University of California Global Food Initiative

Food from the Sea

Supporting aquaculture research and development in California and beyond

October 2018

This report was made possible by funding from the University of California (UC) Office of the President Global Food Initiative. The University of California Global Food Initiative addresses one of the critical issues of our time: how to sustainably and nutritiously feed a world population expected to reach eight billion by 2025. By building on existing efforts and creating new collaborations among UC's 10 campuses, affiliated national laboratories and the Division of Agriculture and Natural Resources, the Global Food Initiative is working to develop and export solutions for food security, health and sustainability throughout California, the United States and the world. For more information, visit: www.ucop.edu/global-food-initiative.

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Introduction

Aquaculture remains the fastest growing food-production sector in the world and will play an increasingly important role in improving nutrition and food security as the global population continues to grow. It is also an important source of employment, especially in developing countries, and the income aquaculture generates contributes significantly to sustainable rural livelihoods. While many countries have considerable potential, current aquaculture production is concentrated in only a handful of countries, primarily in Asia, and exported to major markets. As a result, many developed nations import large quantities of farm-raised seafood, foregoing the benefits of having a well-regulated domestic market. The United States imports 90% of its seafood and has a $10 billion seafood trade deficit, and California alone is responsible for about half of this deficit ($4.5 billion). For this project, we've focused on producing research and tools to facilitate the expansion of sustainable marine aquaculture, both domestically and abroad. Two components of this project are detailed in this report and include (1) creating a financial tool for engaging fishers in the planning of local aquaculture initiatives; and (2) developing methods for mapping and tracking global aquaculture production.

Financial Modeling for Aquaculture Planning

Site selection is the act of determining which types of aquaculture will be permitted, where farms will be located, and the likely impacts of such proposed production. Coastal areas that are already crowded with commercial and recreational activity are frequently targeted for aquaculture development. Current user groups of coastal areas can be staunch opponents of aquaculture expansion, thus engaging these stakeholders to build community buy-in is a vital step in growing the sector. The objective of this project was to assist a local aquaculture initiative and former California Sea Grant project, the Ventura Shellfish Enterprise (VSE), in its mission to increase sustainable mariculture production within the region. The University of California, Santa Barbara (UCSB) has worked closely with VSE for several years, and our partnership has provided exciting opportunities for UCSB to conduct local, applied research initiatives that help advance state and federal mariculture policies. Specifically, we worked to assist VSE with one of their key project features – "Participation opportunities for existing commercial fishers".

While discussing fisher participation incentives with VSE, we identified a major barrier to effectively engaging fishers who were interested in transitioning to aquaculture production - VSE struggled to provide fishers with important and compelling information about the financial prospects of transitioning from capture fisheries to aquaculture. To fill this critical information gap and help make the economic case for switching from capture fisheries to aquaculture production, we chose to develop an open source interactive financial model - the Aquaculture Planning Financial Tool - and publish it online at http://sfg-ucsb.shinyapps.io/aqua_financial/. We believe that this tool will help future aquaculture initiatives provide valuable economic insights to relevant stakeholders and inform their decision-making processes (Figure 1).

