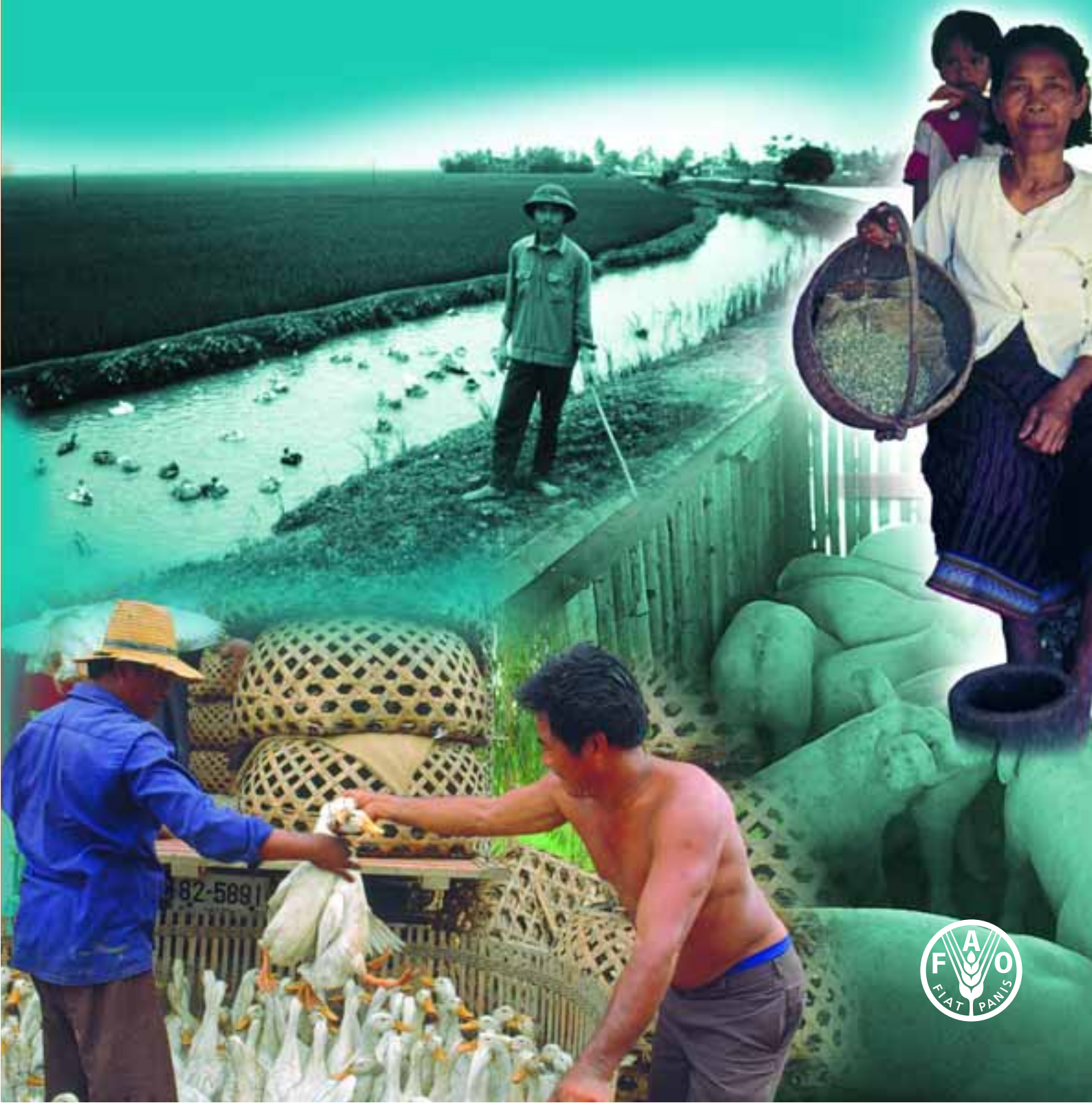


Integrated livestock-fish farming systems



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INLAND WATER RESOURCES AND AQUACULTURE SERVICE
ANIMAL PRODUCTION SERVICE

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Preface

Small farmers in developing countries are poorer than the rest of the population, often not getting enough food to lead normal, healthy and active lives. Dealing with poverty and hunger in much of the world therefore means confronting the problems that small farmers and their families face in their daily struggle for survival. One option for economically and ecologically sustainable development of farming systems is the integration of agriculture and aquaculture.

The various types of aquaculture form a critical component within agricultural and farming systems development that can contribute to the alleviation of food insecurity, malnutrition and poverty through the provision of food of high nutritional value, income and employment generation, decreased risk of production, improved access to water, sustainable resource management and increased farm sustainability.

Livestock production and processing generate by-products that may be important inputs for aquaculture. The main linkages between livestock and fish production involve the direct use of livestock wastes, as well as the recycling of manure-based nutrients which function as fertilizers to stimulate natural food webs.

On a global basis, most cultured freshwater fish are produced in Asia in semi-intensive systems that depend on livestock wastes purposely used in ponds, or draining into them. Much of the vast increase in China's recent inland aquaculture production is linked to organic fertilization, provided by the equally dramatic growth of poultry and pig production. The use of livestock wastes is still needed, even when high-quality supplementary feeds are available and they are still widely used in more intensive aquaculture systems.

The objective of the publication is to provide an analysis of the evolution and current status of integrated livestock-fish systems in Asia, particularly East and Southeast Asia, as well as to provide a sound technical basis for considering their relevance for the planning of livestock-fish systems in Africa and Latin America.

It is hoped that the conclusions and recommendations presented here will be interesting and thought-provoking for a wide audience generally interested in the subject of integrated agriculture-aquaculture, and particularly policy makers, planners, NGOs and senior research and extension staff. It is hoped that the book will stimulate these people at all levels to ensure that agricultural development provides for reasonable rural livelihoods, a clean environment, and adequate food products.

Jiansan Jia - Chief, Inland Water Resources and Aquaculture Service

Irene Hoffmann - Chief, Animal Production Service

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Introduction

Aquaculture is the fastest growing food production sector in the World with annual growth in excess of 10 percent over the last two decades. Much of this development has occurred in Asia, which also has the greatest variety of cultured species and systems. Asia is also perceived as the ‘home’ of aquaculture, as aquaculture has a long history in several areas of the region and knowledge of traditional systems is most widespread. Furthermore, the integration of livestock and fish production is best established in Asia.

In this initial section we introduce the rationale for the study and provide definitions of integrated livestock–fish farming. We then examine the current status and future importance of livestock and fish production being integrated rather than being developed further as specialized, separate activities. Their sustainability and importance in a broader context are then considered.

1.1

Rationale of the study

Livestock–fish production systems develop to satisfy needs if they fit into the resource base or

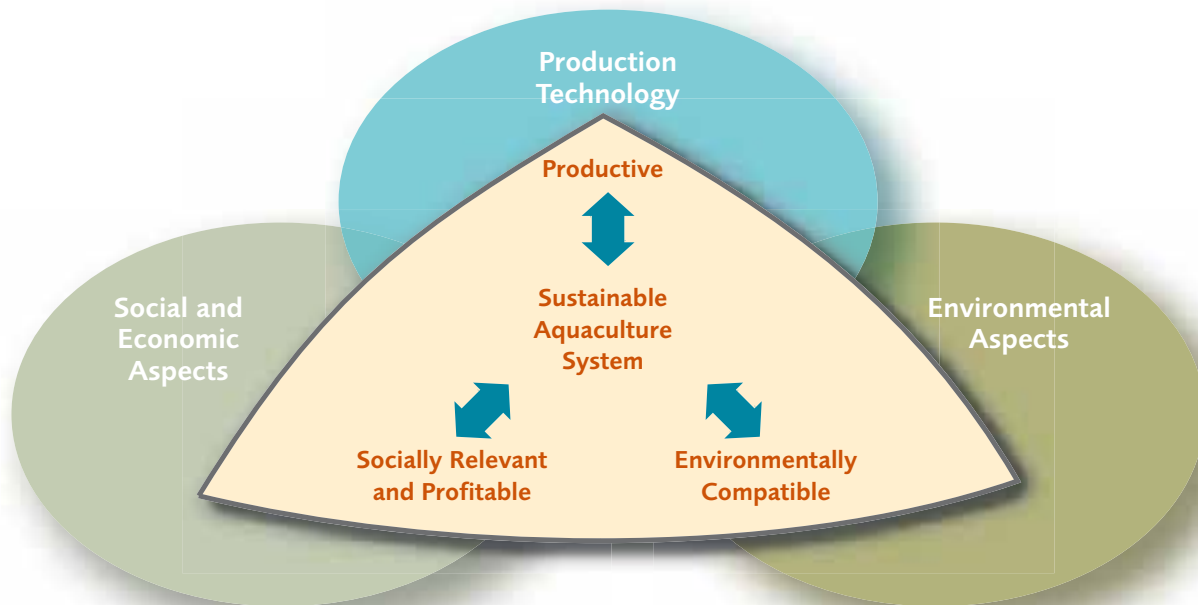
environment, and if they are socially and economically viable. Macro-level factors may also have a significant influence and there are environmental implications, both on- and off-farm, for the development of sustainable systems (Figure 1).

