INITIATIVE ON Low-Emission Food Systems

Modeling Vietnam's Blue Transformation Under Climate Change: A Conceptual Framework

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Executive summary

Vietnam has emerged as a global fish producer. Globally, the country is the fourth-largest producer of aquatic food, and the third-largest fish exporter in the world. Vietnam is at the frontline in meeting the global demand for aquatic foods. Aquatic food is increasingly becoming a primary source of protein and micronutrients, livelihoods, national economy, and well-being for Vietnamese. Therefore, sustainable development of the aquatic food system is critical for human, animal, and ecosystem health, including biodiversity, land and water use, climate, and other aquatic and land-based economic sectors. Nevertheless, the fish sector in Vietnam significantly contributes to greenhouse gas (GHG) emissions and mangrove deforestation. Yet, it is unclear how Vietnam's fish sector and associated agricultural industries can respond to climatic risks and contribute to climate change mitigation despite the country's strong commitment to net-zero emissions by 2025.

Research and innovations that support sustainable decision-making should be prioritized in Vietnam. It is essential to promote science and policy research to increase the knowledge base of Vietnam toward its blue transformation, especially quantitative frameworks, to support and guide decision-making processes toward its net-zero-emission commitment. This priority includes developing and adopting user-friendly integrated modeling and planning frameworks to assist stakeholders in examining the trade-offs and co-benefits of policy options in agriculture and aquaculture food systems, undertaking stock assessments as part of MRV systems (Measurement, Reporting, and Verification), developing scenarios of potential futures, and designing policies and programs. The modeling frameworks also provide effective tools to assess the socio-economic and environmental impact of policy changes on desired objectives and stakeholders, including gender and regional-specific impacts.

Introduction

Vietnam is a key player in the global aquatic food supply system. The country is the fourth-largest producer of aquatic food products in the world (after China, India, and Indonesia), with an annual production of 8.3 million metric tons in 2021 (FAO, 2022; GSO, 2021). It is the third-largest exporter in the world (after China and Norway), with annual exports valued at approximately USD 8.6 billion in 2019, accounting for around 5% of the global total (FAO, 2022; GDC, 2022). Thus, Vietnam plays an important role in meeting the global demand for fish and fishery products (van Dijk *et al.*, 2021).

Vietnam's fish sector is important to the national economy in terms of income, employment, and trade. It accounts for 4-5% of the national gross domestic products (GDP) (WB, 2021) and 9-10% of total export turnover (GDC, 2022). The sector provides about 4.7 million direct and indirect jobs across all production chains of the country, making up about 5% of the total labor force in Vietnam, considerably more than the average of 0.5% for countries in the Organisation for Economic Co-operation and Development (OECD) (WB, 2021).

The fish sector plays an essential role in Vietnam's food supply system, contributing to livelihood improvements and a transition toward environmental sustainability. It's share in agriculture increased from 17.8% to 24.4% from 2010 to 2019, contributing to Vietnam's agriculture structural reform (Minh, 2021; WB, 2021). It provides sources of nutrition and helps improve the population's diet (FAO, 2016). This sector also offers viable alternative livelihood options for small farmers, especially rice farmers, to shift to more economically efficient and sustainable agriculture systems (Li *et al.*, 2019; Nguyen *et al.*, 2022). In addition, there is enormous commercial potential for high-value products made from fish by-products (Toppe, 2018). Sustainable development of the aquatic food system is a critical condition for human, animal and ecosystem health, including biodiversity, land and water use, climate, and other aquatic and land-based economic sectors (FAO, 2022).

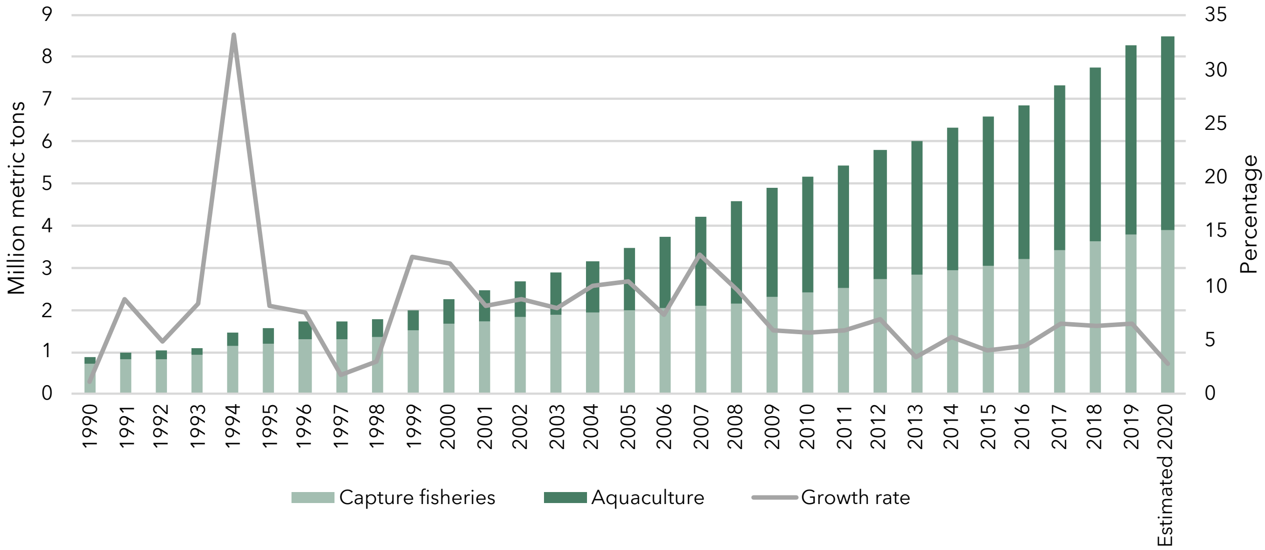
Despite rapid development over the past decade (WB, 2021) and the essential roles at the global and national food supply chain, Vietnam's fish sector and related agricultural industries are highly vulnerable to climate change. The sector, with intensive production zones along long coastal lines, has extremely high exposure to sea level rise and catastrophic hazards such as flooding and cyclones (WB/ADB, 2021). On the other hand, the sector is a significant contributor to Vietnam's GHG emissions and mangrove deforestation (MacLeod *et al.*, 2020; Truong and Do, 2018). These issues, if not properly addressed, will pose substantial risks to the growth of the fishery sector and associated agricultural industries, both in the short-term and long term. Meanwhile, there is a lack of information and understanding about how Vietnam's fish sector and associated agricultural industries can respond to climatic risks and contribute to climate change mitigation despite the country's strong commitment to net-zero emission by 2025 (Giles *et al.*, 2021; NSCC, 2022).

