • Do not mix age groups in one house. • Remove dead birds immediately from the house. • Treat sick birds right away.
Fowl cholera	• Birds are drowsy and have ruffled feathers. • Birds have yellowish or green diarrhoea. • Birds eat less food, but they drink more water. • Egg production is low • The mortality rate can reach 80%.	• Vaccinate the birds. • Remove dead birds from house immediately and dispose of them by either burning them or burying them deep in the ground. • During an outbreak, control the movement of birds between pens/areas. **After an outbreak and before restocking:** • Remove the bedding from the house and burn it. • Clean and disinfect the house and all equipment. • Wash the house, if possible. • Leave the house empty for 3–4 weeks before introducing new stock.
Fowl pox	• There is a watery discharge from the eyes and later an accumulation of yellowish pus. • There are many sores on the head, combs and wattles. • Sometimes, the whole eye can become swollen and closed. • Sores in the mouth cause the birds to eat less. They can also be found in the throat. • Cheese-like, yellowish fluid can form from the sores in the mouth and throat and make breathing difficult if they accumulate.	

Fowl paralysis	• This disease causes paralysis or lameness in the legs. • If one or both legs becomes completely paralyzed, birds cannot walk. If paralysis is slight, birds walk unsteadily. • - Paralyzed wings hang down. • One or both eyes can change color, a condition that is often called "white eye" or "gray eye." • Egg production drops.	• Rear chicks in clean houses. • Do not rear chicks in houses previously used by adult birds. • Remove affected birds and kill them.

Source: Modified from MAL 2013.

6.4.3 Other diseases

6.4.3.1 Internal parasites

These are found inside the chicken and feed inside its body. The most serious internal parasites are those in the digestive system, the most common being roundworms and tapeworms. Most worms occur in the small intestine.

To control worms in chicken, follow these guidelines:
- Do not use old litter, because it can contain the eggs or larvae of the parasites.
- Clean and disinfect the chicken house regularly.
- Do not mix chicks with adult birds, which can infect chicks with worms.
- Feed the birds well.

6.4.3.2 External parasites

External parasites are mites, ticks and lice that are found on the body of a chicken and feed on the chicken intermittently. They can live on the chicken's body throughout its entire life, or in cracks, perch joints and litter.

To prevent external parasites, follow these guidelines:
- Clean and disinfect the chicken house regularly. Remove all birds from the house and spray it with a recommended insecticide.
- Remove the old litter and burn it to kill any external parasites that are in it. The litter can be used as manure in gardens, but the gardens must be far from the chicken house.
- Fix any cracks in the chicken house where insects can hide.
- Dust the birds with recommended dusting powder.
- Dust insecticides on the litter and in the nesting boxes.
- Apply recommended insecticides on the legs or bodies of hens to control mites.

6.4.4 How are diseases introduced into the flock?

There are many ways that diseases can be introduce into the flock:
- Buying chickens from unreliable sources
- Mixing chicks with adult birds, which can be disease carriers
- Allowing potentially disease-carrying chickens from other poultry farms to mix with healthy chickens
- Allowing rodents, flies and wild birds, which can be disease carriers, to mix with healthy chickens
- Allowing people, who carry germs on their feet, hands or clothes, to mix with healthy chickens
- Using contaminated equipment, especially feed and water troughs
- Using old litter, which contains germs
- Not cleaning or disinfecting the poultry

- Feeding contaminated and stale feed to chickens and giving them dirty water.

6.4.5 How can farmers control diseases on their farms?

Farmers can control diseases on their farms by taking the following measures:
- Feed the birds well with the right type of food.
- Give the birds plenty of clean, fresh water in clean troughs.
- Never feed stale food to birds.
- Do not mix chicks with older birds when brooding.
- Never buy chicks from unreliable sources.
- Clean and disinfect the poultry house.
- Clean the feed and water troughs regularly.
- Never use contaminated litter.
- Do not allow visitors into the poultry house.
- Control rodents in the poultry house.
- Carry out recommended vaccination programs.