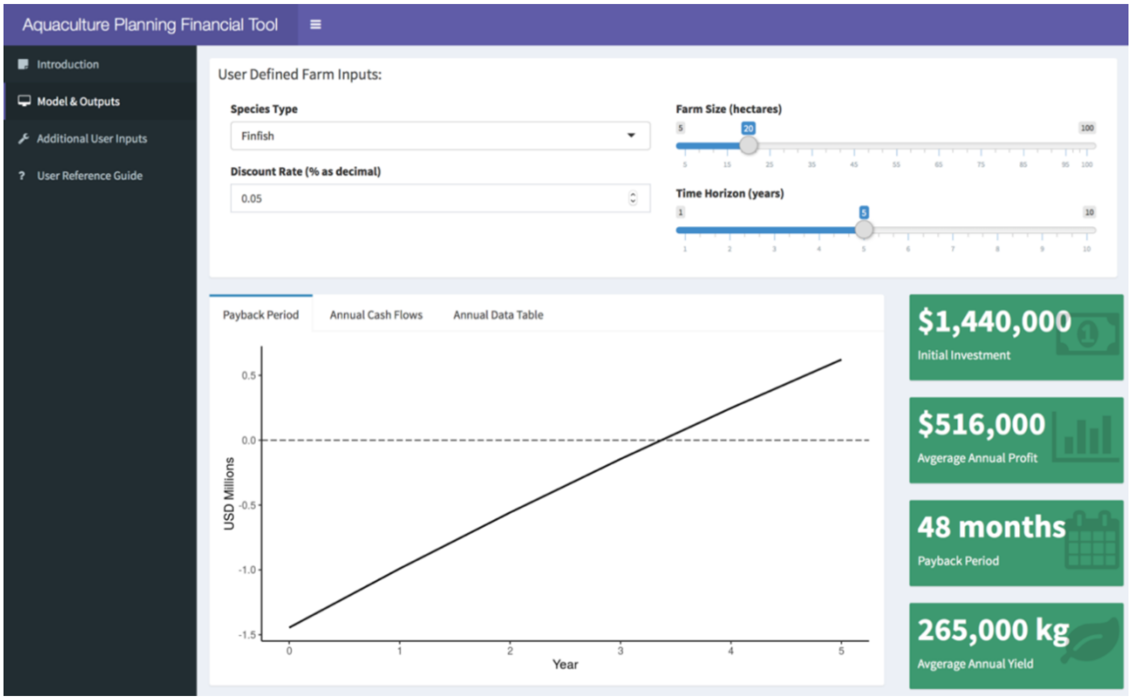

Figure 1: Screenshot of the Aquaculture Planning Financial Tool dashboard.

The Aquaculture Planning Financial Tool allows users to input several key parameters (e.g. farm size, species type, price, etc.) that represent their hypothetical investment in an aquaculture farm. The app then uses a bio-economic model to simulate the timing and magnitude of potential costs and revenues associated with the aquaculture farm, and it visualizes key model results to provide stakeholders with clear, concise information. These visual summaries include plots that show the required initial investment, annual productivity (harvest), cash flows over time, break-even point, and net present value of the farm (Figure 1). The app includes a series of default model parameters for each of the main species types (finfish, shellfish, and seaweed), but it also permits the user to configure additional inputs, such as growth rates and operating costs, to customize the model for a specific context. The flexibility of our tool promotes its extension to aquaculture planning initiatives in California and around the globe. We have designed this tool to support future siting decisions by facilitating a more effective stakeholder engagement process.

Our app streamlines the most relevant financial planning considerations into a single, user-friendly framework, and it can approximate the economic feasibility of aquaculture production for any individual stakeholder. We intend for this app to serve as a base platform that can be adapted and customized to match different geographies and scales of production, and the source code for the application publicly available online at https://github.com/SFG-UCSB/aqua-finance-dashboard. By making the application open source, future users can build off our tool to provide more detailed results that are explicit for any given aquaculture initiative. We hope our financial tool will encourage more robust stakeholder participation in aquaculture planning, thereby fostering a more cohesive coastal economy and improving future planning processes. To support this vision, we are sharing The Aquaculture Planning Financial Tool with our network of partners working on ocean conservation and management and exploring opportunities to use the tool in their current or upcoming projects.

Mapping Global Aquaculture

Aquaculture now produces more seafood for human consumption than capture fisheries. Yet unlike terrestrial agriculture, there is very little information about the spatial distribution and footprint of aquaculture activities. Effectively managing an aquaculture industry requires tracking the precise locations of individual farms, aquaculture areas, and production, as well as information on farm quality. These data are critical for understanding the implications of aquaculture on the industry itself, the environment, and other sectors. Filling this data gap will advance our ability to study aquaculture effectively and manage the sector sustainably. To this end, we have worked to (1) understand the current state of knowledge by compiling existing national datasets; and (2) develop models capable of mapping global aquaculture using high-resolution satellite imagery and machine learning.