This policy note is to provide a high-level review of the fish sector in Vietnam in the context of climate change and recommend key policy directions. We will highlight the possible impact of climatic risks and the opportunities and responses available. The goal of this working paper is to provide transformative adaptation and mitigation options to promote a progressive mindset and stronger measures for sustainable and climate-resilient development of the aquatic food system in Vietnam, contributing to the country's achievement of its net-zero emissions target by 2050 as committed at 2021 United Nations Climate Change Conference (COP26).

Vietnam's fish sector

Vietnam has a vibrant fish sector, with about 35 thousand over-90-hp fishing vessels and 1.1 million hectares of aquaculture in 2020 (GSO, 2021). The total production reached 8.3 million metric tons in 2021, of which 57% was produced by aquaculture, and 43% from capture fisheries (GSO, 2021). The fish sector is the main source of income to about 4% of Vietnam's rural households. The average fish consumption in Vietnam was 40 kg/person/year in 2019.

Figure 1. Booming fisheries and aquaculture production.

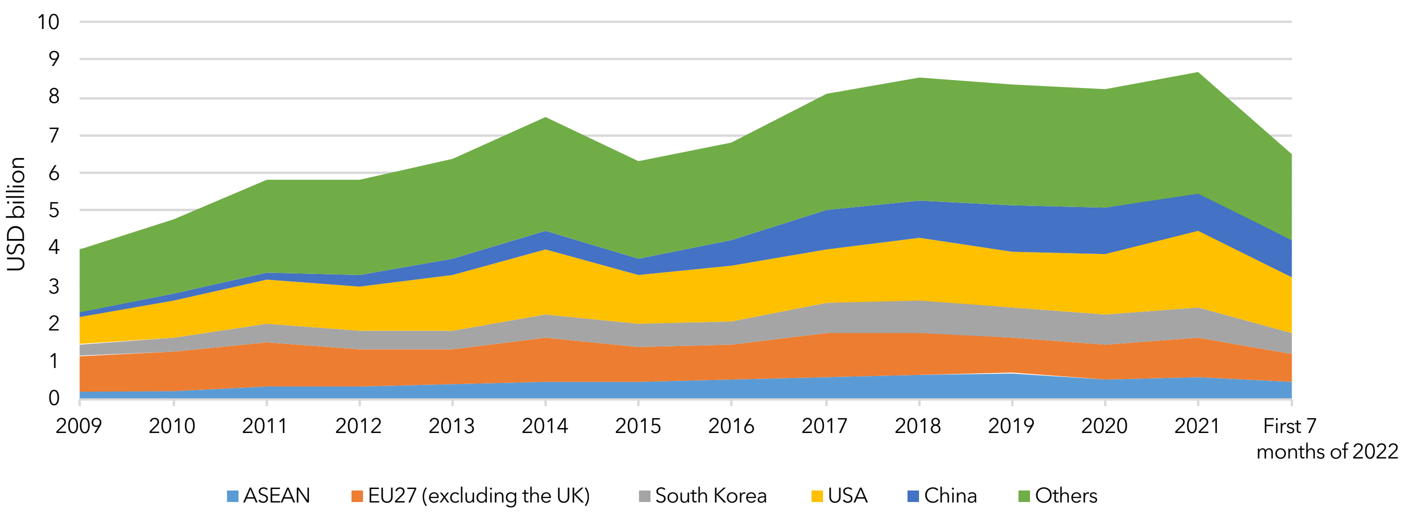


Source: *GSO (2021)*

Aquaculture started to surpass capture fisheries in the mid-2000s to become the main fish producer (Figure 1). The key aquaculture products are catfish and shrimp. The main aquaculture region is the Mekong River Delta which contributes 95% and 80% of national catfish and shrimp exports, respectively (GSO, 2021). Key aquaculture environments are freshwater and brackish water, whereas marine aquaculture only emerged recently within a small area. Aquaculture systems are diversified, including improved-extensive, semi-intensive, and intensive systems. More climate-resilient systems, such as rice-shrimp and mangrove-shrimp farming, are expanding (Jonell and Henriksson, 2015; Li *et al*., 2019; Nguyen *et al*., 2022).