6.4.6 How can a farmer minimize disease outbreaks?

To minimize disease outbreaks, farmers should carry out the following general hygiene practices:
- Clean the night houses periodically to avoid excess accumulation of droppings.
- Wash drinkers and fill them with clean water every day to avoid microorganisms from developing in dirty water.
- Remove and burn nesting grass, and empty shells from the nests after every clutch has hatched.
- Check for pests and parasites and treat the chickens. If a laying cage or any other shelter is infested with external parasites, apply insecticides onto the chickens and on the cages or shelter.
- Wherever diseases or parasites are a persistent problem, all households in a village or settlement should burn old structures made of wood, grass and bamboo, and build new ones every 3 years.
- To kill parasites in mud structures, place a fire in the middle and maintain a very high temperature inside for at least 1 hour. Then put out the fire and allow it to smoke slowly. Chemical disinfectants can also be used.
- Isolate sick chickens in a well-protected place, and provide them with feed (greens too) and water.
- Dispose of dead chickens properly by burning or burying them in a deep pit. If left exposed, carcasses will become sources of infection.
- Boil other equipment in water for 30 minutes and dry them in the sun. Turn the equipment periodically to make sure the sunlight reaches every part. The Sun's rays act as a natural disinfectant.

Farmers should also vaccinate their chickens against NCD, as it is an infectious, highly contagious and destructive disease caused by viruses. Vaccinating chickens against diseases like NCD is recommended, and should be done every 3 months.

6.4.7 Monitoring chicken health

When checking their chickens every morning, farmers should pay attention to the following:
- Observe how quickly each bird leaves the house.
- Observe how active each bird is, as sick birds are usually inactive.
- Check whether or not the chickens are eating and drinking.
- Check for signs of weakness, discharge from the eyes and nose, coughing, diarrhea and other signs of illness.
- Check to see if hens are laying eggs consistently.
- If there is a health problem, examine the whole flock and, if necessary, report the matter to the nearest extension officer.

6.4.8 How safe is it to fertilize ponds with manure from sick animals?

If the animals are not on a treatment, farmers can treat the manure before using it in their ponds. In this case, the manure has primarily a prebiotic effect on the pond ecosystem rather than a direct probiotic effect on the fish. If the animals are on a treatment, the withdrawal period from the drug can be followed to avoid pond contamination through drug residues in fecal matter.

Because more farmers are rearing improved breeds of chickens, new chicken diseases have been introduced to the region, so it is important for farmers to vaccinate their chickens against NCD, infectious bursa disease (IBD) (gumboro), coryza and fowl pox.

Table 12. Vaccination schedule.

Vaccine type	NCD	IBD	NCD	IBD	Coryza	Fowl pox
Day	10	14	18	21	42	52

Afterward, chickens can be vaccinated against NCD every 3 months. Broilers are not vaccinated against coryza and fowlpox because they will be ready to be consumed by the time they are supposed to be vaccinated.

For the NDC vaccine, chickens are given grade 1 maize bran to make them thirsty. Thirty minutes later, the vaccine is administered by mixing it with their drinking water. Because the bran makes the chickens thirsty, they will drink a lot of water and, in the process, increase the uptake of the vaccine from the water.

6.4.9 Biosecurity

To prevent disease on a farm, farmers can take several biosecurity measures: install a quarantine zone and a bath facility to disinfect feet and vehicles. Put up fencing and build proper housing with adequate ventilation. Maintaining hygienic conditions, including routine vaccinations and handwashing facilities. It is also important to restricting entry to the animal units/structures.

7. Integrating aquaculture with goats

7.1 What is the importance of goat production by smallholder farmers?

According to Namonje-Kapembwa et al. (2022), goat production has many positive attributes smallholder farmers as a means of survival, such as the following:

- Goats are prolific.
- They require low inputs for a moderate level of production.
- They reach maturity early, which makes them profitable.
- They make a significant contribution to rural farmers and the stability of small farm systems under climate shocks, such as inadequate rainfall and high temperatures.
- They contribute to food and nutritional security.
- They have a liquid market, meaning goats have lots of buyers and are easy to sell, which allows smallholder farmers to cover their expenses.
- They are used for social events in the rural villages, such as weddings and traditional ceremonies, paying dowries, at funerals and to settle disputes.

According to the MFL, goats are a source of social security for the rural poor—a "Walking Savings Bank Account" (2015:1)—and with the increasing demand in both domestic and international markets, goats are no longer considered a poor man's animal. Additionally, rearing goats creates employment opportunities and is an easy way to accumulate wealth through the sale of animals and their milk, as well as skins, which can be used for making various household goods, such as stools, drums and chairs. They also contribute to motivation and prestige in families, as goats are considered real assets.