The current status of livestock–fish systems reflects their evolution in response to changing circumstances: the past history of current systems is not generally appreciated; nor is their future potential apparent.

The rationale for this study is to interpret Asian, especially East and Southeast Asian experience in integrated systems through analysis of their evolution and current status and to consider their relevance for livestock–fish planning in Africa and Latin America.

FIGURE 1

The development of sustainable aquaculture systems involves consideration of production technology, social and economic aspects, and environmental aspects



Source: AIT (1994)

1.2

Definitions of integrated farming

Integrated farming is commonly and narrowly equated with the direct use of fresh livestock manure in fish culture (Little and Edwards, 1999). However, there are broader definitions that better illustrate potential linkages. Indeed, the term ‘integrated farming’ has been used for integrated resource management which may not include either livestock or fish components. Our focus is the integration of livestock and fish, often within a larger farming or livelihood system. Although housing of livestock over or adjacent to fish ponds facilitates loading of wastes, in practice livestock and fish may be produced at separate locations and by different people yet be integrated. Chen *et al.* (1994) distinguished between the use of manures produced next to the fishpond and elsewhere on the same farm. A wider definition includes manures obtained from off-farm and transported in bags, e.g. poultry manure, or as a

slurry in tanks, such as for pig and large ruminant manure.

Integrated farming involving aquaculture defined broadly is the concurrent or sequential linkage between two or more activities, of which at least one is aquaculture. These may occur directly on-site, or indirectly through off-site needs and opportunities, or both (Edwards, 1997). Benefits of integration are synergistic rather than additive; and the fish and livestock components may benefit to varying degrees (Figure 2). The term “waste” has not been omitted because of common usage but philosophically and practically it is better to consider wastes as “resources out of place” (Taiganides, 1978).

1.3

Potential linkages between livestock and fish production

The main potential linkages between livestock and fish production concern use of **nutrients**, particularly reuse of livestock manures for fish

production. The term nutrients mainly refers to elements such as nitrogen (N) and phosphorous (P) which function as fertilizers to stimulate natural food webs rather than conventional livestock nutrition usage such as feed ingredients, although solid slaughterhouse wastes fed to carnivorous fish fall into the latter category. There are also implications for use of other resources such as capital, labour, space and water (Figure 3). A variety of factors affect potential linkages between livestock and fish production (Box 1.A).

Both production and processing of livestock generate by-products that can be used for aquaculture. Direct use of livestock production wastes is the most widespread and conventionally recognized type of integrated farming. Production wastes include manure, urine and spilled feed; and they may be used as fresh inputs or be processed in some way before use.

Use of wastes in static water fishponds imposes limitations in terms of both species and intensity of culture. Stimulation of natural food webs in the pond by organic wastes can support relatively low densities of herbivorous and omnivorous fish but not a large biomass of

BOX 1.A

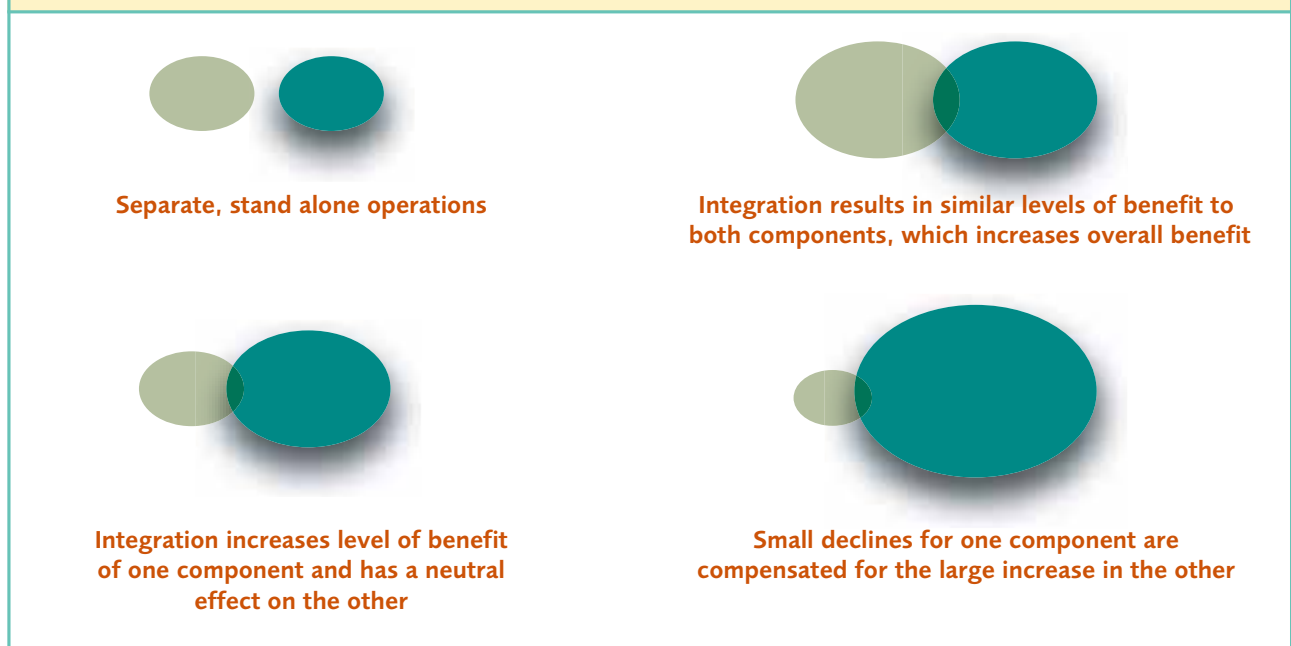
Checklist of key issues affecting linkages between livestock and fish production

- Is there demand for fish species capable of feeding on natural foods generated by fertilization using livestock wastes?
- Are the livestock monogastrics or ruminants?
- Can the wastes be cost effectively collected?
- Will legislation require processing of wastes before use for fish culture?
- Do livestock wastes have a high opportunity cost?
- Will low ambient temperatures (<18°C) restrict waste-fed aquaculture?
- Is fish culture already established based on conventional feeds and systems?

carnivorous fish. These biological processes are also temperature dependent. The optimal temperature range is between 25-32°C although

FIGURE 2

Potential outcomes of livestock–fish integration



waste-fed aquaculture in sub-tropical and temperate zones where temperatures rise seasonally has also been successful. Processing wastes through organisms such as earthworms and insect larvae that feed on them and concentrate nutrients to produce 'live feeds' is an alternative approach to raising fish needing high levels of dietary animal protein. Livestock processing can also provide a wide variety of wastes that vary from dilute washing water to high value meat and bloodmeal that can be used as high value fish feeds or feed ingredients. If enough of these types of feeds are available, high density and intensive production of carnivorous fish species can be supported. Aquaculture may also provide inputs and other benefits to livestock production. A variety of aquatic plants e.g. duckweeds and the aquatic fern *Azolla* have proven potential as livestock feeds; and invertebrates such as snails and crustaceans can be used for poultry feeds.