Vietnam's fish and fishery products are exported to 160 countries. The top 10 client countries – all considered high-end markets including the United States, Europe, Japan, China, South Korea, ASEAN, Australia, United Kingdom, Canada, and Russia – account for about 93% of Vietnam's total exports (Figure 2). Fish and fishery products rank fifth in export value, following telephone, textiles, electronics, and footwear (WB, 2021). Shrimp, catfish, and tuna are the key export commodities, making up 44%, 18%, and 8% of the total export value, respectively (GDC, 2022).

Figure 2. Export markets of Vietnam's fish and fishery products



Source: *GDC (2022)*

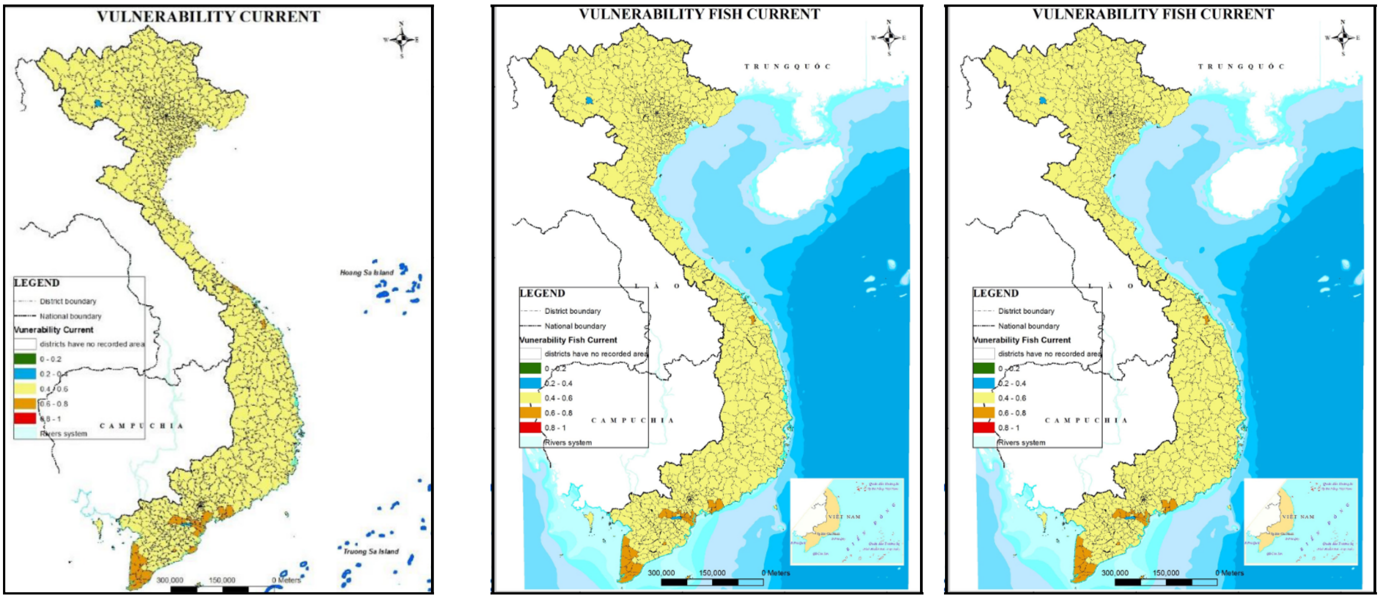
Fisheries, aquaculture sector and climate change

GHG emissions from fisheries and aquaculture in Vietnam have been growing because of increases in feed and fuel uses (FAO, 2022; Parker *et al*., 2018). While the fish sector emits less GHG than some other agricultural sectors (FAO, 2022; MacLeod *et al*., 2020), Vietnam is among the top countries with high emissions due to its large aquaculture area and high-emission-intensity products (catfish and shrimp) (MacLeod *et al*., 2020; Yuan *et al*., 2019) (Table 1). Vietnam contributes to Asia's high rank in fuel use intensity and emission intensity for fisheries (Parker *et al*., 2018). This fact suggests that there are opportunities for reducing GHG emissions by (i) shifting from high-emission production, such as rice farming and terrestrial livestock (MacLeod *et al*., 2020) to aquaculture and (ii) improving input efficiency in the fisheries and aquaculture sector to reduce GHG emissions at the food system level.

Vietnam has one of the world's most vulnerable aquatic food systems to climate change and extreme events (Soto *et al*., 2018). Climatic impacts on aquaculture include short-term losses of production output and infrastructure arising from extreme events such as floods, increased risks of diseases, parasites and harmful algae blooms. Aquaculture is also impacted by long-term risks such as reduced availability of wild seed and reduced precipitation, leading to increasing competition for freshwater (Figure 3).

All three culture environments in Vietnam are highly vulnerable to climate change (Soto *et al*., 2018). Among the 20 most vulnerable countries, Vietnam ranks first for the vulnerability of freshwater aquaculture, second for brackish aquaculture, and fifth for marine aquaculture (Table 2). In addition, the Mekong River Delta, the largest aquaculture area in the country, has the highest score for the vulnerability index (FAO, 2021). This lowland region is vulnerable to climate change-induced sea level rise, salinization, and coastal inundations. In terms of species, shrimp culture is more vulnerable than fish culture as shrimp farming in Vietnam is mostly located in coastal areas (FAO, 2021).