Goat production can be integrated with fish farming, which can increase the efficiency of both forms of production. This will enhance the resilience of smallholder farmers against climatic risks. There are also several breeds of goats in Zambia for farmers to choose from, as shown in Table 13.

Table 13. Breeds of goats in Zambia and their characteristics.

BREED	CHARACTERISTICS	USE
Plateau goat	• Found in the plateau areas of Zambia • Medium-sized • Mixed colors • Adults males weigh 45 kg and females 25–30 kg	• Mostly for meat and skins • Sometimes for milk
Gwembe goat	• Predominantly found in Gwembe District of Southern Province • Small, hardy, compact	• Mostly meat and skins
	• Mixture of black, brown and white • Prolific breeder • Adult males weigh 25 kg and females 20 kg • Poor milker (0.2 L/day)	
Sinazongwe goat	• Predominantly found in Sinazongwe District of Southern Province • Relatively larger than the Gwembe goat • Has a long beard • Small, hardy, compact • Mix of black and white, or brown and white	• Mostly meat and skins

BREED	CHARACTERISTICS	USE
Unidentified goat strains	• Mainly found in Central Province • Tuft of long hair on the forehead	• Meat and skins
Bantu goat (local)	• Medium-sized • Mixed colors • Adult males weigh 30 kg and females 25 kg	• Meat and skins
Boer goat (exotic)	• South African origin • White with brown spots or reddish-brown heads and neck • Adult males weight 70 kg and females 50 kg • Can produce 0.5–2 L of milk per day • Large droopy ears	• Meat, milk and skins
Saanen goat (exotic)	• Originally from Ireland • White • Adult males weigh 75 kg and females 65 kg • Can produce 3–5 L of milk per day • Erect ears	• Milk
Toggenburg (exotic)	• European breed, adopted in East Africa • Brown with white lines on face • Adult males weigh 80 kg and females 70 kg • Can produce 3 L of milk per day • Slightly forward-pointing, erect ears	• Mainly for milk
Anglo-Nubian (Nubian)	• Originally a cross of British, African and Indian goats • Roan and white • Weighs 65–75 kg • Long and pendulous udder • Looks proud, graceful, with a roman nose • Can produce 2.5 L of milk per day • Long, dangling ears	• Milk and meat
Alpine (French Alpine)	• Hardy and adaptable • Various colors • Adult males weigh 60 kg and females 65 kg • Excellent milkers • Forward-pointing erect ears	• Milk

Source: Modified from MFL 2015.

Goat excreta is a good source of organic manure since it is made up of 60% organic carbon, 2.88% potassium, 2.7% nitrogen and 1.78% phosphorus K-2.88%, and its urine is equally rich in both nitrogen and potassium (Farm Design 2021). To fertilize a 1 ha pond, at least 50–60 goats are needed, which will yield of 1.502 t of manure. The goats should be provided with a dry, safe, comfortable house protected from excessive heat (Farm Design 2021). If done properly, goat farming can yield 500–600 kg of meat and 3000 L of milk per year, as well as providing skins and fiber such as mohair and cashmere (Singh n.d.).

According to Kumar et al. (2012:208, "The solid excreta of goats are several times richer in nitrogen content and phosphoric acid than the excreta of other animals. Goat urine is equally rich in both nitrogen and potash." The authors also state, "Goat droppings have the advantage of direct application into grow-out fish ponds as the size of droppings is around 6–7 mm pellet, coated with mucus and floats in a semi dried state. The droppings have been observed to be consumed by the fish. Goats can be kept under a house constructed on the elevated portion of the dyke for facilitating the waste disposal into the ponds" Goat manure can be applied weekly at a rate of 10 kg/100 m2 (Lundeba et al. 2021). The manure should be bagged and placed in the corners of the pond, with the bags hung on stakes so that they are easy to remove the manure if excessive algal blooms occur. The manure (pellets) can be bagged whole to allow only nutrients to leach out and fertilize the pond water. Alternatively, the pellets can be crushed to quickly unlock the nutrients into the water. (2012:208).

Plate 15. Direct integration of fish and goats.