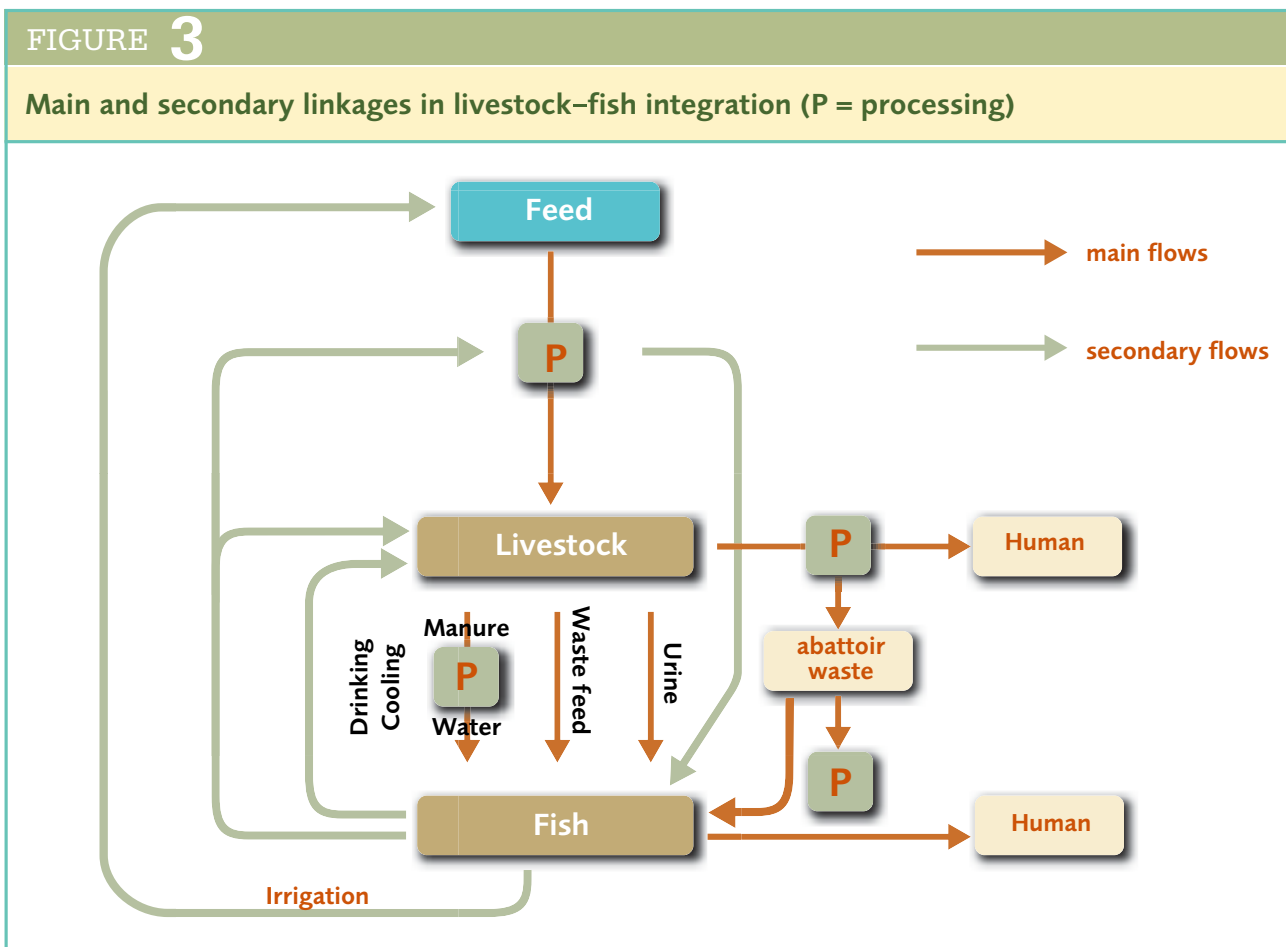
Our study focuses on the integration of fish and livestock. The use of cultured fish or fish

products as livestock feeds, although currently uncommon, holds promise and is reviewed. Other, more minor beneficial linkages between fish and livestock production include use of fish culture water for drinking/bathing livestock and cooling livestock housing. Nutrients contained in culture water and sediments may be used to produce arable crops for livestock. The viability of these options depends on a variety of factors, including the types of livestock and fish that can be raised profitably and the production systems used.

1.4

Relevance of integrated farming

The integration of fish and livestock production is probably closer today, and more important than ever before (FAO, 2000). On a global basis most cultured freshwater fish are produced in Asia in semi-intensive systems that depend on fertilizer



nutrients. Moreover, with increasing need for multipurpose use of water resources, community water bodies used for watering livestock are increasingly stocked with fish seed and their management intensified. Several studies of small-holder aquaculture in Bangladesh, India, Thailand and Viet Nam indicate that livestock wastes are the most commonly used input. Fish yields may not be optimized for a variety of reasons but livestock wastes purposely used in ponds, or draining into them, support the production of most cultured fish in Asia.

An analysis of China, the ancestral home of aquaculture, indicates that whilst intensive practices based on formulated pelleted feed are developing rapidly, much of the vast increase in China's recent inland aquaculture production is linked to organic fertilization, provided by the equally dramatic growth of poultry and pig production. Trends in those parts of Asia which are undergoing rapid industrialization and urbanization suggest that livestock–fish systems can retain a relative advantage over intensive aquaculture for production of low-cost carps and tilapias. A strong link to the use of livestock wastes remains even when high-quality supplementary feeds are available and widely used.

A major issue is the potential competition for, and relative efficiency of the use of, limited amounts of feeds between livestock and farmed fish. This has both local and global implications. Supplementary feeds, such as ricebran and oil cakes, which are traditionally fed to livestock, are often in demand for feeding fish. Continued growth in demand for livestock and fish has raised alarm bells over the sustainability of feed supplies and the impacts of such growth on the environment.

1.5

Sustainability issues at micro- and macro-levels

Sustainability may be considered at global, national, regional, community and household level and from a variety of perspectives. Sustainability as defined by an ecologist, may be

very different to that by an economist, but most can support the essence of that in the Brundtland Report (WCED, 1987) which incorporates social and economic as well as environmental concerns. Important questions relate to the role of integration of aquaculture with livestock to improve sustainability of food production in socially and economically advantageous ways while safeguarding or improving the environment. For this to occur, the roles of culture and institutions both have to be considered also since they are major forces for change or conservatism. A major issue of this book is how integration, rather than specialization and separation, of livestock and fish production can enhance sustainability at all levels and perspectives.

BOX 1.B

A widely used definition of sustainability

"Sustainable development is that which meets the needs of the present without compromising the ability of future generations to meet their own needs"

Source: WCED (1987)

1.5.1 MICRO-LEVEL

The interpretation and measurement of sustainability have become focal points of rural development. In a smallholder farmer's world, key parameters of sustainability have been identified as high levels of species diversity, nutrient cycling, capacity (total production) and economic efficiency (Lightfoot *et al.*, 1993; Bimbao *et al.*, 1995; Dalsgaard *et al.*, 1995). At the micro-level, watershed, community, farm, plot and pond may be used as a basis for assessing sustainability, but the role of people is central to development.

Most poor rural people do not rely entirely on their own land to sustain them. Typical livelihoods are complex and depend on a variety of resources, many of which are off-farm (Ellis, 1992). At the heart of the issue of 'sustainability' are peoples' livelihoods (Box 1.C). Holistic

thinking is required to analyse and describe livelihoods with a focus on peoples' relative strengths rather than 'needs'. Building up assets is a core component of empowerment (Figure 4). How the inclusion of intensified management of aquatic resources can support, or detract, from this process is indicated in Table 1.1.

People base their livelihoods on a range of assets in addition to financial capital that include natural, human, physical and social capital. A pentagon can represent these five types of asset or capital although in practice

there is overlap between them (Figure 4). Understanding trends in peoples' assets over time can indicate if positive or negative developments are occurring, and if livelihoods are deteriorating or improving. The approach can be applied on a community, group or household level to inform and guide the development process. Knowing about the assets of different wealth and social groups in the same community can allow better targeting of poorer people and monitoring of changes that occur. The impacts of shocks of various types, and how assets are used to reduce vulnerability, are important aspects of assessing livelihoods.

Forging links between ecosystem theory and farming system analysis (Dalsgaard *et al.*, 1995) can be useful, provided that the results are placed within a broader framework of sustainability issues. A range of different system attributes has been identified that provides measures of how livestock and fish can improve sustainability of farming systems (Table 1.2). As sub-systems within the wider farming system (Edwards *et al.*, 1988), fish culture and livestock can improve nutrient recycling and concentration. This feature is important in both nutrient-rich, peri-urban systems and nutrient-poor, rural situations (Little and Edwards, 1999). Diversity, stability and capacity can all be enhanced through inclusion of livestock

BOX 1.C

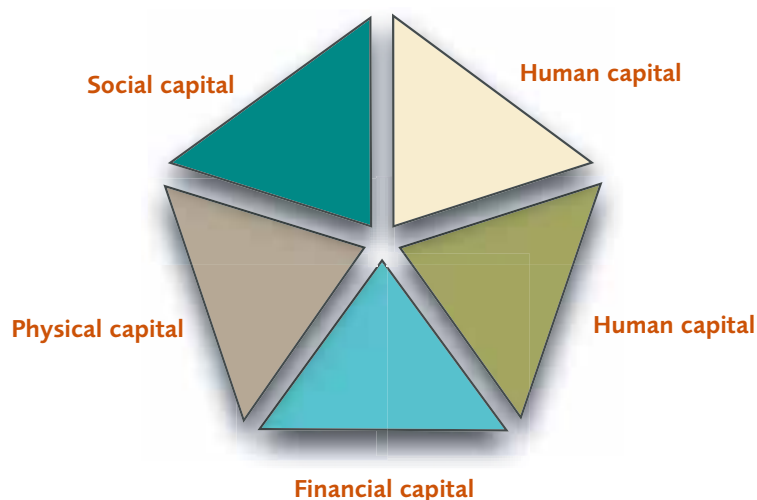
Livelihoods defined

"A livelihood comprises the capabilities, assets (including both material and social resources) and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stresses and shocks and maintain or enhance its capabilities and assets both now and in the future, while not undermining the natural resource base".