Figure 3. Vulnerability maps of Vietnam's aquaculture.



Spatial maps of aggregated Vulnerability level on aquaculture (2010-2016). (Institute Agricultural Environmental cited in FAO, 2021)

Vulnerability level of fish farming to climate change (Cao, 2018)

Vulnerability level of shrimp farming to climate change (Cao, 2018)

Sources: *Cao (2018) and FAO (2021)*

Capture fisheries are also highly exposed to climate risks. Capture fisheries are impacted when oceans and freshwater become warmer and more acidic, with declining oxygen content and destabilizing patterns of global marine primary productivity (Bopp *et al.*, 2013). Higher temperature also shifts freshwater habitats and the biodiversity and fish assemblages they support (Jones and Cheung, 2014). Taking into account both naturogenic and anthropogenic stressors, Vietnam is among 60 countries facing climatic stress in the short term, and the country is projected to face medium climatic pressure to inland fisheries in the long term (Harrod *et al.*, 2018). For marine fisheries, the catch potential of Vietnam is projected to decline 6.8% by 2050 and 11.7% by 2100 as compared to 2000 under the RCP2.6 climate scenario. Under the RCP8.5 climate scenario, the projected reductions are 7.5% (by 2050), and 40.8% (by 2100), respectively (Cheung *et al.*, 2018).

It is also important to highlight that the risks to capture fisheries and aquaculture are related. Both sectors have to face a variety of anthropogenic pressures that may amplify the impacts of climate change, such as over-extraction of water, over-exploitation of fish, the introduction of non-native species, pollution, habitat degradation (including fragmentation), and increases in human populations. In other words, the impact of risks on one sector and associated industries will probably impact the other. As a result, policy responses to mitigate these risks should take into account possible multi-faceted impacts rather than focusing on the impact on an individual sector.

Table 1. Direct CH_4 and N_2O emissions from different freshwater aquaculture systems in the global top 21 producing countries and regions in 2014.

Country or region	Rice-fish systems		Extensive plus semi-intensive systems		Intensive systems	Total	
	CH_4 ($GgCH_4$/year)	N_20 (MgN_20/year)	CH_4 ($GgCH_4$/year)	N_20 (MgN_20/year)	N_20 (MgN_20/year)	N_20 (MgN_20/year)	CH_4 ($GgCH_4$/year)
China	696	5988	3408	11653	5152	3524	22793
India	108	925	487	1667	-	512	2591
Indonesia	66	571	91	313	1955	142	2839
Vietnam	19	161	173	590	344	162	1095
Bangladesh	-	-	323	1106	4	268	1109
Myanmar	-	-	50	172	0	42	172
Brazil	-	-	45	153	430	37	584
Thailand	2	15	71	244	91	61	350
Nigeria	-	-	-	-	-	-	-
Philippines	-	-	8	28	373	7	401
Iran	0	2	28	97	316	24	415
USA	15	128	35	119	76	44	323
Egypt	268	2306	1	3	442	269	2752
Pakistan	-	-	8	28	0	7	28
Taiwan	0	0	34	116	0	28	116
Russia	-	-	57	194	71	47	265
Cambodia	0	2	1	3	208	1	213
Uganda	-	-	6	19	67	5	86
Lao	2	20	21	71	55	20	146
Turkey	-	-	0	0	268	0	268
Malaysia	12	101	3	12	50	15	162
Total	1188	10219	4851	16586	9903	6039	36709

Source: *Yuan et al. (2019)*

Table 2. Average vulnerability values (V) highest to lowest, sensitivity (S), exposure (E) and adaptive capacity (A) for the 20 most vulnerable countries in relation to freshwater, brackish water and marine environments.

Freshwater					Brackishwater					Marine				
	V	S	E	A		V	S	E	A		V	S	E	A
Vietnam	0.690	0.999	0.395	0.519	Ecuador	0.558	0.950	0.277	0.355	Norway	0.307	0.809	0.357	0.000
Laos	0.561	0.583	0.358	0.633	Vietnam	0.557	0.664	0.368	0.519	Chile	0.273	0.486	0.045	0.209
Bangladesh	0.544	0.498	0.436	0.676	Belize	0.524	0.758	0.312	0.389	China	0.160	0.068	0.347	0.393
Myanmar	0.514	0.462	0.318	0.702	Egypt	0.483	0.528	0.426	0.450	Madagascar	0.156	0.044	0.194	0.725
China	0.504	0.616	0.452	0.393	Taiwan	0.460	0.267	0.383	1.000	Vietnam	0.123	0.036	0.232	0.519
Taiwan	0.404	0.207	0.363	1.000	Thailand	0.457	0.536	0.356	0.407	Malta	0.112	0.077	0.152	0.166
Uganda	0.342	0.181	0.408	0.767	Nicaragua	0.358	0.278	0.293	0.547	Peru	0.111	0.045	0.152	0.329
Cambodia	0.334	0.201	0.406	0.633	Philippines	0.332	0.258	0.360	0.462	Philippines	0.096	0.023	0.283	0.462
Thailand	0.322	0.254	0.409	0.407	Honduras	0.325	0.236	0.349	0.496	Greece	0.095	0.058	0.179	0.146
India	0.293	0.153	0.455	0.616	Indonesia	0.308	0.236	0.209	0.501	South Korea	0.095	0.052	0.378	0.071
Indonesia	0.268	0.172	0.25	0.501	Iceland	0.265	0.554	0.232	0.075	Seychelles	0.090	0.042	0.118	0.229
Belize	0.253	0.172	0.343	0.389	Malaysia	0.241	0.223	0.211	0.286	New Zealand	0.085	0.119	0.073	0.055
Honduras	0.241	0.125	0.403	0.496	Guatemala	0.222	0.100	0.337	0.575	Thailand	0.077	0.019	0.148	0.407
Philippines	0.239	0.134	0.351	0.462	Bangladesh	0.207	0.075	0.379	0.676	Croatia	0.069	0.021	0.222	0.230
Costa Rica	0.224	0.173	0.308	0.280	Panama	0.171	0.116	0.222	0.269	Japan	0.069	0.028	0.379	0.066
Nepal	0.213	0.071	0.416	0.756	Finland	0.142	0.107	0.373	0.097	Cyprus	0.068	0.026	0.201	0.164
Malaysia	0.213	0.164	0.264	0.286	Costa Rica	0.125	0.058	0.250	0.280	Turkey	0.066	0.014	0.216	0.358
Moldova	0.206	0.088	0.545	0.453	China	0.111	0.032	0.391	0.393	Iceland	0.064	0.026	0.317	0.075
Nigeria	0.199	0.062	0.438	0.743	Guam	0.109	0.015	0.449	1.000	Canada	0.063	0.022	0.396	0.068
Iran	0.195	0.095	0.542	0.327	Brunei-Darussalam	0.103	0.064	0.186	0.154	Mozambique	0.061	0.005	0.165	0.965