7.2 Housing goats

Good housing is key to prevent unnecessary losses of goats from diseases, predatory attacks, thefts and unfavorable weather. Most health problems in goats are attributed to poor hygiene in their houses and premises. Kids, if not properly housed, will be attacked by predators such as dogs and will be exposed to parasites and diseases. This can lead to loss of animals in the flock and, ultimately, productivity and income. To minimize the cost of building a goat house and to maximize profits, farmers should use appropriate and locally available materials such as poles, grass thatch or iron roofing sheets (MFL 2015).

7.2.1 Siting a goat house

A goat house should be built within 100 m from the farmer's own home. It should be sited on well-drained ground and on western side of the farmer's house to avoid the smell of manure.

To build a good goat house, farmers should use the following guidelines:

- Keep construction simple, and use local materials, such as poles and grass thatch.
- Ensure that the house protects the goats against rain, sun, wind, predators and thieves.
- Have a raised slatted floor to prevent diseases and reduce attacks from predators and to make it easy to collect manure.
- Build it in such a way that it prevents the goats from damaging crops.
- Include feed and water troughs.
- Make sure the house has good ventilation to prevent respiratory infections, such as pneumonia.
- Create adequate space to avoid overcrowding, contamination and discomfort.
- Build strong doors to protect the goats from predators and thieves.
- Give the roof a good slope and an overhang of at least 0.5 m to allow efficient run-off and to prevent water from draining inside.
- Make the slats on the floor no more than 1.5–2 cm apart (about the thickness of an adult thumb) to prevent injury to kids.
- Build the house at least 1.2 m above the ground to make it easy to remove the manure underneath.
- Fence off the goat house to contain the animals during bad weather.
- Partition the house for kids, sick animals, etc.
- Plant trees for shade on the site of the house or locate it under the shade of a tree.

Plate 16. Picking of goat pellets from a raised goat house

7.3 Good management practices for goats

The following are routine management practices that farmers should carried out to run a goat farm efficiently:

- Observe the health of the goats and check for any signs of illness.
- Feed the goats well to help them fight off diseases.
- Give the goats adequate clean water in drinking troughs within the fence or inside the goat house.
- Remove the goat manure regularly.
- Deworm the goats two or three times during the rainy season to help control internal parasites.
- Dip and spray the goats to help control external parasites, such as ticks, lice and mites.
- Castrate males to control breeding for desirable characteristics (traits).

7.4 Feeding and nutrition for goats

Maintaining good health among goats helps them fight off diseases. It also makes for faster growth rates, good reproduction and high milk yields.

The following are points to note for goat feeding and nutrition:

- Goats are more browsers than grazers and might not do well if denied access to bushes and trees. Goats will eat a wide range of vegetation, including thorny bushes.
- Good quality pasture must have a balance of grasses and legumes. Grasses are rich in fiber and energy while legumes are rich in protein.
- Goats will do well if given access to carbohydrate- and protein-rich feeds like maize, millet, sorghum, cereal bran, sunflower cake, groundnut cake and soybeans. Soybeans must be boiled and crushed before being fed to goats.
- Goats prefer to eat tree leaves and tender green grass.
- Like any other animal, goats need regular water to drink for survival. Local goats require an average of 2–10 L of water daily, depending on their size.
- Goats feeding on young, growing grass might appear to do well without water, but this would seriously affect their milk production and growth rate.
- Other feedstuffs include crop residues, cereal stover/straw, stover and hulls of cowpeas, beans and groundnuts.
- Adult goats can eat about 1–1.6 kg of dry grass or 4–6 kg of fresh grass every day.
- During the dry season, pastures become old and tough and contain fewer nutrients, so goats require supplements.

7.5 Diseases and health management of goats

Generally, goats are highly resistant to many diseases. However, improper conditions, such as overcrowding, poor housing and sanitation, and inadequate ventilation, can lead to many diseases, which can result in low production and productivity. To avoid losses, it is important to follow proper health management that includes preventative measures. Table 14 lists some of the most common diseases among goats, as well as symptoms, prevention and treatment.

