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Integrated Agriculture-Aquaculture Systems for Climate Change Adaptation, Mitigation and Livelihoods

Key Messages

- Integrated agriculture-aquaculture (IAA) systems, a strategy first developed in China over 2,000 years ago, have long been used in parts of Southeast Asia as a way to improve households' diets, increase incomes and enrich the soil, even with limited resources, by recycling nutrients.
- IAA is a circular approach that reduces waste and increases productivity by using livestock waste and other farm and household by-products as fertilisers and as fish/animal feed. Water from fish ponds can also be used for irrigation, and rice and fish can be produced together in trenches. IAA systems require fewer external inputs, such as fertiliser, pesticides and animal feed.
- IAA can be an effective climate change adaptation measure. It can diversify livelihoods, use scarce water more efficiently, and offer another productive use for the land in coastal areas experiencing saltwater intrusion. Alternating shrimp with rice farming, for instance, can take advantage of changing conditions, boost incomes and provide an additional protein source for households.
- IAA systems can also help reduce greenhouse gas emissions, but the mitigation potential still needs to be quantified. Key benefits include avoiding methane and nitrous oxide from decomposing animal waste – which is instead used for fish feed – and reducing the need for fertiliser and for animal feed, avoiding the emissions associated with their production.
- IAA has become less common in recent decades, due to growing intensification of both agriculture and aquaculture. To promote wider adoption, countries need to develop supporting programmes and policies, and integrate IAA into broader adaptation planning and strategies, as well as watershed and coastal zone management. The Association of Southeast Asian Nations (ASEAN) has guidance and policy frameworks that can support regional cooperation on IAA.
- Attention to equity and inclusion, including gender equity as well as the needs of very poor households, is crucial to realising the full potential of IAA systems for poverty alleviation and resilience-building. This includes tailoring approaches to the local context and to farmers' own priorities and existing practices. It is also important to provide extensive capacity-building, not just on technical matters, but on the broader principles behind integrated systems and their effective management.

Climate change poses many challenges for agriculture, including crops, livestock and aquaculture. In Southeast Asia, key hazards include rising sea levels, with associated flood risks saltwater intrusion; more extreme and variable precipitation; rising temperatures; and ecosystems degradation, all of which have implications for food security and livelihoods (Hijioka et al. 2014). Climate-related disasters can also ruin crops and damage or destroy infrastructure.