Source: *Soto et al. (2018)*

Conceptual frameworks for modeling Vietnam's blue transformation

Vietnam has recognized the strategic role of the fisheries sector and other agricultural sectors in the context of ongoing climate change. This is a key sector in Vietnam's Nationally Determined Contribution (NDC, 2020) and its Action Plan to respond to climate change for 2016–2020, vision to 2050 (MARD, 2016). During 2021-2022, Vietnam's government promulgated important strategies to promote the sector and acknowledge the importance of improving climate resilience and sustainability. Examples include (i) the Strategy for Fisheries and Aquaculture Development to 2030, Vision to 2045, (ii) the National Program for Aquaculture Development for the Period of 2021–2030, and (iii) the National Program for Efficient and Sustainable Development of Fisheries for the Period of 2022-2025, Orientations to 2030.

Research and innovation are critical driving forces of the transition toward green growth, mitigation, and adaptation to climate change. They play a vital role in technological progress and support effective management and decision-making processes. However, research about food systems is not a strength of Vietnam. Data and methods for measuring GHG emissions at the food system level are not adequately updated. There is a lack of insights into carbon and non-carbon opportunities in the food system. Understanding of what and how interventions work and their impacts are limited. There are few concrete examples of scalable technologies that can transform the entire food system from GHG sources to net carbon sinks (CGIAR, 2021). These factors pose significant obstacles to the effective design and implementation of mitigation and adaptation measures, not only in fisheries and aquaculture but also in the entire agricultural sector, which is the key action area in Vietnam's roadmap to achieve its climatic commitments (NDC, 2020).

Research and innovations that support sustainable decision-making should be prioritized in Vietnam (IPCC, 2014b; NRC, 2014; FAO, 2022a). It is essential to promote science and policy research to increase the knowledge base of Vietnam toward its blue transformation, especially quantitative frameworks, to support and guide decision-making processes toward its net-zero-emissions commitment. This priority includes developing and adopting user-friendly integrated modeling and planning frameworks to assist stakeholders in examining the trade-offs and co-benefits of policy options in agriculture and aquaculture food systems, undertaking stock assessments as part of MRV systems, developing scenarios of potential futures, and designing policies and programs (CGIAR, 2021). The modeling frameworks also provide effective tools to assess the socio-economic and environmental impact of policy changes on desired objectives and stakeholders, including gender and regional-specific impacts.

Developing bioeconomic models for assessment and evaluation purposes

Bioeconomic modeling (BM) is a key step in developing and promoting sustainability indicators of fisheries, aquaculture, and related agricultural industries. In Vietnam, bioeconomic models can be developed for stock assessment of marine fisheries. They can be used to evaluate the status of fisheries at different points in time to implement inventory methodology and MRV systems. They provide opportunities to improve systematic data collection and develop reliable measurements and databases for aquatic food systems and other related agricultural industries. They can provide direct and indirect estimates of GHG emission factors at the food system level.

BM is an analytical tool that integrates biophysical and economic models, which allow for analysis of the biological and economic changes caused by human activities (Bobojonov, 2021). There is growing popularity and interest in bio-economic models as tools for policy analysis to assess the impact of alternative policies on natural resources and human welfare (Castro *et al.*, 2018; Prellezo *et al.*, 2012) to support decision-making processes. BM is used to evaluate environmental externalities associated with policy reforms and technological modernization, including climate change impact analysis and to explore the negative consequences of global warming (Skonhoft, 2013). Bioeconomic models are developed in various sectors, including agriculture, fisheries, and forestry, and at different scales, e.g., farm, regional, country, and global scales.