In the first stage of this project we sought to better understand the landscape of existing spatial aquaculture data and how these data could be used to inform, complement, or validate analyses on the impacts of aquaculture's footprint. While these data are indeed monitored and reported in some cases, we found that few countries collect these data and, when they do, the format of the datasets varies considerably, often limiting their usefulness. Though it is sparse and far from uniform, we have been able to use existing aquaculture data to develop two important products. First, in collaboration with other researchers from the Sustainable Fisheries Group at UCSB, we translated and processed a 33-year dataset of aquaculture and fishery statistics from China, the world's largest seafood producer by a significant margin. Using that dataset, we co-authored a manuscript (Szuwalski et al., in review) on China's seafood strategies and the role of aquaculture. Second, a handful of countries that collect spatial aquaculture data have developed online platforms for accessing the data. We compiled all the national aquaculture data from these platforms into a single dataset and developed a web application to share the results (Figure 2). The dashboard is publicly available online at https://sfg-ucsb.shinyapps.io/aqua-mapping-dashboard/ and will be updated as more data are identified.

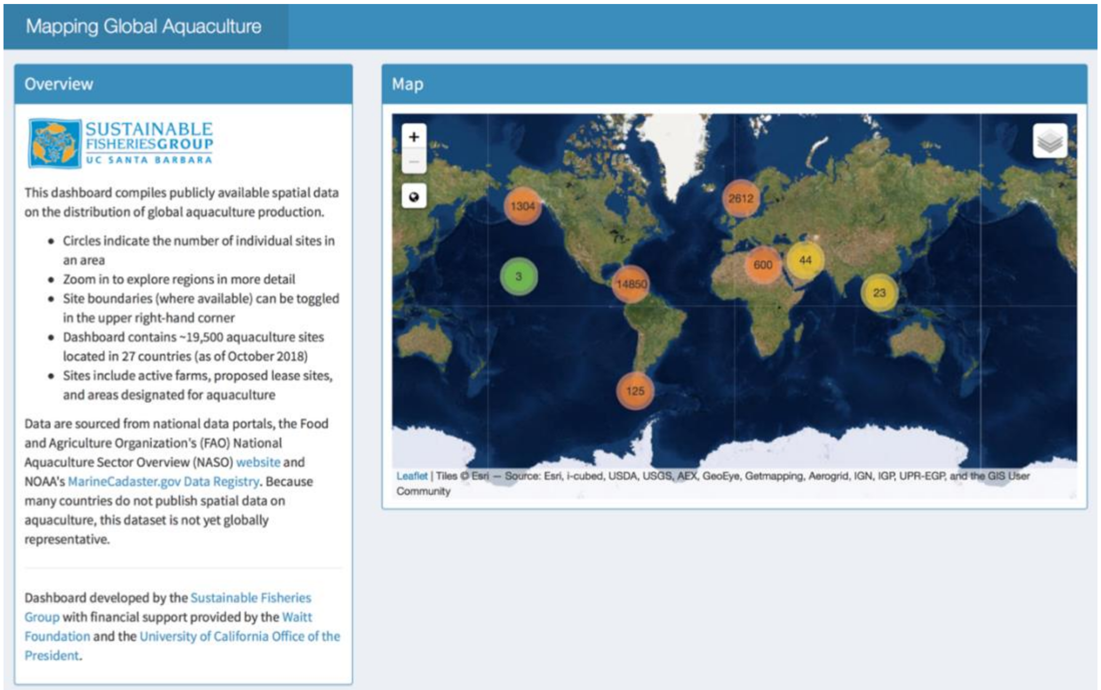

Figure 2: Screenshot of the Mapping Global Aquaculture dashboard.

The Mapping Global Aquaculture dashboard currently contains more than 19,500 aquaculture locations (active farms, proposed lease sites, and areas designated for aquaculture) in 27 countries. Data for the U.S. are sourced from the National Oceanic and Atmospheric Administration (NOAA) MarineCadastre data portal and include approximately 10,000 aquaculture locations in 20 states (Alabama, Alaska, California, Connecticut, Florida, Hawaii, Louisiana, Maine, Maryland, Massachusetts, Mississippi, New Hampshire, New Jersey, New York, North Carolina, Oregon, Rhode Island, Texas, Virginia, and Washington). The available data for California contain just 27 aquaculture locations (10th highest among U.S. states), including sites in Eureka, Tomales Bay, Santa Cruz, Morro Bay, Santa Barbara, and Long Beach.

