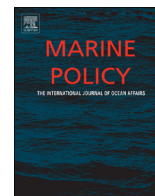




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# Economic impacts of climate change and climate change adaptation strategies in Vanuatu and Timor-Leste

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## ABSTRACT

The fisheries sectors in Vanuatu and Timor-Leste are important sources of food and income. Similar to other developing countries and those in the Pacific, they are vulnerable to the impacts of climate change more so because of their geographic location, socioeconomic conditions and political instability. Nonetheless, there are approaches to alleviate the damaging effects of climate change in the region's fisheries sector. Using economic modeling, this paper estimates the economic costs of potential climate change adaptation strategies for the fisheries sector in Vanuatu and Timor-Leste through assessment of alternative future scenarios. Strategies include aquaculture development, natural resource management through establishment and/or expansion of marine protected areas, and deployment of low-cost inshore fish aggregating devices. Modeling results demonstrate that the above innovations will enable the two countries to significantly improve coastal and freshwater fish production in the medium-term (2035) and long-term (2050). Fish consumption is projected to grow due to population and income improvements; yet considerable increases in production will augment demand. Furthermore, national-level gains are projected from these adaptation strategies through fish exports. Improved production under climate change will require significant investments from the national governments of Vanuatu and Timor-Leste and/or private sectors.

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## 1. Introduction

Throughout the tropical Pacific where the majority of rural people still live and depend on subsistence agriculture, the fisheries sector (including aquaculture) is vital to economic development, livelihood, and food and nutrition security. Vanuatu has a long tradition tied to inshore and offshore fisheries; the sector supplies the main source of income and protein for many island inhabitants and makes up the country's biggest export. On the other hand, Timor-Leste has historically depended on the rural interior for the bulk of its calories and national revenue, despite its sea surroundings. Since gaining sovereignty over a decade ago, efforts to stimulate sustainable fisheries development in Timor are increasingly in the spotlight. Like other maritime islands and nations in the region, Vanuatu and Timor-Leste are particularly susceptible to climate change because of their geographical location, socioeconomic status, and political instability. Nonetheless,

adaptive strategies are available to alleviate vulnerability in the region's fisheries sector to the damaging effects of climate change. Using economic modeling, this paper estimates the potential impact of climate change and climate adaptation strategies for the fisheries sector in Vanuatu and Timor-Leste.

Among the Melanesian countries, Vanuatu has the smallest total water area and exclusive economic zone (EEZ) of 680,000 square kilometers (km<sup>2</sup>) [1]. Fisheries is fundamentally important to the nation's economy and food security, and generates income for many of its inhabitants; approximately 72% of the country's rural households are involved in some form of fishing [2]. Vanuatu's fisheries resources can be categorized into six groups: coastal commercial fisheries, coastal subsistence fisheries, offshore foreign-based fisheries, offshore locally based or domestic fisheries, freshwater fisheries, and aquaculture [3]. Unlike Fiji and Solomon Islands, coastal subsistence fisheries produce the highest value of fish harvest in Vanuatu. The four major commercial species of tuna (bigeye, yellowfin, skipjack, and albacore) dominate fish exports within Vanuatu's EEZ [2].

In contrast to Vanuatu, Solomon Islands and Fiji, which have numerous islands, Timor-Leste has only two: the 144-km<sup>2</sup> Atauro Island and the 8-km<sup>2</sup> Jaco Island [4]. Fisheries supplements income and protein for many of Timor-Leste's coastal and inland

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communities, though at smaller scale than Vanuatu. An estimated 7600 of its inhabitants were employed in the fisheries sector in 2008 [5]. Since the country only gained independence in 2002, historical information on the fisheries sector is scant and effective data systems (and policies) have been slow to develop. Timor-Leste currently lacks a domestic commercial fishing fleet and motorized vessels were largely destroyed during the struggle for independence. This limited offshore fishing and concentrated the industry to mostly small-scale fisheries near the coast. In the mid-2000s the government signed bilateral agreements allowing foreign fishing vessels limited access to the country's deep-sea fishing grounds, under conditions that fish landings and shipment be channeled through Timor's ports [5]. However, some of these agreements have expired and others have suffered from non-compliance. Freshwater fishing in Vanuatu is mostly subsistence and restricted during monsoon season. The government has identified aquaculture as a means to improve food and nutrition security and generate income for both inland and coastal communities, although little progress has been made since aquaculture is costly and requires a heavy governmental hand and infrastructure. Despite current status, the fisheries sector in Timor-Leste is at a pivotal time as the government grapples with new policies, infrastructure and strategies that aim to sustainably develop the sector for improved food security and welfare. In 2012, for example, the National Coral Triangle Initiative Coordinating Committee of Timor-Leste reported the preparation of an integrated fisheries policy: *The Future of Fisheries: A Policy and Strategy for the Responsible Development and Management of Fisheries in Timor-Leste*. This policy encompasses optimal use and management of living resources, habitat conservation and development of fishing and aquaculture industries and fisheries institutions [6].