Disease	Description/symptom/cause	Control and Prevention
Worm infestation	Parasites are found inside the goat's body and can cause reduced productivity or death. Symptoms include anemia, diarrhea, weight loss, rough coat, poor growth, swelling under the jaw, potbelly and sudden death.	• Change the grazing area every 3 weeks to reduce worm infestation. • Avoid grazing goats in dambos and wetlands. • Do not graze them early in the morning when the larvae are active until the dew has dried up. • If worms are suspected, deworm the goats every 3 months using albendazole or Nilzan. • Inject them with Ivermectin.
Foot rot	This is a contagious disease, common during the rainy season, that causes decay (rotting) under the hoof producing a bad smell. Symptoms include lameness, loss of fitness and a smelly foot.	• Trim hoofs regularly. • Avoid keeping goats in wet and muddy areas. • Provide goats with good housing. • To treat the disease, walk or dip the goat in a footbath containing 10% copper sulfate or zinc sulfate.
Pneumonia	This disease affects the lungs. Symptoms include high fever, coughing, breathing problems, discharge from the nose, anorexia (loss of appetite), weight loss.	• Avoid overcrowding. • Improve ventilation. • Supply clean water. • Vaccinate the goats every year. • If caused by a bacterial infection, treat it with antibiotics such as penicillin or oxytetracycline and sulfonamides.
Diarrhoea	This disease is common in kids and causes high mortality. Symptoms include watery and loose feces, depression, dehydration and weakness.	• Ensure that kids drink a lot of water. • Always provide enough clean water. • Maintain a clean environment. • Provide enough feed. • Isolate sick animals. • -or treatment, mix 1 L of clean water, a half teaspoon of salt and 4 tablespoons of sugar or honey. • Use charcoal mixed with water or black tea. • Keep kids warm. • Use antibiotics such as penicillin or sulfonamides or oxytetracycline.

Disease	Description/symptom/cause	Control and Prevention
Brucellosis	This disease causes abortion during last stages of pregnancy. Symptoms include loss of fitness, coughing, lameness, abortion and retention of placenta.	• Maintain good sanitation and use nutritious food. • Vaccinate females with the S19 vaccine at 2–4 months of age. • Slaughter positive cases and destroy the meat. • Report abortions to a veterinary health care provider. • There is no treatment.
Tick-borne disease	This disease is transmitted by ticks. Symptoms include anemia and paleness under the eyelid, fever, muscle tremors, dark red urine, poor growth, skin damage, sudden death, and signs of nervousness such as paddling, convulsions and going around circles.	• Dip the goats in oxytetracycline, imizol, doxycycline or berenil once a week during the rainy season and once every 2 weeks during the dry season, especially when there are many ticks on the body.
Poisoning	This is caused by eating poisonous plants like lantana. Symptoms include uncoordinated movements, salivation and difficulty breathing.	• Do not plant poisonous plants near goat houses. • To treat poisoning, mix 500 g of powdered charcoal and 500 g of powdered limestone (optional) in 10 L of cold black tea, and give an adult animal 1 L of the antidote.
Bloating	This is a condition where the goat gets too much gas trapped in the rumen (stomach) and cannot burp. Symptoms include swelling (budging) of the stomach on the left side, loss of appetite, difficulty breathing, grinding teeth and grunting.	• Regulate food consumption. • Avoid feeding excess amounts of maize and legumes, such as soybeans. • To treat bloating, give the goat 250 ml of cooking oil and walk it animal around to encourage belching. • Do not give water because this will add to the fermentation of grains in the gut and cause them to further expand.
Mange	Symptoms include loss of appetite, loss of hair and scratching against hard surfaces leading to wounds, which can get infected. If left untreated, lesions can extend over the whole body, leading to loss of weight, general weakness and loss of appetite. Severe cases can result in death.	• Build good housing, with good ventilation and adequate space. • Dip or spray the goats periodically. • Only bring healthy animals into the existing flock. • For treatment, scrub the skin and remove the scales and flakes until it bleeds. Then apply any of the following: sodium benzoate, used engine oil or castor oil liquid paraffin. Do this every 2–3 days until the condition clears • Inject with Ivermectin.

8. Gender inclusion in integrated agriculture-aquaculture

Gender equity is a vital component to realize the full potential of IAA systems for sustainable land management, food and nutrition security, resilience and poverty reduction. IAA is not a complicated system. It is easy to apply for smallholder farmers with a lower level of education and a limited resource-base—most of whom are vulnerable women. By adopting IAA systems, these women can strengthen their capacity to cope with social and economic stresses, such as food and nutrition security, raise their household income, increase their empowerment, improve their decision-making and diversify their livelihoods. The result is increased resilience of their rural livelihoods.