Source: Carney (1998)

FIGURE 4

Asset pentagon to analyse sustainable rural livelihoods



Source: Carney (1998)

TABLE 1.1

How the integration of fish culture into small-holder crop/livestock systems affects asset accumulation and livelihoods

Capital assets	Possible impacts of introduction of intensified aquatic resource management	
	Positive	Negative
Natural	<ul style="list-style-type: none"> • Reduced pressure on remaining natural aquatic resources can relieve pressures on biodiversity and integrity of remaining natural habitats 	<ul style="list-style-type: none"> • Increased pressure on natural resource stock for water, nutrients and fish seed
Social	<ul style="list-style-type: none"> • Increased fish and other aquatic products available for enhancing social relationships 	<ul style="list-style-type: none"> • Increased discordance on use of resources within household, increased opportunities for theft, increased conflicts over water (quantity and quality) available for other purposes
Human	<ul style="list-style-type: none"> • Skills and knowledge developed that can be used to further diversify livelihood strategies • Improved nutrition enhances physical and mental health 	<ul style="list-style-type: none"> • Competition with more vital activities for time and attention • Extra labour burden and change in use of nutrient resources could reduce physical and mental health
Physical	<ul style="list-style-type: none"> • Improved potential for diversification of farming systems and livelihoods generally through transformation of land and water holding to reduce risk to both flood and drought • Physical assets may be multipurpose e.g. for communication and machinery 	<ul style="list-style-type: none"> • Reduced area available for staple crops
Financial	<ul style="list-style-type: none"> • Improved overall income and regularity of income, credit worthiness, and savings • More diversified production reduces financial risk 	<ul style="list-style-type: none"> • High investment cost for pond construction may cause indebtedness that poor subsequent management cannot repay

Framework for role of capital assets in sustainable livelihoods adapted from Scoones (1998) and Carney (1998)

and fish on farms, as can both economic efficiency and the scope for future change or ‘evolvability’.

The greater ecological similarity of low external input than intensive systems to natural ecosystems reduces adverse environmental impacts (Kautsky *et al.*, 1997). But very low input systems, especially in nutrient-poor environments, may not adequately support livelihoods, driving poor people to ever more extractive and unsustainable practices off-farm. Small external nutrient injections may enhance performance or help to regenerate degraded agro-ecosystems

(Kessler and Moolhuijzen, 1994). The productivity and stability of farming systems in Machakos, Kenya, improved considerably as incomes from off-farm employment were reinvested in agro-forestry, livestock and horticulture. Intensification of livestock and soil management have also reduced land degradation in heavily populated parts of Uganda (Lindblade *et al.*, 1998). Integration of livestock and fish at a community or watershed level may have more potential than household-level in some situations.

TABLE 1.2

How livestock and fish improve the sustainability of farming systems

System attribute	Livestock
Nutrient recycling	Feeding crop byproducts such as ricebran and terrestrial and aquatic plants to livestock increases recycling of nutrients within the farm. Pigs are used particularly for this purpose in parts of China and SE Asia
Nutrient concentration	Feeding off- and on-farm feeds can allow concentration of nutrients, and act as a pathway for nutrients to be cost-effectively gathered or harvested from common property. Ruminants are important for this aspect of enhanced sustainability
Diversity	Most small-holder farms manage a range of livestock that utilize the variety of feed resources available. Important advantages include pest control, recycling, manageability, economic reasons (risk aversion and cash flow)
Stability (resistance to change)	Livestock are a stabilizing influence, reducing perturbation on households during time of physical or social stress. Their variety of uses (draught, fertilizer, social value, fuel, cash, food) allows small-holders to better maintain productivity when faced with change
Capacity	Livestock waste improves soil quality and fertility; grazing can improve species richness and reduce soil erosion
Economic efficiency	Livestock products are often the major source of cash in small-holder systems. Having a variety of livestock types improves versatility with respect to investment, cash flow and risk aversion
Evolvability	Dominance of commercial livestock systems threatens the scope for small-holder production to change in response to demand

Fish	Notes
Nutrients from other sub-systems in the farm are retained in fishpond sediments and water and can be used for crop production	Use of livestock wastes in fishponds may be the most practical way to reduce nutrient losses, especially N
Natural and stocked fish can harvest nutrients from common property for direct human food or use in livestock diets	Overgrazing of common land by ruminants may lead to deterioration, increased erosion and declining sustainability of the surrounding watershed or ecosystem
Efficiency of polycultures within aquatic systems in exploiting the range of aquatic niches. Control of livestock and human pests with an aquatic phase within the life cycle	Increasing diversity of livestock and fish may complement or compete within the farming system. Whereas increased amounts of monogastric waste are valuable for planktivorous fish, grass carp and ruminants may compete for limited amounts of grass
Maintenance of a water body necessary to raise fish improves the stability of water availability for the whole farming system	Livestock can be a contributing factor to destabilization, especially through deforestation, overstocking and soil erosion
Increased water and nutrient holding improves productive capacity around the pond. Sealing of pond traps nutrients and prevents loss to ground water	Fertile ponds may not contaminate groundwater significantly but more research is needed
Small individual size of fish often improves local marketability. Polyculture and perennial water increases opportunities for strategic marketing	Returns to labour are often attractive for livestock and fish production, and integration is particularly favourable. Integration reduces market risk and improves flexibility
Aquaculture systems are generally recent and are evolving rapidly around resources and markets. The dominance of small-holder compared to commercial production, and importance of aquaculture and fisheries as suppliers of fish, are major issues with policy implications	Concept coined by Pullin (1993) to describe the scope for future change of any system

1.5.2 MACRO-LEVEL

Sustainability viewed at a macro-level may include global, national, regional and watershed contexts. The expected dramatic increases in global trade following recent WTO agreements are expected to have wide ranging impacts on the nature of food production and viability of farming systems. Agribusiness is positive about the effects such measures will have on sustainability of food product (Box 1.D) but other groups fear a rapid undermining of poorer national economies and marginalization of small-holders with little market leverage.

Global trends in resource use for livestock and fish production, trade and consumption are important for understanding constraints at the

BOX 1.D

Agribusiness view on sustainability

It is generally accepted that intensification of livestock and fish production is required as low production levels do not meet people's needs. The major issue is the level of intensification that can support overall sustainable development.

The feed and pharmaceutical industries make the following claims:

Aspects of intensification that support sustainable development:

- **intensive agriculture allows livelihoods to be sustained through increased production to satisfy needs, without the need to further encroach on the natural environment with losses to biodiversity;**
- **removal of political and trade barriers that artificially support agriculture and lead to expensive surpluses;**
- **high yield agriculture can protect the environment by reducing soil erosion e.g. use of minimum tillage, intensified ruminant production can reduce greenhouse gases, and**
- **without veterinary medicines, livestock in Europe would need to increase from between 25 percent to 89 percent to maintain existing production levels.**

farm, or even plot or pond level. One example of how macro and micro-level sustainability issues can interact, and be affected by institutions, is the changing basis of pig and fish production in the Red River Delta of Northern Viet Nam (Box 1.E).

Pig and poultry production using modern systems have been challenged as unsustainable in the long term on a global basis because of dependence on concentrates, which are based on non-renewable, fossil-fuels (Preston, 1990). Examples exist where modern systems, following 'shocks', have collapsed. These include oil exporting countries where oil price decline, and associated revenues made imported concentrates and poultry production uneconomic. Cuba saw major disruption in its imported, concentrate-based livestock industry as Soviet Union support was withdrawn and favourable terms of trade shifted. Even if concentrate feeds can be used economically, and the wastes productively reused for aquaculture, there may be inequities in the system that prove unsustainable in the longer term. Thus, an analysis of current systems using sustainability indicators can lead to the development of relevant research agendas. Given its complexity, some advocate the use of consensus indicators of sustainability in aquaculture production (Caffey and Kazmierczak, 1998).