Though several studies have analyzed the vulnerability of Asia-Pacific fisheries (including aquaculture) to climate change and adaptation scenarios (see, for example [7–10]), this is the first study to evaluate economic impact of climate change adaptation strategies in the region. Through modeling applications, trends in fish production, consumption, and trade for medium-term (2035) and long-term (2050) can be projected with and without adaptation strategies. These scenarios provide important information in developing and supporting national strategies and policies to ensure food security, nutrition, assured income and improve economic conditions, particularly for the coastal communities of Vanuatu and Timor-Leste. While the climate adaptation strategies analyzed represent only a few of the potential alternatives for an inherently uncertain future, the developed model and the analyses presented in this paper are robust for the scenarios implemented. Sensitivity analyses of a range of demand and supply elasticities around best estimates show that orders of magnitude in the results are stable with respect to the range of plausible elasticity estimates. A companion article in this special section [6] discusses the study's methodologies in greater detail including data collection, assumptions and modeling. The rest of the paper is divided into modeling scenarios, results and discussion of country case studies, and summary of conclusions.

## 2. Data, methodology and modeling scenarios

### 2.1. Vanuatu

Vanuatu has adopted four main climate change adaptation strategies: (1) aquaculture (coastal and freshwater [AQ]); (2) regulations concerning habitat protection in marine protected areas (MPAs), with seasonal closure, traditional management of natural resources, control of critical species (sea cucumber, Trochus, parrot

fish, giant clam), and selective control of fishing methods and gears; and (3) low-cost fish aggregating devices (FADs).

AQ was introduced to Pacific Island countries as early as the 1920s, specifically in Vanuatu with the introduction of Pacific oysters [11]. This was followed by the short-lived culture of *Macrobrachium* in Santo Island from 1978 to 1983, tilapia from New Caledonia in Efate Island in the early 1980s, *Trochus* in the late 1980s, and the ongoing Teouma prawn hatchery in Efate at commercial-scale.

MPAs in Vanuatu have an estimated size of 58 km<sup>2</sup> [12]. Marine conservation activities implemented by the communities have been ongoing for several years, starting with the assistance of the Vanuatu Department of Fisheries (VDOF) in the 1990s [13]. VDOF persuaded the North Efate communities to close certain marine areas for *Trochus* recovery. This was followed by turtle monitoring spearheaded by the Vanuatu Wan Smolbag to conserve turtles in Nguna-Pele Islands. In 2003 the Nguna-Pele MPA established its network, comprised of local and indigenous non-government organizations (NGOs) of 16 communities from the two islands, with the main objective of sustainable use and long-term existence of marine and terrestrial resources. In 2007 Nguna-Pele joined the locally marine managed area (LMMA) network, and is currently in the initial phase of establishing it countrywide [14]. Pascal, Seidi and Tiwok [15] analyzed the economic benefit of MPAs in Vanuatu and demonstrated their positive effects on marine resource productivity, coastal environment, as well as income growth through tourism revenue.

Previous studies suggest climate change is likely beneficial for tuna and oceanic fish production [16] but detrimental for coastal fish production [17] in Vanuatu. Furthermore, the likely impact of various climate change adaptation strategies on fish production indicate favorable responses: use of FADs is expected to increase tuna and other oceanic fish catch in coastal waters; and various natural resource management (NRM) strategies (such as MPAs and LLMAs) are likely to mitigate some of climate change's negative effects on coastal fisheries. Therefore, NRM and FAD strategies are anticipated to expand supply of all four capture fisheries groups (tuna, other oceanic species, coastal finfish and coastal invertebrates).

Given that many of these strategies are still in the formative stage, three climate change adaptation scenarios were modeled. *Scenario 1* (AQ development involves improvements in the productivity of freshwater (both finfish and invertebrate) aquaculture. *Scenario 2* (NRM+FAD) addresses changes in production and productivity in coastal and oceanic capture fisheries resulting from FADs, various management regime shifts, and adoption of resource enhancement practices. *Scenario 3* is a combination of scenarios 1 and 2. Estimated assumptions about the production impact of these strategies are described in Dey et al. [6] and given in Appendix Tables A.1 and A.2.

Over the period 2009–2013, real per capita income in Vanuatu essentially stagnated. A modest recovery in income growth over the longer run was assumed. For both medium- (2035) and long-term (2050), two baseline (most plausible) scenarios were implemented representing two annual growth rates of real per capita income: medium (1.5% per year) and high (2.5% per year). Populations were assumed at 424,122 in 2035 and 538,707 in 2050 [18].

Validated baseline data (production, consumption, trade, and price) used in the Vanuatu model are presented in Appendix Table A.1. Supply quantities reported in Table A.1 do not include catch by foreign fleets, which is small in Vanuatu. Supply volumes reported in Table A.1 and used in the analysis include catch by national fleets in both national and international waters. Appendix Table A.2 reports the coefficients of supply shifters used in the Vanuatu model to represent climate change and climate change adaptation strategies. The coefficients for climate change, as reported in

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