Bioeconomic models for Vietnam can be developed in a number of ways. They can be simulation models or optimization models, or both. Simulation models aim to simulate a system by projecting a set of biological and economic variables or parameters into scenarios to evaluate alternative management strategies or modeling the impact of exogenous variables (e.g., oil prices or climate change). Optimization models are designed to find an optimal solution to an objective function under certain economic and biological constraints. BM can also be input-oriented (effort, gear restrictions, area closures) or output-driven (quota, catch composition, minimum landing size). Bioeconomic models can be developed to investigate short-term impacts (i.e., fishery/fleet and population dynamics) or long-term structural behavior (i.e., investment or entry/exit decisions) on a temporal or spatial disaggregated scale. They can be deterministic or stochastic through the implementation of uncertainty (process, observation, estimation, model, or implementation errors) (Prellezo *et al.*, 2012), or single-objective (more frequently applied at the farm level) and multiple-objective (applied to meet concerns at the landscape level) (Castro *et al.*, 2018).

In the context of fisheries, bioeconomic models have some advantages as compared to traditional economic models. Bioeconomic models may provide a better understanding of complex systems by combining biological, social, and economic research on the grounds of scientific and technological advances (Castro and Lechthaler, 2022). They allow the integration of biophysical limits and resource scarcity to economic growth and help gain a better and more comprehensive indication of the feedback effects between human activity and natural resource dynamics. BM can support management and policymaking on aquatic production and land-use systems, with applications in fields like ecosystem services provision, biodiversity conservation, pest management, water and soil management, climate change, and risk management (Castro and Lechthaler, 2022).

Marginal Abatement Cost Curves

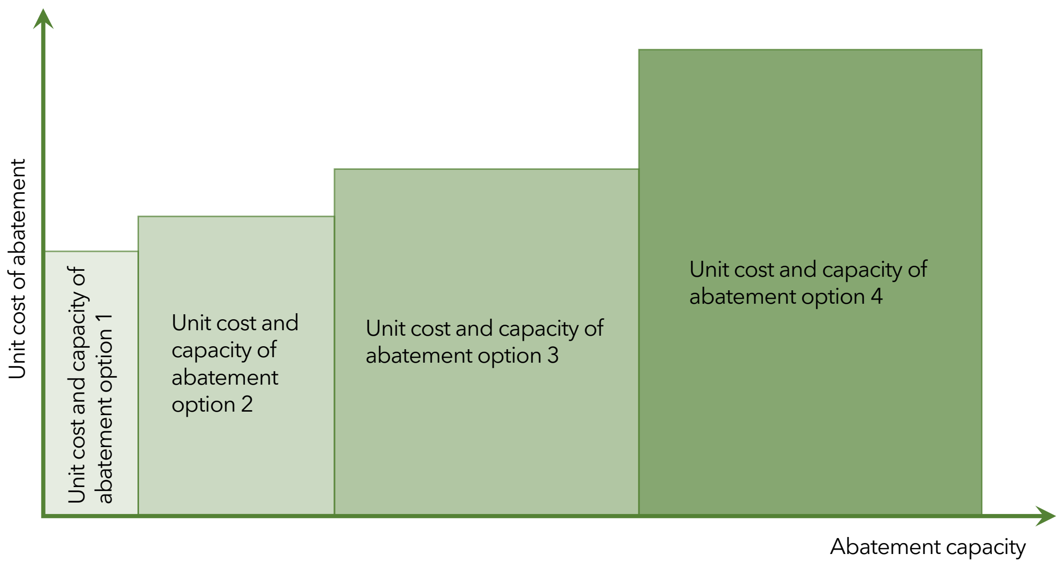
Marginal Abatement Cost Curves (MACC) are necessary costs to pay per additional unit of emissions reduction. Put differently, MACC can be defined as the supply curve for emission reduction (Nordrum *et al.*, 2011), which represents the relationship between the quantity and price of emission reduction. Since GHG reduction and economic development are sometimes in conflict, it is critical to identify cost-effective measures to balance economic growth and GHG reduction (Huang *et al.*, 2016). By constructing a relationship between the reduction potential of emissions and associated costs, a MACC allows researchers and policymakers to evaluate this balance (Kwon and Yun, 1999). The MACC are widely used in climate change research and policies to assess and identify GHG cost-effective reduction potential at different scales (within a single economic sector, across multiple sectors, and between countries) and in various social, environmental, and economic contexts. MACC can be used in emission reduction negotiations among different sectors or nations (Ellerman, 1998).

Most MACC construction methods are model-based. These methods have evolved gradually from simple, static, and single-sector toward complex, dynamic, and multi-sector (system) interactions (Huang *et al.*, 2016). Generally, MACC methods are divided into three categories: bottom-up, top-down, and hybrid models. The bottom-up approach usually starts with measure-explicit policies, as it assesses detailed characteristics of technologies to calculate abatement quantity and related direct costs for cost-effective abatement options (Sathaye and Shukla, 2013). The top-down approach emphasizes the potential opportunity cost for achieving a specific emissions reduction target by breaking down the production process, responding to market behaviors, investigating producer and consumer hidden costs, and looking at the price rebound effects (Kok *et al.*, 2011). The bottom-up and top-down approaches can be combined to account for the technology portfolio and economic impacts while finding a low-carbon and cost-effective development pathway (Kiuila and Rutherford, 2013).

An important advantage of MACC is that they can be constructed for different purposes to optimize options for achieving an objective and analyzing possible market responses to price signals. They can show the relative cost-effectiveness of all available options. They can be used for ranking options for prioritization in either a specific sector or in-between sectors by relative values against the baseline rather than by the absolute value of individual measures because it is challenging to take into the full uncertainty in the future (Levihn *et al.*, 2014).