IAAS interventions must reflect local settings and the livelihood strategies of women farmers, and IAA must be integrated into their existing farming practices. Most women in rural areas traditionally raise chickens, which offers potential for chicken-fish integration.

Plates 17–20 show several different farmers in Zambia using IAA.

Plate 17. A female farmer in Mpulungu District who owns chickens as her source of livelihood and is a decision-maker over her livestock.

Plate 18. A group of women farmers in Luwingu District who use chicken and goat manure to fertilize their ponds.

Plate 19. A fish farmer in Luwingu District explaining how he integrates his aquaculture farm with poultry.

Plate 20. Women fish farmers in Mbala District, who use manure from their chickens to fertilize their fishponds and gardens, tending to their chickens.

9. Conclusion

IAA is a suitable technology to use in the face of climate change. It is an adaptive measure that can help increase the resilience and adaptive capacity of communities and ecosystems. This system is environmentally friendly and uses water as a scarce resource responsibly. Through diversified food production, IAAS can enhance the livelihoods of smallholder farmers and reduce poverty in rural communities.

10. References

Agrifarming. n.d. Integrated fish and poultry farming, cost and profits. https://www.agrifarming.in/integrated-fish-and-poultry-farming-cost-profits#:~:text=The%20best%20and%20suitable%20fishes,an%20excellent%20feed%20for%20fishes

Asia Farming. n.d. Integrated farming of fish and livestock. https://www.asiafarming.com/integrated-farming-fish-livestock

[AQAI] Apgromalin. 2021. Advantages of integrated duck and fish farming. https://www.aqai.in/blogs/post/Advantages-of-Integrated-Duck-and-Fish-Farming

[C2ES] Center for Climate and Energy Solutions. 2019. What is climate resilience and why does it matter? Climate essentials. https://www.c2es.org/wp-content/uploads/2019/04/what-is-climate-resilience.pdf

Chazya R. 2009. Village chicken and goat production training manual. Ministry of Fisheries and Livestock. Mumbwa, Zambia.

Chibinga M.M. 2016. A training manual on practical village chicken production. Brethren in Christ church. Choma, Zambia.

[CSO] Central Statistical Office. 2010. 2010 Census of Population and Housing National Analytical Report. Lusaka, Zambia: Ministry of Finance and National Planning.

Ekemini M. Okon, Reuben C. Okocha Babatunde T. Adesina, Judith O. Ehigie, Olayinka O. Alabi, Adeniran M. Bolanle, N. Matekwe, Babatunde M. Falana, Adebisi M. Tiamiyu, Isaac O. Olatoye and Olufemi B. Adedeji (2022) Antimicrobial resistance in fish and poultry: Public health implications for animal source food production in Nigeria, Egypt, and South Africa SYSTEMATIC REVIEW article Front. Antibiot., 10 November 2022 Sec. Antibiotic Resistance Volume 1 - 2022 | https://doi.org/10.3389/frabi.2022.1043302

Endebu M, Tagie D and Negisho T. 2016. Fish growth performance in ponds integrated with poultry farm and fertilized with goat manure: a case in Ethiopian Rift Valley. International Journal of Fishery Science and Aquaculture 3(2):40–45.

European Environmental Agency. n.d. What is the difference between adaptation and mitigation? https://www.eea.europa.eu/help/faq/what-is-the-difference-between

Farm Design. 2021 Integrated goat and fish farm. Modern goat fish farming. https://discoveragriculture.com/integrated-goat-and-fish-farming-modern-goat-fish-farming/

[FAO] Food and Agriculture Organization. 2009. Climate change implications for fisheries and aquaculture: Overview of current scientific knowledge. FAO Fisheries and Aquaculture Technical Paper 530. Rome: FAO.

[IUCN] International Union for Conservation of Nature. 2017. Climate Change Gender Action Plan of the Republic of Zambia.
https: //www.climatelinks.org/sites/default/files/asset/document/2017_IUCN_Climate-Change-Gender-Action-Plan-Zambia.pdf

Kakwasha K, Mudege NN, Sichilima T, Sebele M, Nabiwa L and Lundeba M. 2020. Smallholder fish farmer population census report 2020: Northern and Luapula provinces, Zambia. Penang, Malaysia: WorldFish. Program Report: 2020-40.