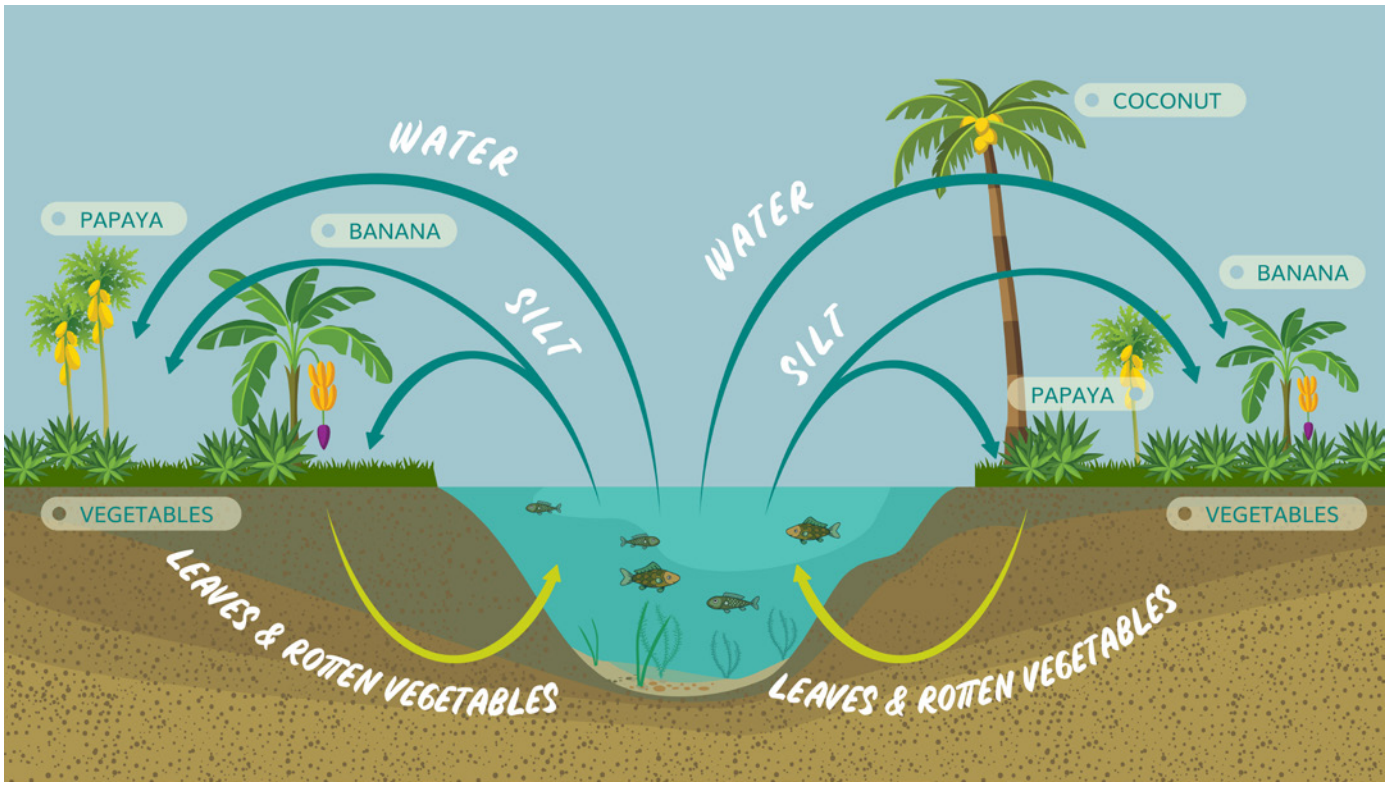
Diversifying food systems and integrated agriculture production systems can be important climate change adaptation measures (Mbow et al. 2019). Integrated systems reduce waste and increase productivity by using by-products from crops, livestock and fish systems and other waste as inputs for other subsystems. This also reduces farmers' dependence on agro-industrial products such as commercial inorganic fertilisers and formulated pelleted feed (see Figure 1). By applying the concept of circularity, integrated agricultural systems can thus minimise energy and materials use, reduce environmental impacts, and create new business opportunities (Padilla-Rivera et al. 2020).

In this context, an age-old practice, integrated agriculture-aquaculture (IAA) systems, may hold particular promise for members of the Association of Southeast Asian Nations (ASEAN). Developed in China more than 2,000 years ago, IAA has traditionally served as a way for farm households to improve their diets, increase incomes, and enrich the soil even with limited resources by recycling nutrients (Yang et al. 2001).

Understanding integrated agriculture-aquaculture systems

Farm diversification is a key livelihood strategy for smallholder farmers to diversify their incomes, spread risk, stabilise production, and increase resource efficiency. IAA links aquaculture with plant crop or livestock farming systems in one of two ways: on-farm or direct integration, and indirect integration, using off-farm by-products as inputs into aquaculture systems. IAA is common in extensive and semi-intensive culture systems. IAA can be highly productive: a semi-intensive system can produce fish yields of up to 10 tonnes per hectare (Yuan et al. 2019).

Figure 1. Illustration of an integrated agriculture-aquaculture system



In an integrated system, materials flow between the crop system and the fish pond. For example, nutrient-rich pond mud can be used as a fertiliser for growing crops, pond water can be used for irrigation, and farm residues can be used as fish feed (adapted from Tripathi and Sharma 2001).

In extensive systems, inputs are primarily provided by natural foods such as plankton, molluscs, and insect adults and larvae, while in semi-extensive systems, natural or supplementary feeds are used. The feeds used in IAA systems can include agricultural by-products such as rice bran, broken rice and waste vegetables; food waste from households, restaurants or factory canteens; and agro-industrial by-products from factories, such as rice bran, broken rice, oil cakes and waste noodles.

In addition, farmers may use wild or cultivated terrestrial vegetation as feed, such as grass and weeds, wild or cultivated aquatic macrophytes such as duckweed, water spinach and pond weeds, and sometimes pelleted formulated feed (Edwards 2019). In inland settings, farm ponds themselves can come to serve both for raising fish and for irrigation (see Figure 1).