MACC can provide a policy tool to evaluate emission abatement potential and associated abatement costs in Vietnam's fish sector and related agricultural industries. Figure 4 provides a conceptual framework for an MACC. This MACC can be constructed by comparing the cost-effectiveness of different abatement measures and estimating the associated capacity. In Vietnam, it is also important to construct the MACC by comparing the average abatement cost in different locations because spatial heterogeneity is significant. Sensitivity analysis can be undertaken to investigate the robustness of MACC in relation to underlying assumptions. MACC in Vietnam should also be updatable along the country's zero net emission pathway.

Figure 4. Conceptual framework of MACC in Vietnam.



It is important to note that MACC should be used jointly with other decision-making tools. MACC may omit ancillary benefits of GHG emission abatement, treat uncertainty in a limited manner, exclude intertemporal dynamics, and lack the necessary transparency concerning their assumptions (Kesicki and Ekins, 2012). MACC must be combined with a Marginal Benefit Curves (MBC) to determine the optimal emission level (Eory *et al*., 2013). However, MACC may also suffer from an inconsistent baseline, double counting and limited treatment of behavioral aspects (especially the bottom-up approach). Thus, MACC should be interpreted with adequate attention to the underlying assumptions and dependencies, non-financial costs and important uncertainties (Kesicki and Ekins, 2012).

Economic Equilibrium Modeling

Economic equilibrium models have gone beyond their economic origins and become the most integrated assessment models for economic and environmental systems (Cantele *et al*., 2021). They are usually employed to examine the potential impacts of economic, energy, and trade policies, including the impacts of economic development on GHG emissions, and the economic impacts of climate change (Kompas *et al*., 2018). Economic equilibrium modeling has also been applied to investigate the ex-post impacts of policies and counterfactual "what-could-have-been" scenarios (Jean *et al*., 2014). These models are used more extensively in high-income countries compared to low-income countries, covering economic, energy, agriculture, forestry, and other land use (Cantele *et al*., 2021).

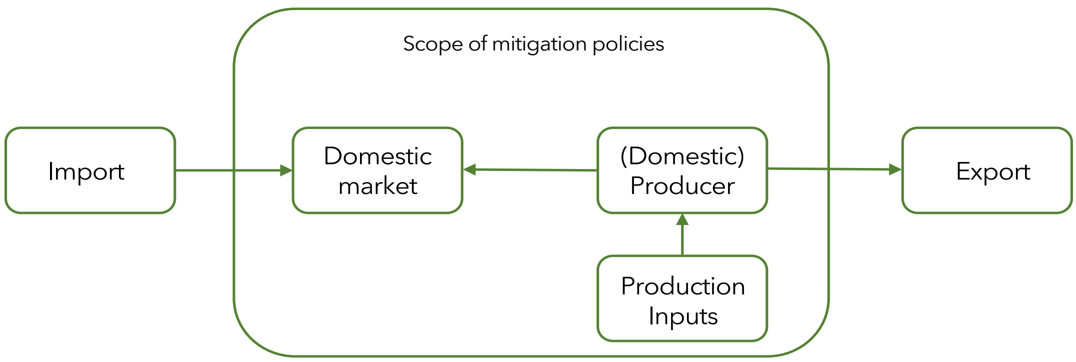
Economic equilibrium models are optimization models with value and commodity flows among economic agents, including households, private firms, and the government (Corong *et al*., 2017). Households and firms are self-maximizing microeconomic behavior (supply and demand) under constraints and accounting equations (Burfisher, 2021). Variables are either endogenous (estimated within the model) or exogenous (explicitly specified by the modeler). The baseline equilibrium state is determined by base year data derived from input-output tables produced by national statistical offices or standardized global databases. Policy changes or alternative scenarios are represented as shocks to the exogenous variables, which in turn causes endogenous variables to adjust in order to find the new optimal solution, yielding a deviation from the baseline that represents the impact of the implemented policy or scenario.

Two types of economic equilibrium models can be developed, namely partial equilibrium (PE) and computable general equilibrium (CGE), to support Vietnam's climate policies. PE models are common within agriculture, forestry and other land use (AFOLU), particularly among agriculture, forestry, and fisheries, e.g., the Global Forest Sector Model, the European Forestry Institute Global Trade Model (EFIGTM) (Cantele *et al*., 2021), and the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) model for aquaculture and fisheries (Chan *et al*., 2021; WB, 2013). PE models focus on a single product/market or a small group of products/markets. They provide a tool to analyze the impact of climate change policies and possible responses on domestic production, the share of exporting markets, the import market (in case of two-way trade of a product), and the domestic market (via the substitution of domestic and international markets from the producers' point of view and the possible substitution of domestic and imported products from the consumers' point of view).

PE is a powerful tool for answering what-if questions. The calibration of PE models requires a reasonable amount of data and assumptions. They can be implemented at a disaggregate level, which enables decision-makers to focus on a product or a small group of products (Havlík *et al*., 2011). Also, PE models are intuitive, allowing effective communication of the results of individual economic sectors to a non-technical audience. However, when allowing a high level of focus on a single product, PE models do not take into account cross-sector links within an economy and are unable to evaluate the impact on other products (Cantele *et al*., 2021; Perez, 2018).