Kalantary C. 2010. Climate change in Zambia: Impacts and adaptation. Global Majority E-Journal 1(2):85–96.

Kumar S, Dey A, Kumar U, Chandra N and Bhatt BP. 2012. Integrated farming system for improving agricultural productivity. In Bhatt BP, Sikka AK, Mukherjee J, Islam A and Dey A, eds. Study of Agriculture Development in Eastern India. City, Country: Publisher. 205–30.

Leal Filho W. 2011. Experiences of climate change adaptation in Africa. Berlin: Springer.

Little D and Kriengkrai Satapornvanit. 1997. Poultry and fish production: A framework for their integration in Asia. Livestock Feed Resources within Integrated Farming Systems. https://www.fao.org/ag/aga/agap/frg/conf96.pdf/little2.pdf Retrieved 20 August 2022.

Lojewska E and Sakowicz T. 2021. An alternative to antibiotics: selected methods to combat zoonotic foodborne bacterial infections. Current Microbiol ogy (2021) 78: 4037–4049. https://doi.org/10.1007/s00284-021-02665-9

Lundeba M, Steven MC, Wagdy M, Yossa R, Basiita RK, Nyirenda M, Muyuni N and Benzie JAH. 2021. On-farm participatory evaluation of feeding approaches used by farmers for tilapia (Oreochromis macrochir) production in northern Zambia. Aquaculture 549(2022):737747.

[MAL] Ministry of Agriculture and Livestock. 2013. Poultry production manual for extension workers. Department of Livestock Development. Lusaka, Zambia.

Maulu S, Hasimuna OJ, Haambiya LH, Monde C, Musuka CG, Makorwa TH, Munganga BP, Phiri KJ and Nsekanabo JD. 2021. Climate change effects on aquaculture production: Sustainability implications, mitigation, and adaptations. Front. Sustainable Food Systems. 5:609097.

Mbow C, Rosenzweig C, Barioni LG, Benton TG, Herrero M, Krishnapillai M, Liwenga E, Pradhan P, Rivera-Ferre MG, Sapkota T, et al. 2019. Food security. In Shukla PR, Skea J, Calvo Buendia E, Masson-Delmotte V, Pörtner HO, Roberts DC, Zhai P, Slade R, Connors S, van Diemen R et al., eds.. Climate change and Land: an IPCC special report on climate, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems.
https://doi.org/10.1017/9781009157988.007

Ministry of National Development Planning. 2017. 7th National Development Plan 2017–2021: Accelerating development efforts towards Vision 2030 without leaving anyone behind. https://www.mndp.gov.zm/wp-content/uploads/2018/05/7NDP.pdf

[OECD-DAC] Organisation for Economic Co-operation and Development's Development Assistance Committee. 2011. Tracking aid in support of climate change mitigation and adaptation in developing countries. https://www.oecd.org/dac/financing-sustainable-development/development-finance-topics/48708083.pdf

Onada OA and Ogunola OS. 2016. Climate smart aquaculture: A sustainable approach to increasing fish production in the face of climate change in Nigeria. International Journal of Fisheries and Aquatic Studies 4(3):444–48.

Ramanathan K, Sangeeviraman V, Chandrahasan P et al. 2020. Integration of fish culture and poultry rearing in transplanted rice for nutritional security in smallholder farms. Sci R 10:10566. doi: 10.1038/s41598-020-67657-4

Selaledi et al. 2020; Lojewska and Sakowicz 2021 Selaledi AL, Hassan MZ, Manyelo TG, and Mabelebele M. 2020. The Current status of the alternative use to antibiotics in poultry production: An African perspective. Antibiotics 9(9):594. doi: 10.3390/antibiotics9090594.

Singh SK. nd. Integration of fisheries: A potential option to increase farmers' income.

[UNFCCC] United Nations Framework Convention on Climate Change. n.d. What do adaptation to climate change and climate resilience mean? https://unfccc.int/topics/adaptation-and-resilience/the-big-picture/what-do-adaptation-to-climate-change-and-climate-resilience-mean

[WWF] World Wide Fund for Nature. n.d. What's the difference between climate change mitigation and adaptation? https://www.worldwildlife.org/stories/what-s-the-difference-between-climate-change-mitigation-and-adaptation

aiccra.cgiar.org