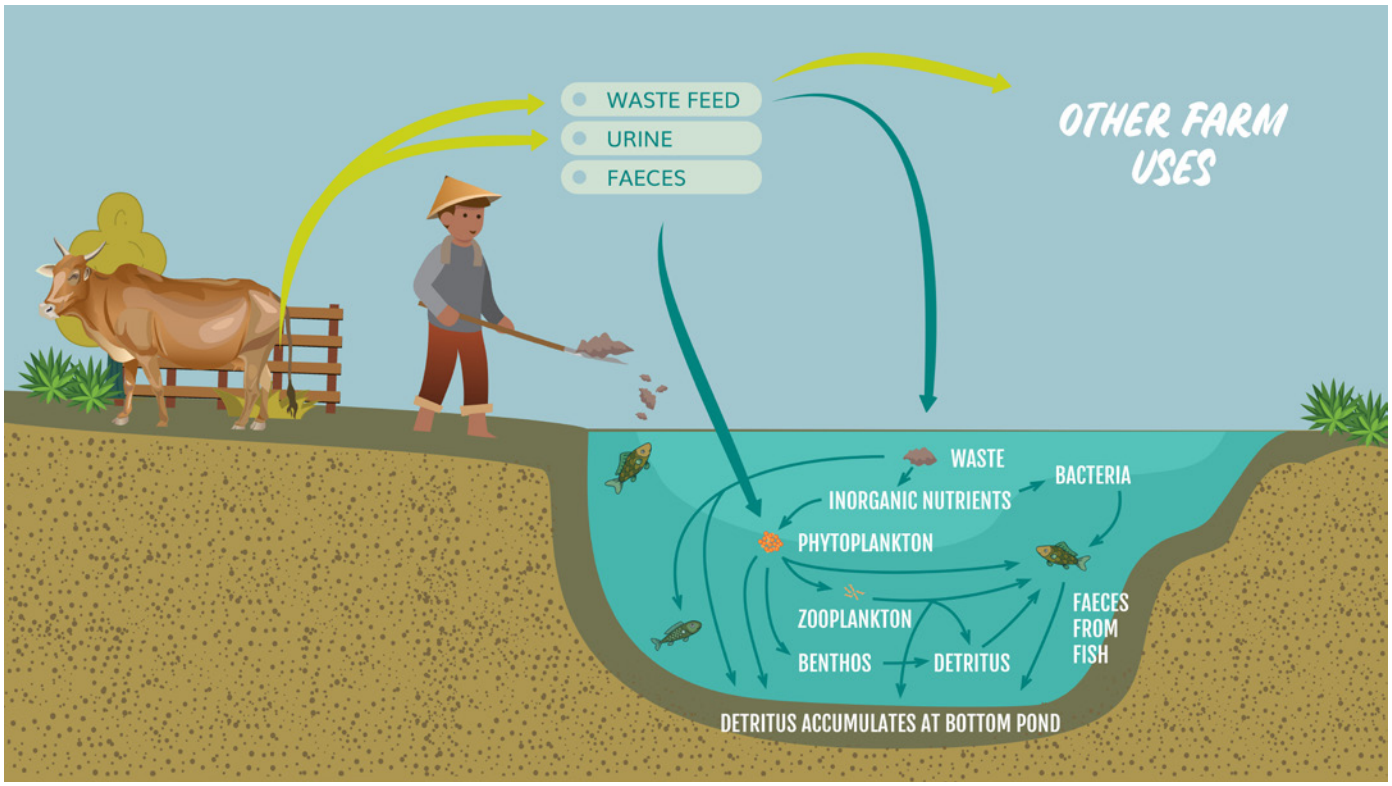
There are many options for implementing IAA, including aquaculture-based fisheries on open water, combined rice and fish production in excavations or trenches, and the use of ponds (Yuan et al. 2019). Common types of freshwater, semi-intensive IAA systems include rice-fish farming; integrated fish and livestock farming; and integrated fish, pond and livestock, or VAC (a Vietnamese acronym for vuon, ao, chuong, which means garden, pond, livestock pen).

In coastal systems, common types of IAA include rice-shrimp farming and mangrove-shrimp farming.
The remainder of this brief focuses mainly on freshwater inland systems.