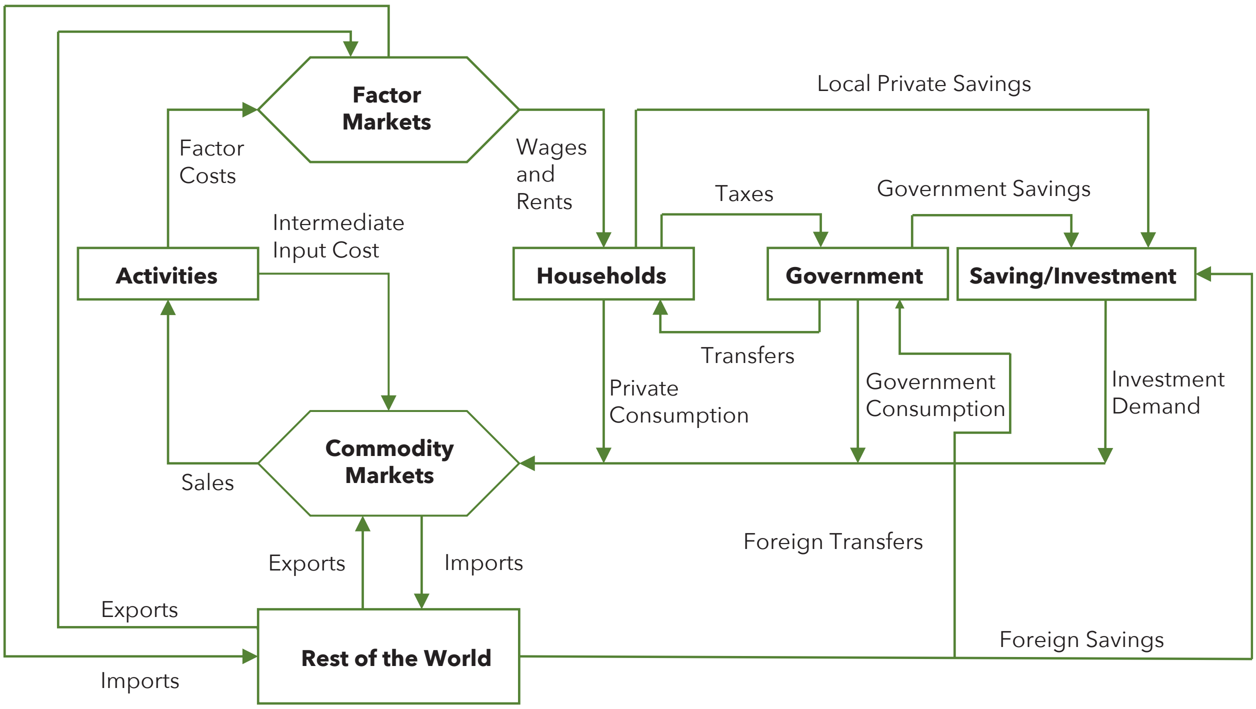
PE models can be constructed to investigate policy impacts on commodities of importance in Vietnam, such as fish, feed, and fertilizers. They can answer quantitative questions that are difficult (if possible) for other approaches, e.g., when only a part of the product is subject to policy change (e.g., when the EU imposes Carbon Border Adjustment Mechanism (CBAM) on fertiliser starting 2026). A conceptual framework for PE models is summarised in Figure 5. At the center of the model are production and consumption. The output of domestic producers can be exported, and domestic consumers can also consume products imported from abroad. PE can be used to evaluate the impact of changes in input markets on the supply and demand of a product.

Figure 5. Conceptual framework for PE modelling: Commodity flows.



CGE is also a very powerful tool, with uniqueness, to answer what-if questions. CGE is a well-established model for analyzing the impact of policy changes, i.e., taxes, fees, and prices, on an economy. This modeling approach has also been used in the impact assessment of climate change policies. Figure 6 shows the basic flows in a CGE model. The key strength of a CGE model is the ability to take into account the cross-sector links within an economy, and it can evaluate the direct and indirect impacts of a policy change. CGE models can evaluate the mobility of resources across economic sectors, investment, and the dynamics of economic development. They can also be used to assess the macroeconomic impacts of climate policies and possible responses (e.g., impacts on GDP, fiscal balance, international trade, and inflation). However, CGE is data demanding and subject to hard-to-verify hyper-parameters and assumptions. CGE models cannot be too disaggregated with a focus on the details of a single market/product. Also, CGE is not as intuitive as PE and is sometimes criticized as being a black box.

Figure 6. Basic final flows in a CGE model.



Source: *(Lofgren, 2004)*

One of the challenges in constructing and calibrating economic models for Vietnam is data quality. Economic data in Vietnam is not very scant, but they are often published by different organizations with inconsistencies and incompatibilities. As a result, modeling experts will have to update and cross-check data to ensure consistency. The modeling team may have to customize the PE and CGE models to fit with available data in Vietnam. Table 3 lists some challenges and possible solutions for economic equilibrium modeling in Vietnam.

Table 3. Challenges in equilibrium modeling in Vietnam and possible solutions.

Challenges	Solutions
Some data is outdated, and there are many inconsistencies and incompatibilities	Updating data, cross-checking, customizing models
There are uncertainties in policy implementation and possible responses from economic agents	Survey and consultation with stakeholders
Many hyper-parameters (especially CGE) must be specified	Elicitation, sensitivity analysis, large number of randomized parameter sets

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