The need for alternatives to the narrow range of feed ingredients used in most concentrates has been identified as urgent, especially for the tropics where little research has been conducted so far (Preston, 1990). In China, the substitution of semi-intensive aquaculture integrated within farming systems by intensive, feedlot production has been advocated on the grounds of improved productivity and reduced negative environmental impacts (Box 1.F). The analysis, though flawed, does identify a general tendency towards intensification of aquaculture. This may have particularly large impacts since intensive aquaculture is relatively more profligate than livestock in its use of feed resources and is more polluting. The major species raised intensively (salmonids and shrimp) are fed diets high in fishmeal (Naylor *et al.*, 1999) and often have large impacts on the local environment. Potentially the intensification of semi-intensive culture of carps

Challenges to sustainable farming in the Red River Delta, Viet Nam

In this region of historically high population density, both traditional farming systems and the 'green revolution' have failed to sustain livelihoods alone. Sustainable central and local level institutions have been critical to the maintenance of irrigation and flood prevention structures essential to maintain productivity in this area characterized by climatic perturbations¹. Government policy changes towards a market system with increased availability of inorganic fertilizers, livestock feeds and breeds and fish farming systems are highly productive, use many external inputs and recycle intensively but recent studies indicate that sustainability is threatened by a declining capacity as soils become acidic². Shortages of organic inputs, and excess inorganic fertilization, may exacerbate these problems. Traditional household pig production is valued for its role in asset accumulation and provision of organic manure for field crops. Certain

developments may further undermine the sustainability of the system by reducing the availability of pig manure for application to the land:

- Government policy change towards support for industrial pig production, leading to concentration of the national herd among fewer, larger producers, and
- increase in aquaculture leading to a demand for more inputs, including pig manure.

Changes in demand are also occurring:

- market for more and leaner pork, increasing demand for balanced feeds i.e. concentrates and modern strains of pig, and
- increase in demand for tilapia³, which has become dominant in other parts of Asia where commercial, feedlot livestock–fish occurs.

Source: ¹Adger (1999); ²Patanothai (1996); ³Binh (1998)

an tilapias will have even greater impacts on the environment through raising demand for such feeds (Naylor *et al.*, 1999).

Difficulties in maintaining feeds or disposing of wastes will probably be only part of the problem of sustaining intensive livestock and fish systems on a macro-level scale. Control of pathogens may prove a more important constraint and pose greater threats to human populations (see 6.1.4). Densities of pigs exceed 9000 animals km⁻² in parts of Western Europe as economies of scale and demand for cheap pork favour intensified production close to concentrated markets. The cost of disease epidemics such as classical swine fever, and the difficulties in their control at such levels of density, are prompting a rethink and new legislation (MacKenzie, 1998). Similar experiences are occurring with intensively raised fish such as the Atlantic salmon and black tiger shrimp. Control of pathogens through isolation is particularly problematic because of

the need for water exchange in intensive systems.

High input, export driven agriculture (agronomy, animal husbandry and aquaculture) is more likely to be non-diverse (monoculture), highly extractive and polluting (little recycling) and unstable in the face of environmental change. Moreover, its economic efficiency can be drastically affected by the vagaries of global markets. Smaller livestock units spread more evenly, based on local production of feeds and disposal of wastes, are likely to improve the sustainability of the livestock and associated farming systems.

Intensification is important, however, to ensure that smaller scale systems are economically viable and sustainable. Improvements in productivity at the local level have also been shown to be important globally. Low productive ruminants have been implicated in the increase in greenhouse gases, which could undermine sustained food production worldwide (see 4.2.1).

BOX 1.F

A decline in integrated farming in China?

Rapid increases in production of cultured freshwater fish have occurred in China since 1985-86, the time of the Chen *et al.*, study¹. Economic growth both created demand and the resource base to support an estimated 400 percent increase in production between 1985 and 1995. It has been estimated that by 1996, 40 percent of total production was based on 'aquafeeds', complete and incomplete feeds from small and large feed mills². This infers that the other 60 percent (6.56 tonnes) were still dependent on 'no inputs' or 'organic farming'. This level of production is nearly 250 percent of that recorded in 1985, suggesting that integrated farming, far from being redundant, has expanded massively.

Since these systems are based primarily on waste from livestock production, which has also soared, any reduction in recycling in fish culture might further impact the wider environment that is rapidly deteriorating. Although aquaculture itself is acknowledged as partly responsible for the general decline in surface water quality that threatens further expansion, they² suggest that traditional manure-based integrated systems are the 'most significant' contributors. This is at odds with any other comparison of nutrient accounting

which conclude that in semi-intensive pond culture, most nutrients are retained within sediments that can be removed occasionally and utilized locally³.

The expected rate of pond expansion² (1-3 percent annually) suggests that even as availability of improved feeds encourages intensification, semi-intensive practices will dominate in the foreseeable future. Lack of self-sufficiency in food grains and protein concentrate could moderate tendencies towards intensive, feed-only based fish culture systems in China. Demand for 'fed' fish species is increasing rapidly but of the major species in the category tilapia, as a filter feeder, is known to be very cost effectively raised through fertilization and feeding⁴. Filter feeding carps still represent 38 percent of total production and registered an annual increase of 13 percent in 1996². These levels of growth are more sustainable than those recorded for high priced luxury species (>40-80 percent year⁻¹) such as eels and turtles for which markets are quickly saturated and production costs highly sensitive to imported feed ingredients.

Source: ¹Chen *et al.* (1994); ²Cremer *et al.* (1999); ³Edwards (1993);
⁴Diana *et al.* (1996)

Evolutionary Development of Integrated Livestock-Fish Farming Systems in Asia

Understanding how farming households meet their needs is essential to assess the likely adoption of fish culture. A study of the evolutionary development of farming systems provides a useful framework since the nature and intensity of farming activities may indicate the likelihood of fish culture being appropriate. We analyse the factors that have stimulated intensification of farming and relate this to prospects for integration of livestock and fish production. Agricultural development has been linked to the pressures of human population growth and we also examine this effect, together with the impacts of changes caused by urbanization and industrialization.

2.1

Systems and scale

A schema of the possible evolutionary development of integrated farming systems is given in Figure 5. Settled agriculture is divided into three phases to indicate the potential role of integrated farming, particularly with respect to smallholder farmers in less developed countries (LDCs). Pastoral nomadism and shifting cultivation have limited aquaculture potential.

Pastoral systems occur in arid regions in which seasonal availability of grazing limits carrying capacity of livestock and nomadism is a necessary part of a livelihood strategy. This movement of both pastoralists and shifting cultivators has necessarily constrained development of fish culture. The limited extent and duration of surface waters in arid regions also constrains natural fish production; and fish consumption is usually unimportant or absent among peoples living in such areas. Harvesting wild stocks generally remains important for aquatic foods after settled agriculture is well

developed, whereas hunting and gathering terrestrial food declines rapidly as agriculture evolves.

The evolutionary development of both livestock and fish production can be classified within a schema derived from the same broader farming systems context (Figure 6). Settled agriculture I is typical of many pre-industrial societies where there is little integration between crops and livestock managed principally for draught and to meet social obligations. If fish culture occurs it is normally at a very extensive level and closely associated with management of wild fish stocks. In settled agriculture II, the production of livestock and crops are more intimately linked, with livestock fed on crops and crop by-products and their manure essential for maintaining soil fertility. Use of N fixing plants together with other inputs such as nightsoil is also a common strategy for maintaining productivity. It is in this context that most traditional integrated fish culture is found. The trend towards industrial monoculture (settled

agriculture 3) is a model followed by both livestock and fish production and is widely adopted in developed economies. Recently however, environmental concerns about heavy use of agrochemicals and waste disposal, consumer pressure and legislation are leading to some return to a more balanced approach to food production.

The tendency to develop more intensive farming systems that produce more food per unit area per unit time has traditionally been linked to increasing population pressure. Global population is expected to rise further from the current level of 6 billion, and may double before stabilizing, even at the most optimistic projections. Global population is split more or less equally between urban and rural areas but urban areas are expected to surpass rural area in population around the year 2005 and to account for 60 percent of the total by 2020 (UN, 2000).