Yuan et al. (2019) identify multiple ecological benefits of IAA, including:

- biological pest/weed control;
- nutrient resuspension/recycling by aquatic animals, supporting crop production, as in rice-fish culture;
- removal and harvest of waste nutrients from aquaculture by plants;
- productive use of wastes from feedlots/poultry houses as fertilisers to sustain fish growth in semi-intensive aquaculture ponds;
- multiple uses of water and land, which makes the overall system more stable and resilient and reduces the negative environmental impacts associated with food production.

Figure 2. How farm wastes contribute to aquaculture in IAA systems



In integrated systems, animal wastes can be used for fertiliser or as fish feed (see, e.g., Sevilleja et al. 2001). In practice, the direct value of animal waste as fish feed is low compared with its indirect value from stimulating algal (including phytoplankton) and beneficial bacteria growth (adapted from Tripathi and Sharma 2001).

A key advantage of IAA is that it uses fewer pesticides and chemical fertilisers than conventional agriculture. Fish can feed off of harmful insects, which decreases the need for insecticides, and nutrient recycling reduces the need for fertilisers (Yi 2019). The overall use of land and water can also be more efficient than separate systems would be, improving ecosystem health and reducing greenhouse gas (GHG) emissions.

From a development and adaptation perspective, IAA systems are valued for their potential to create synergies between different farming systems and strengthen their complementarities (Zajdband 2011). IAA contributes to enhancing food security and poverty alleviation without requiring substantial investments. It is therefore promoted as a low-cost way to increase farm productivity even when there is poor infrastructure, inadequate institutional support and limited fertiliser availability.

As Yuan et al. (2019, p.85) put it, "there is no doubt that IAA is one of the most effective approaches to improve efficiency of small-scale farming in resource poor rural communities and that it should be promoted."

Requirements for effective IAA implementation

In order to successfully implement an IAA system, farmers need to understand the interconnections between different aspects of the system, so they can make appropriate farm-level decisions (Murshed-E-Jahan and Pemsl 2011). Adopting the principles of agro-ecology – most notably diversity, efficiency and recycling – can help ensure that IAA systems optimise the interactions of plants, animals, humans and their environments (Beveridge and Dabbadie 2019).

Despite their use of animal waste, IAA systems pose only limited risks to public health. Livestock enteric bacterial and viruses are eliminated rapidly in fertilised green water ponds, as photosynthesis from fast-growing phytoplankton drives up the pH of the water, as shown in Figure 2 (Little and Edwards 2003). Proper agricultural practices, land use planning, sanitation and hygiene can further reduce those risks.

However, sediments and sludge can still have other negative environmental effects, such as methane emissions and the accumulation of nitrogen in the ponds (Astudillo et al. 2015). Careful management of these issues is crucial to realising IAA's full ecological and climate benefits and avoiding negative outcomes, such as pond eutrophication.

Climate change mitigation and adaptation potential

IAA has a long history in Asia, but is has declined in relevance over the years due to the increasing intensification of aquaculture and the availability of new off-farm income sources (Edwards 2019). However, the need to respond to the impacts of climate change has revived interest in integrated systems as a way to reduce emissions while building resilience and reducing vulnerability.

It is not clear how widely IAA systems are currently used in Asia, as they are not explicitly identified in national statistics. There has been significant research over the decades on integrated systems in West Java, Indonesia (Edwards et al. 1988). In Myanmar, pond fertilisation is not widespread, but 80% of the country's aquaculture production involves indirect use of off-farm rice bran and peanut cake with pelleted feed (Edwards 2019). The Philippines has limited IAA. In Thailand, feedlot livestock/fish integration is common (ibid). In Vietnam, especially in the Red River Delta, traditional IAA is widely practiced, such as the VAC method described above (Yuan et al. 2019). In Laos, rice-fish culture is now being promoted (Sirimanotham and Innes-Taylor 2019).

With low-income households in Southeast Asia facing by far the greatest risks of food insecurity and livelihood stress due to climate change, and ecosystems degradation compounding those risks (Hijioka et al. 2014), IAA is a particularly promising adaptation strategy for the region. Along with its potential for substantial ecological benefits, this approach stands out as a way to build households' resilience by diversifying livelihoods and providing more food. In rural Southeast Asia, fish is an important source of cheap protein, and IAA's food and livelihood security benefits are already well established.

The tight integration between system processes in IAA also means that it can easily be undertaken by an individual household. For example, VAC systems in Vietnam are tailored for small-scale implementation, allowing farmers to recycle most agricultural and household wastes within the system, using supplies and tools already available on the farm (Luu 2001).

Many IAA systems also involve crop diversification, which is considered as "no-regrets" adaptation option (Phuong et al. 2018). This means that even if some expected climate change

impacts ultimately did not occur, households and communities would still enjoy other benefits that make the effort worthwhile, such as lower production costs, reduced risks, higher incomes, reduced overall water needs, and integrated pest management. Furthermore, building synergies between agriculture and aquaculture systems can work to restore biodiversity and ecosystem services (Beveridge and Dabbadie 2019).

As noted earlier, IAA also offers some emission reduction potential. Traditional IAA systems are semi-intensive, with limited feed and nutrient inputs and minimal use of electricity. This means that the GHG emissions from traditional IAA are negligible. Furthermore, in livestock-fish systems, where the manure of farm animals such as chickens is converted into nutrients for fish, methane and nitrous oxide emissions produced by decomposing animal waste are avoided.

The Intergovernmental Panel on Climate Change (IPCC) has found that IAA systems can play an important role in making food systems more resilient while reducing GHG emissions (Mbow et al. 2019). By providing more protein for household diets, they may also reduce the demand for other kinds of meat production, including less sustainable forms of aquaculture. Ahmed et al. (2017) have estimated that converting 25% of the world's aquaculture area (4.5 million ha, of a total of 18 million) to agriculturally eutrophic impoundments and IAA would increase carbon storage by 95.4 million tonnes per year.

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

Method	Description	Adaptation	Mitigation
Rice-fish systems	Rice-fish systems maximise land and water resources while providing carbohydrate and protein sources. This method of rice production may need higher cash investment, but fish production generates additional income and reduces labour and material inputs.	Rice-fish systems can improve on-farm water management and allow for income diversification. The method might also increase the outputs of both rice and fish and reduce the need for fertiliser and pesticides.	Certain species of fish can be fed with livestock manure, which avoids emissions from the decomposition of animal waste. Also avoids emissions associated with fertiliser and fish feed production.
Integrated fish, pond and livestock or VAC	A traditional low-input agricultural method in Vietnam, the VAC model consists of three integrated components: garden (V), pond (A) and livestock pen (C). Food waste and animal manure are used as fertilisers and as feed for the fish.	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 also maximises land use by enabling several production systems at the same time.	The gardens can add to carbon sinks, and the use of animal wastes as fertiliser and fish feed avoids emissions from waste decomposition. Also avoids emissions associated with fertiliser and fish feed production.
Fish-livestock systems	Individually, intensive agriculture and aquaculture systems can create large amounts of waste as well as pollution. Manure, for example, can be used as fertiliser on land, the excess can leach into waterways. In integrated fish-livestock systems, farm effluents and wastes can be recycled in fish ponds and contribute to the production of animal protein (Little and Edwards 2003).	Recycles excess waste and provides added nutrients, particularly nitrogen and phosphorus, for fish production. This method reduces pressure on natural aquatic resources, making farm systems more resilient.	Proper manure management can decrease GHG emissions. Also avoids emissions associated with fish feed production.

Ensuring equity and inclusion in IAA implementation

It is clear that IAA holds great promise for Southeast Asian smallholder farmers whose livelihoods are increasingly threatened by climate change – including low-income households with limited land and little cash to buy farm inputs. However, realising that promise requires careful implementation to ensure that vulnerable households truly benefit and no one is left behind, and avoid any unintended consequences.

ASEAN Member States have highlighted gender and social inclusion as key components to adaptation measures (ASEAN 2015). These objectives require meaningful participation in decision-making, access to and control over resources, benefit-sharing, and balancing power relations. Furthermore, social inclusion also requires the removal of institutional barriers and expanding opportunities for all groups in society. However, limited resources and strict budgets often make it difficult to reach smallholder farmers.

Using IAA to enhance smallholders' resilience will require deliberate policy support, finance and capacity-building programmes tailored to the needs of the communities that are most affected by climate change. These are also populations that are likely to have the greatest difficulties accessing resources and information to implement IAA.