Population pressure has not occurred, nor exerted its impact on intensification of food production evenly. Historically more fertile, well-

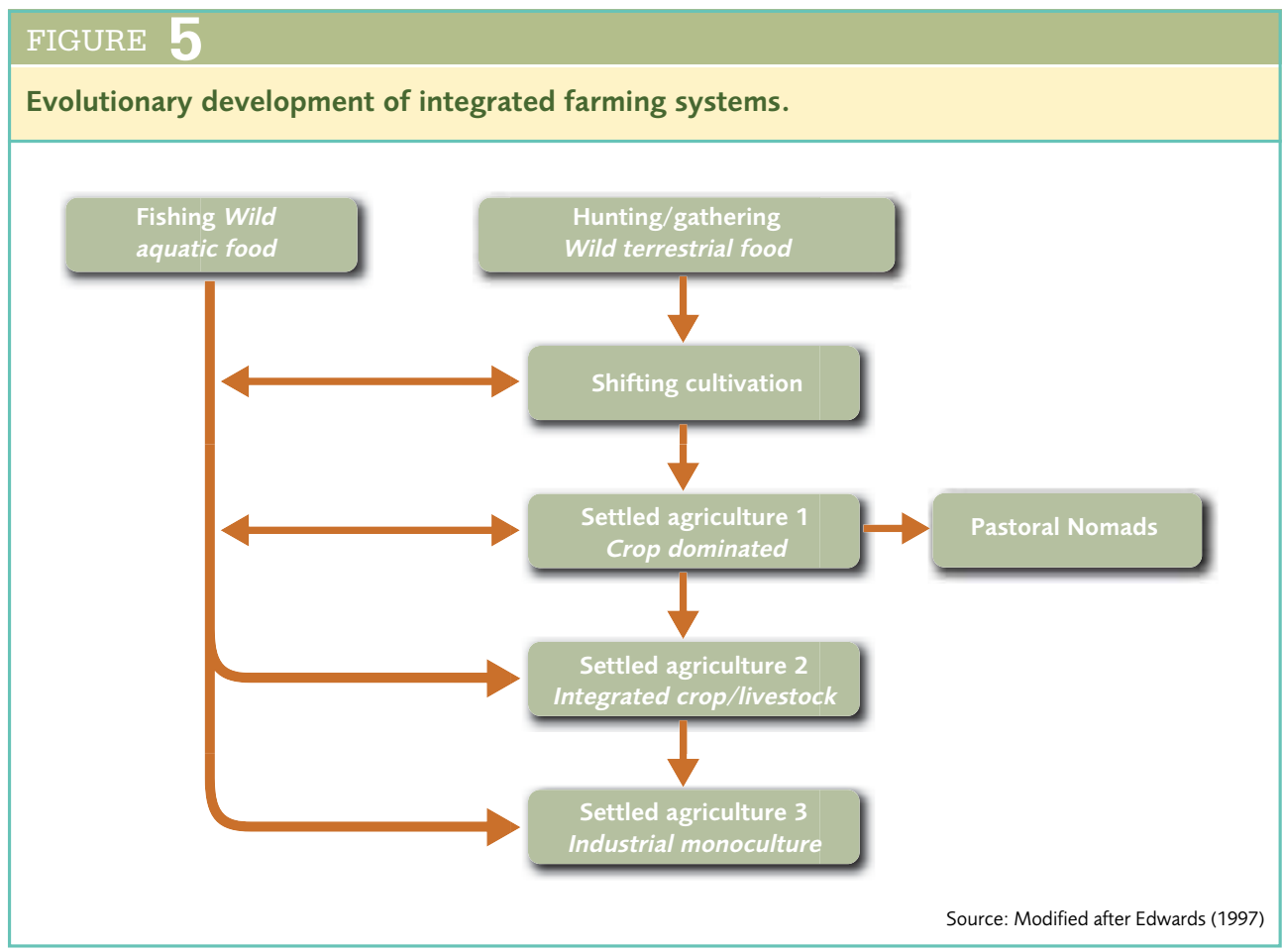
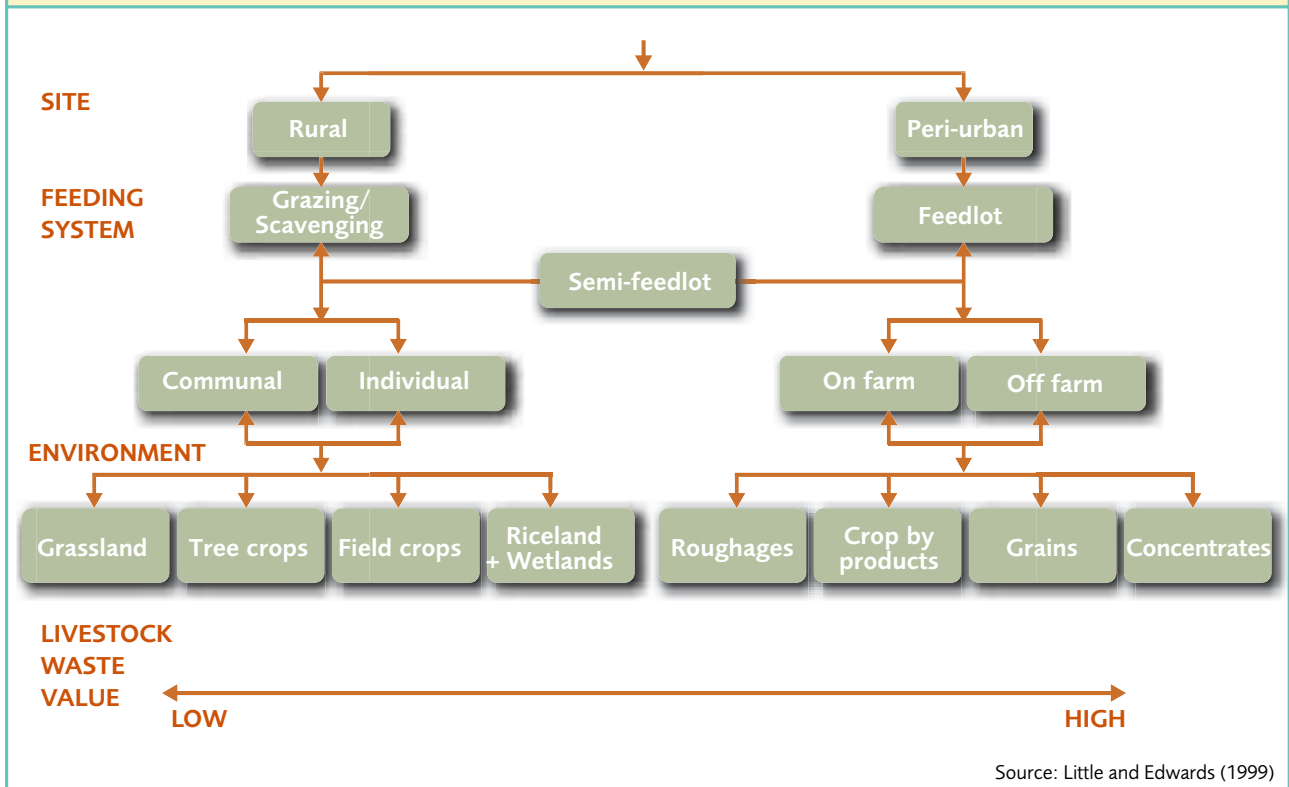


FIGURE 6

Classification of livestock production and relationship to value of livestock waste for aquaculture



Source: Little and Edwards (1999)

watered environments have had greater productive potential and supported higher human populations. Thus, well-endowed floodplain agroecosystems in Asia have become the site of the most intensive traditional agricultural practices. Globalization of trade pre-dating the colonial era, industrialization and major changes in human medicine have fundamentally de-linked food production and human population densities. If the concept of agro-climatic population, or the population in terms of food production capacity is used, today semi-arid zones are typically under much greater population pressure relative to land endowments than humid areas (Binswanger and Pingali, 1988). Although historically most of Africa has had little pressure on land resources, by 2025 the majority of the continent will comprise high-density countries requiring highly productive agricultural techniques.

Accelerating urbanization has stimulated demand for industrial food production in both

developing and developed countries. Industrial food production requires intensive applications of resources, particularly energy, nutrients and water and is dependent on scientific knowledge. Farming operations spanning a wide range of intensity levels can be found increasingly within the same country although some doubt that coexistence of less intensive production systems with industrial methods is possible over the long term. Integration of livestock and fish, in which one or both sub-systems does not become entirely agro-industrially based, may better fit the limited resource base of smallholders and improve environmental sustainability.

2.2

Environmental effects

Environments have shaped cultures and dietary norms and taboos that in turn explains current

distribution and dependence on livestock and fish. Recent anthropological research has shown that the concepts of the 'sacred' cow and 'abominable' pig have an environmental basis (Harris, 1997). The advantages of ruminants that digest cellulose and thus do not compete for food with humans, together with their more multipurpose attributes, are the bases for the cultural bias. The rejection of fish as food is also common among people in arid environments where surface water and natural stocks of aquatic animals are rare. The lack of large livestock in traditional slash and burn-based societies in Africa, and elsewhere, can be related to a low requirement for tillage, and their poor survival because of the tsetse fly (Binswanger and Pingali, 1988). Animal protein needs could be met by the harvest of game and wild fish and intensification of livestock and fish production was unnecessary (Little and Edwards, 1997) at the low human population densities found in typical swidden agricultural societies.

If natural supplies of wild stocks are particularly rich, much higher population densities may be supported, provided human dietary energy needs are met. The rice-fish societies of lowland Asia are good examples of this situation where diets based on cultured, calorie-rich rice were balanced by diverse, aquatic plant and animal food gathered from the floodplains. Indeed, whilst natural fish supplies remain adequate, there is little interest in fish culture (Gregory and Guttman, 1996). Seasonal inundation of flood plains that led to dependence on aquatic-based food sources probably also limited the importance of livestock because of seasonal shortages of feed.