For effective implementation, IAA needs to be included in a suite of integrative approaches to agriculture, built around the principles of agro-ecology, with the goal of reducing the environmental impacts of fish production and build ecosystem resilience. This may include rethinking chemical fertiliser subsidies that make IAA uncompetitive – though this, too, has equity implications that must be considered carefully.

IAA systems also require better land use planning to avoid fragmentation, as IAA requires the integrated systems to be close together. And in IAA systems that reuse wastewater or use waste as inputs, standard environmental and health guidelines need be promoted, with clear, easy-to-understand guidance for farmers (even those who with limited or no reading skills).

Extension programmes are thus critical to effective IAA implementation, combined with public awareness programmes and enabling policies. Farmers may need access to new inputs and tools, and along with technical knowledge, they need capacity-building to generate a more holistic understanding of resource management strategies.

IAA interventions must also reflect local circumstances and farmers' own livelihood strategies and priorities. Failing to integrate IAA into existing practices and decision-making processes can lead to farmer engagement "traps" which put technical solutions above farmers' own choices (Nhantumbo et al. 2016).

Farmers in Ilocos Norte (Philippines) catch fish in their rice paddies. Photo: Ilocos Norte

Ensuring gender equity, is another vital component of realising IAA's full potential for sustainable land management, resilience and poverty reduction. IAA has proven beneficial for women farmers, who are often particularly vulnerable due to pervasive gender inequality in rural communities, lower literacy levels and other constraints.

In Nepal, for example, women involved in an IAA project since 2000 have achieved higher incomes, are happier, gained enhanced self-confidence, and increased their education and skills set (Farquhar et al. 2018). In Laos, fish production from IAA systems has reduced the amount of time women and children spend fishing to provide food for their households (Sirimanotham and Innes-Taylor 2019). In Vietnam, rice-shrimp farms, which were more labour-intensive and engaged women more actively than rice production alone, were found to have significant social and economic benefits (Grassi et al. 2017).

Yet although worldwide, women make up about 20% of the labour force involved in aquaculture (FAO 2020), women's needs and voices have been noticeably absent from aquaculture-related policy and decision-making, with only slow efforts made to rectify that situation (Williams et al. 2012). Aquaculture production data is also not collected in a gender disaggregated manner, so information on women's employment, income, benefits from aquaculture, and needs is sparse (Waite et al. 2014).

Ultimately, while there is overwhelming evidence showing the benefits of inclusive approaches to agricultural development, increased programmatic focus and funding allocation are needed to ensure that the most disadvantaged do not miss out on key opportunities.

Building on ASEAN guidelines and policy frameworks to scale up IAA

ASEAN resources and frameworks for cooperation can help Member States expand the use of IAA systems and adopt best practices, learning together to fully realise the potential climate and development benefits. The ASEAN Technical Working Group on Agriculture and Rural Development in particular could play a key role in encouraging and enabling broader IAA implementation across the region while building on the region's collective knowledge on traditional integrated systems and the benefits of IAA methods as mitigation and adaptation measures.

The Strategic Plan for ASEAN Cooperation in Food, Agriculture and Forestry 2016–2025 (AMAF 2017) and the ASEAN Joint Submission on Issues Related to Agriculture to the United Nations Framework Convention on Climate Change (ASEAN 2015) meanwhile, could provide the institutional framework for IAA as a tool for food security and an approach to mitigation and adaptation. Furthermore, activities under the ASEAN Framework Action Plan on Rural Development and Poverty Eradication highlight the importance of knowledge-sharing in relation to adaptation efforts in the agriculture sector and can contribute to increasing resilience to environmental risks (ASEAN 2017).

The Strategic Plan of Action for the ASEAN Co-operation in Fisheries (2016–2020) calls for increased investment in research and development for technologies and management systems, with a focus on resilience (ASEAN Secretariat 2016). It specifically mentions climate-smart agriculture, opening an opportunity for broader investment in IAA practices. At the same time, the ASEAN Public-Private Partnership Regional Framework for Technology Development in the Food, Agriculture and Forestry (FAF) Sectors can provide guidance for engaging a variety of stakeholders in such work (ASEAN Ministers of Agriculture and Food 2017a).