In contrast, arid environments have stimulated pastoral systems in which low densities of ruminant livestock are grazed on extensive, common property pastures. The challenges associated with increasing productivity in such marginal, community-based resources systems are similar in both water-short, livestock-based pastures and water-rich, communally exploited wetlands. Major issues include how intensification can occur whilst safeguarding equity and the environment (Table 2.1).

2.3

Crop domination

In contrast to most shifting farming, in which livestock is relatively unimportant, or pastoralists in which livestock dominate, animals fulfil small but important roles within the household in settled agriculture. Furthermore, settled agriculture has much greater potential for aquaculture. Most land is reserved for crops and livestock are kept mainly for draught in settled agriculture phase I. Pigs and poultry may also be kept in small numbers, and usually scavenge and are fed wastes from the household. There is little integration between crops and livestock, largely because the number and nutritional status of the livestock are low. Ruminants depend mainly on limited rough grazing of harvested fields and common land. Limited crop diversity, as well as little recycling of crop residues and manures, are characteristics of crop-dominated systems. Such resource-poverty is typical of most small-scale farmers in developing countries today, except those that have leap-frogged to settled agriculture III through the green revolution. Crop-dominated systems include crops grown as the dietary staple such as rice and maize, often for subsistence, together with other crops grown for cash. Various levels of intensification may be evident e.g. irrigation, terracing, fertilization and weeding. Orchard crops and vegetables are often grown in home gardens.

In some parts of the developing world, such as Southern Viet Nam, both livestock and fish are relatively important even in crop-dominated livelihoods (Ogle and Phuc, 1997) but the potential is far from realised by most households which rely mainly on wild fish. One survey indicated that farms in Central Thailand, which had diversified away from rice monoculture were more likely to use animal waste for fish culture than farms continuing to concentrate on rice production (Figure 7). Such intensification of livestock in settled agricultural phase I is often limited by poor feed availability. Also, draught animals tend to be used irregularly so although their productivity is low, farmers have little

TABLE 2.1

Comparison of common property management and scope for intensification in water-scarce and flood-prone environments

Characteristic	Environment		Notes
	Water-scarce	Flood-prone	
Dominant livelihood strategy	<ul style="list-style-type: none"> • Pastoral ruminant production 	<ul style="list-style-type: none"> • Aquatic food harvest 	
Density and yield area ⁻¹	<ul style="list-style-type: none"> • Low 	<ul style="list-style-type: none"> • Low 	
Stock and habitat enhancement	<ul style="list-style-type: none"> • Disease control • Improved water availability • Selective feeding 	<ul style="list-style-type: none"> • Maintenance/ enhancement of habitats • Stocking of juveniles 	<ul style="list-style-type: none"> • High demand for indigenous species
Indigenous species	<ul style="list-style-type: none"> • Largely replaced but interest in return to ranching 	<ul style="list-style-type: none"> • Typically still dominate though increasingly small, low value species 	
Challenges to sustainability	<ul style="list-style-type: none"> • Overstocking • Range degradation 	<ul style="list-style-type: none"> • Over-exploitation • Siltation • Irrigation structures and management 	
Challenges to equity	<ul style="list-style-type: none"> • Herd accumulation by richer individuals 	<ul style="list-style-type: none"> • Water extraction for surrounding agriculture including aquaculture by richer individuals • Intensification results in lack of access for the poor 	

interest in improving their performance. Parallel development of intensive feedlot operations may also reduce opportunities for small-scale pig and poultry production (Little, 1995).

Widespread adoption of fish culture may not have occurred within crop-dominated systems, even when fish are valued and consumed. Stocks of wild fish may remain at a level that satisfy rural peoples' needs. Poorly developed on-farm water storage, or a lack of seed or knowledge may also constrain adoption. Traditional aquaculture in the valleys of upland areas of Indochina and Southern China, where population densities are high and wild fish stocks are very limited, suggest that aquaculture can evolve under these conditions, but that linkages between livestock and fish were relatively weak. Intensification of fish production based on animal manures would be constrained by the limited numbers of livestock and

BOX 2.A

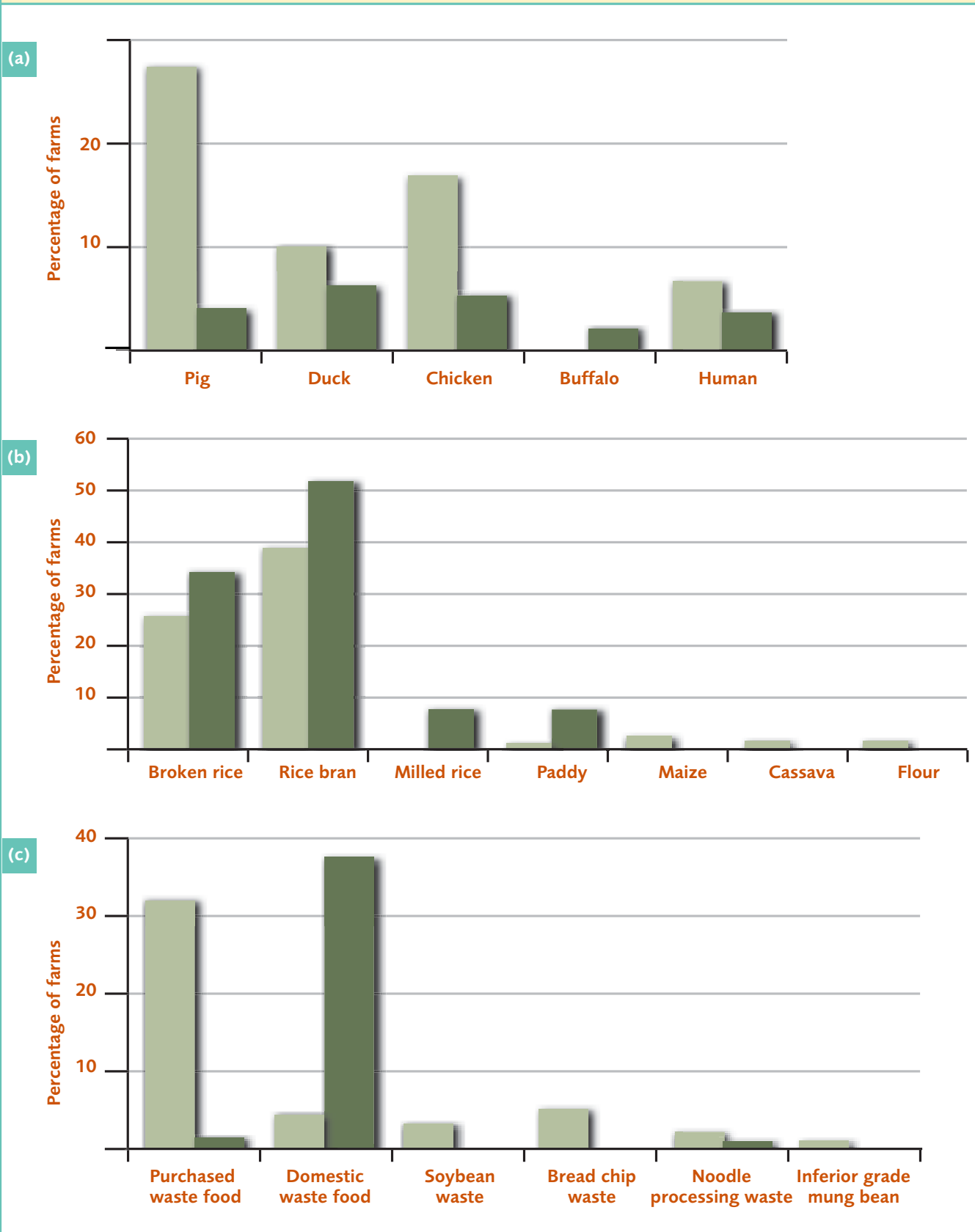
Disease constrains livestock production

Aquaculture is a recent development among certain ethnic minorities, such as the Hmong in upland areas of Indochina, for whom pig production is both traditional and important. Under current conditions disease is a greater constraint to expansion of pig production than feed availability; more arrowroot or cassava can be grown, or vegetables and banana stems cut from the forest, if supplies of maize are limited. Pig wastes are used extensively, with wastewater directed towards opium-poppy growing plots, but the siting of pens over fish ponds has been adopted by some households.

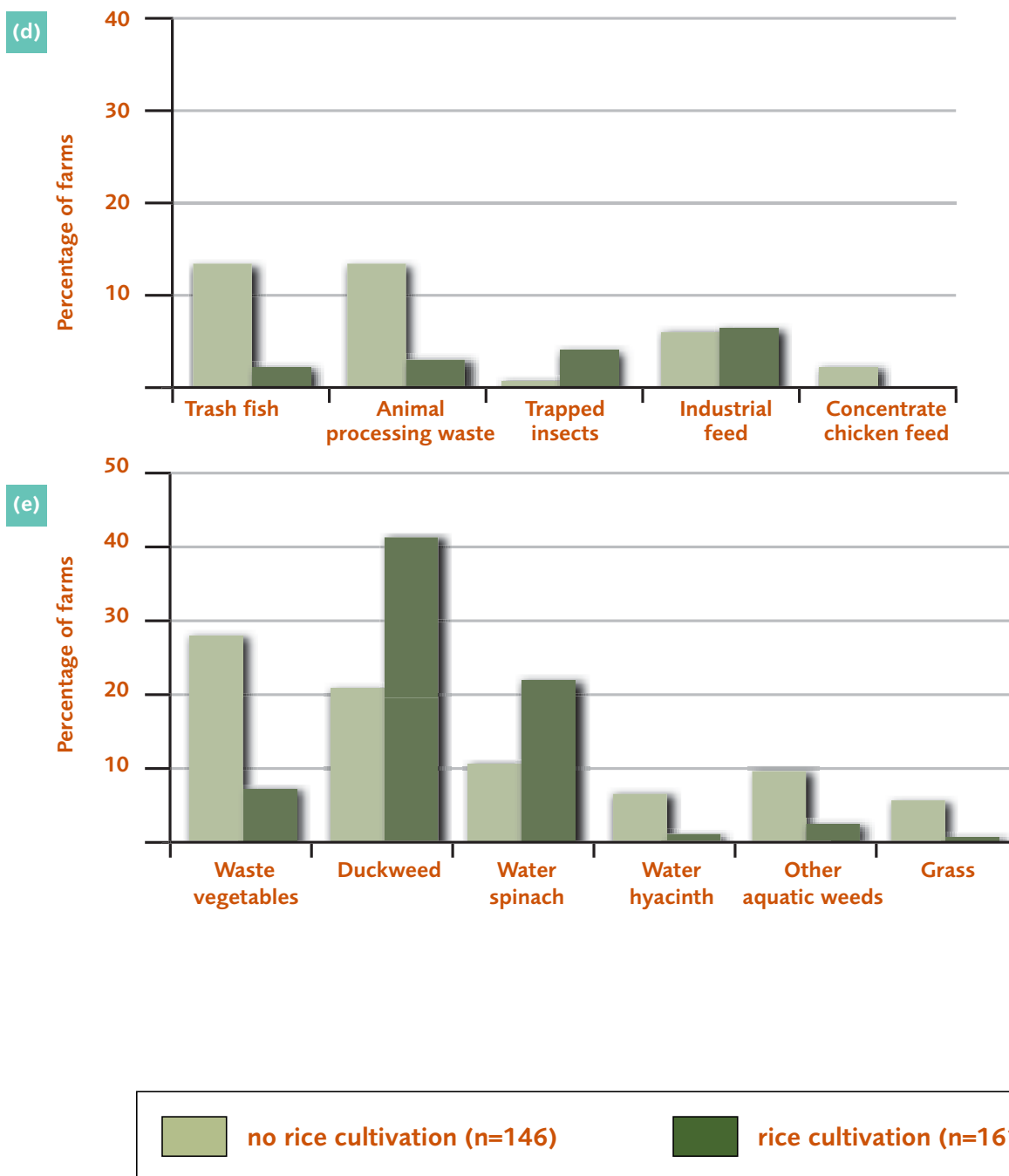
Source: Oparaocha (1997)

FIGURE 7

Percentage of farms in Central Thailand using various fertilizer and supplementary feed inputs for fish agro-industry (d) animal by-products and animal feed (e) vegetable matter.



culture (a) manure (b) rice and grain products (c) waste food from human consumption and



Source: AIT (1983)



Small flocks of mixed poultry, allowed to scavenge for natural feed and given small amounts of supplementary feed such as paddy grain or ricebran, are common in Asia

difficulties in collection and use of their waste. Livestock diseases also constrain inventories of livestock in many instances (Box 2.A)

2.4

Integrated crop/livestock

The integration of livestock with crops, or mixed farming, is the major characteristic of settled agriculture phase II. Livestock fed arable crops and improved pasture produced on the farm is the main focus. Crops are intimately integrated with livestock as manures are used to maintain soil fertility together with N fixing legumes. Much of the farming in Western Europe and Eastern USA was of this type between 1850-1945. However, the recent increased control of nutrient effluents has begun to favour this form of farming again over industrial monoculture.

The origins of mixed farming lie in increased demand for livestock products from urban centres. Various methods were adopted to increase livestock such as production and

feeding of turnips to livestock during the winter and the rotation of cereal crops with legumes such as clover. More inputs such as nightsoil from urban centres, followed by inorganic fertilizers and feed concentrates, increased livestock densities and soil fertility.

Integration of fish culture into farming systems has developed in areas where ponds were essential to diversification of rice-dominant systems and livestock were relatively few and feed limited. This has occurred in flood-prone areas, often where rice yields were low (Ruddle and Zhong, 1988) and land was raised to make dikes for planting perennial or upland crops. Increasingly, buildings and roads are constructed on raised dikes and fill is obtained from borrow pits. The ponds excavated often serve primarily for storing water on-farm. Expansion of on-farm reservoirs (OFRs) has also expanded in areas in which drought otherwise constrained any intensification of cropping.

Analysis of traditional integration of fish production within the highly diversified farms in the Zhujiang Delta, Southern China, indicates that wastes from livestock (pigs, silkworms) and

people were important inputs. Fish production, however, was mainly based on the feeding of wild, uncultivated grasses for the macrophagous grass carp. This fish species largely filled the niche occupied by ruminants in mixed farming systems in Europe. Recently other macrophagous fish species such as the silver barb have been promoted to utilise seasonally abundant duckweed in Bangladesh (Morrice, 1998). The feeding of leafy vegetable material is traditional for raising macrophagous giant gourami in Indonesia, and potential exists for similar systems elsewhere based on herbivorous tilapias and *Collossoma* spp.

The major constraint to fish culture within farming systems based on leafy vegetation is the availability of adequate amounts to meet the needs of growing fish. Constraints to, and opportunities for, intensification of macrophagous fish production are similar to ruminants (Box 2.B). Opportunistic use of crop harvest by-products would not normally provide consistent levels of feed or feed quality. Continuous

cropping of arable crops, e.g. cassava leaves has trade-offs in terms of the main crop yield. The use of arable weeds from intensive horticulture has unrealised potential in some situations (Moody, 1995) but would normally be constrained by irregularity of supply. Where such products are available, there will usually be competition with livestock.

2.5

Industrial monoculture

Many 'modern' settled agricultural farms stages I and II have intensified production by adopting some aspects of the scientific-industrial 'revolution'. Industrial monoculture (settled agriculture phase III) has evolved to supply ever larger, more concentrated markets with homogenous products. Increasingly dependent on the fruits of science and engineering, traditional mixed farming has changed over the last fifty years, using a greater range and volume of inputs. Improved varieties, agricultural chemicals, feeds and mechanization are used to produce fewer products in greater volume; many farm operations have become monocultures. The technical complexity and economies of scale characteristic of industrial agriculture encourage this tendency. In most cases the ready availability and low cost of industrial nutrients has reduced the need for integrating crop and livestock production. Industrial aquaculture, often of carnivorous species, evolved from using local surpluses of trash fish of little value to fatten wild fish and there were few links with land-based agriculture.

Two important reasons suggest that industrial monoculture will evolve towards greater integration with other food production. Firstly, the real costs of adverse environmental impacts of specialized production are now becoming clear and closer integration can reduce or eliminate them. Secondly, wastes from intensive animal production can be valuable inputs into other parts of the farming system.

BOX 2.B

Intensification of ruminant and macrophagous fish have similar constraints

- Consistent quality and quantity of green fodder required to match needs of growing stock
- Seasonality of availability
- Harvest by-products often useful only as an occasional supplement
- Trade-offs in regular harvest of green leaves from growing crops
- Development of 'cut and carry', in which intensively grown vegetation that can be cut regularly and grows back rapidly, is a major step and requires significant land and labour resources
- Key factor is the value of livestock and fish products relative to resources such as land and labour

Apart from maintaining soil structure in arable systems, these include their direct and indirect use in fish production.

In parts of Asia where concepts of waste recycling are traditional and well understood, the industrialization of agriculture and changing demand are both challenging and opening new possibilities for integration. On the one hand integrated livestock–fish systems are evolving in China to rely increasingly on wastes from non-traditional livestock such as dairy cows and broiler chickens. Livestock wastes are also being used for a greater range of purposes; mushroom, maggot or earthworm production may be more profitable than aquaculture (Wang, 1994). However, rapid industrialization and moves towards intensive aquaculture practices can also undermine traditional integrated practices and threaten ecological stability.