Guidance on integrated farming systems and rice-shrimp systems is already available at the regional scale, such as in Volume II of the ASEAN Regional Guidelines for Promoting Climate Smart Agriculture (CSA) Practices (ASEAN Ministers of Agriculture and Food 2017b, pp.27–35; 61–67).

Information on the aquatic biodiversity of ASEAN, which is directly relevant to the sustainable implementation of IAA, can be found in the ASEAN Biodiversity Outlook (ASEAN Centre for Biodiversity 2017). For instance, the Outlook notes that inland waters are the most threatened habitats in ASEAN, and pollution is a key threat. Recycling wastes through IAA can help address this threat.

An agenda for action

At a time when climate change poses growing threats to livelihoods and food security in ASEAN Member States, IAA systems offer an opportunity to support adaptation, development and emission reduction, with particular benefits to poor and vulnerable households.

Many farmers across Southeast Asia already have substantial experience implementing IAA systems. But in order to scale up the practice, further support is needed. The development community, national policy-makers, project implementers and researchers all have roles to play:

Recommendations for policy-makers

- National policy-makers should embrace IAA as part of agriculture and food policies and programmes, giving priority to initiatives that bring these practices to particularly low-income and resource-poor smallholder farmers, with support from agricultural extension programmes.
- Ensure that national policies are translatable at the local level and ensure that the most resource-poor small-scale farmers are able to access the training, resources, and finance needed to implement IAA. National policies should also reflect the diversity of local circumstances and farmers' own livelihood strategies.
- Promote the adoption of suitable types of IAA, especially rice field and earthen-pond-based systems, as alternatives to conventional pellet-fed aquaculture, thus offering a more sustainable and resource-efficient option to operators of intensive farming and aquaculture systems. It is important to recognise, however, that in the absence of stronger environmental regulations and enforcement, IAA may not always be economically attractive to those farmers.

Recommendations for donors and project implementers

- Development partners and international funders should promote and support IAA implementation as a strategy for poverty alleviation, livelihoods diversification, food security and climate change adaptation and mitigation, providing project finance, policy support, capacity-building, and strategic investments in research and development.
- Relevant organisations and networks should work with ASEAN Member States to integrate IAA fully into climate change adaptation and food security policies at the national level and thus ensure that it is incorporated into broader development planning.
- Promote and support opportunities for practitioners and policy-makers across ASEAN Member States to share their experiences, knowledge and best practices through the work of key regional institutions and networks, including the ASEAN Climate Resilience Network (ASEAN-CRN), the Network of Aquaculture Centres in Asia-Pacific (NACA) and the Southeast Asia Fisheries Development Centre (SEAFDEC).
- Work at the community level to identify opportunities to incorporate IAA into local development planning and climate change adaptation, such as in the design of local adaptation plans.
- Ensure broad participation by women and other marginalised groups by designing IAA trainings tailored to the needs and contexts of those specific groups, setting targets for participation and outcomes for different groups, and collecting disaggregated data. Developing a Gender Action Plan to ensure that women and men have equal access to resources, training, decision-making and job opportunities is an important step towards ensuring true gender equality in IAA.

Priorities for further research

- As IAA techniques are further explored as climate-smart land use approaches, it is crucial to study and better document how these systems can contribute to adaptation and especially to greenhouse gas emission reduction. Those findings then need to be synthesised in clear, easy-to-understand formats to guide policy-makers and practitioners. In this context, it is also important to consider trade-offs and synergies between mitigation and adaptation needs.
- More research is needed on how IAA can be used to produce chemical-free and/or organic products, including through integration of organic rice fields and fish culture, aquaponics, and other techniques.
- Develop approaches to integrate agro-ecological principles in using IAA as a tool to promote climate-smart land use by addressing reliance on industrial inputs such as fertilisers and promoting synergies among plant, animal, human and environmental systems (see, e.g., Beveridge and Dabbadie 2019).

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All briefs are available at https://asean-crn.org/overview/publications/study-and-policy/.

The CSLU project builds on the successes of the Forestry and Climate Change Project (FOR-CC) under the Former ASEAN-German Program on Response to Climate Change (GAP-CC), which supported ASEAN in improving selected Framework conditions for sustainable agriculture and Forestry in AMS. CSLU aims to strengthen the coordination role of ASEAN in contributing to international and national climate policy processes for climate-smart land use in agriculture and forestry.

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