In the second stage of this project, we sought to develop a machine learning model capable of mapping aquaculture in high-resolution at a global scale. The objective of this work was to create a model that can fill the large gaps in global aquaculture data by producing maps for countries where spatial aquaculture data does not currently exist. After obtaining an Education and Research account with Planet Labs, a provider of high-resolution satellite imagery, we compiled a reference library of satellite images containing different forms of aquaculture (Figure 3). To date, this dataset covers approximately 30,000 km2 and includes aquaculture farms in over 20 countries.

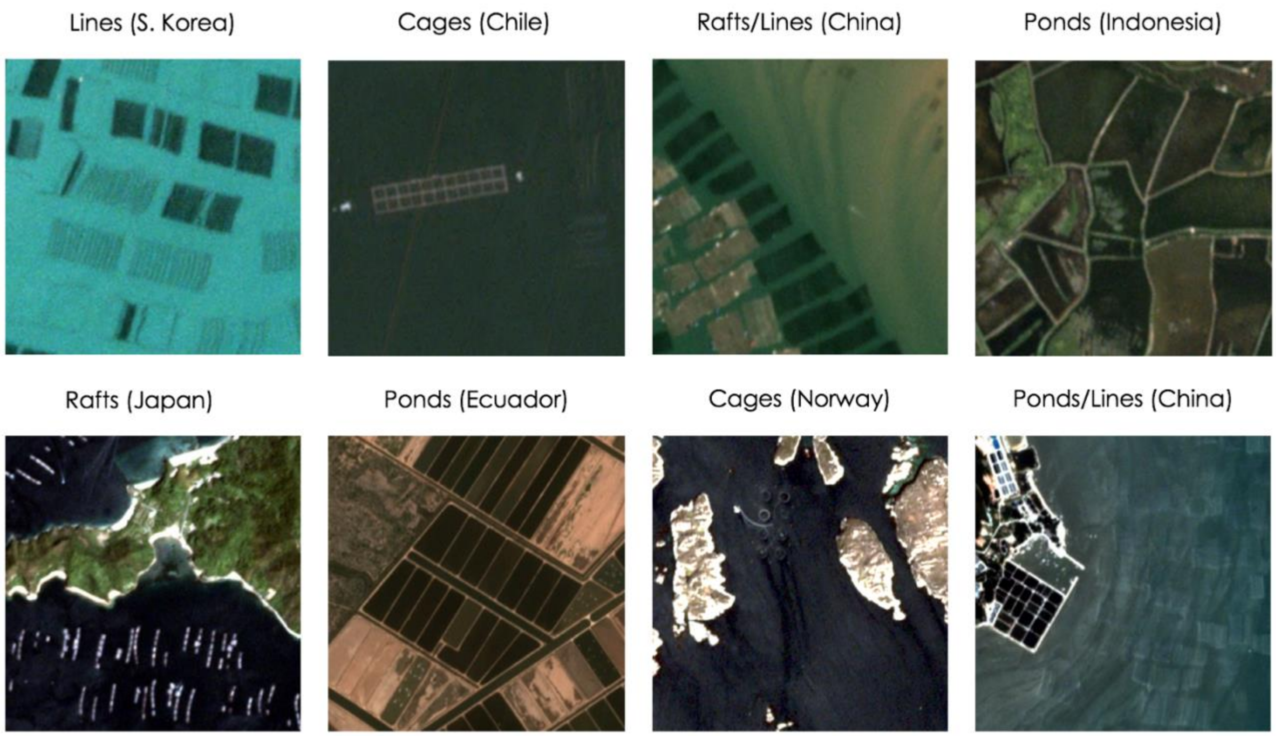

Figure 3: Example reference images for select aquaculture types and geographies.

We then used this reference library to build a training dataset - a collection of images where aquaculture objects are labeled - that can be fed into machine learning models. In particular, we identified convolutional neural networks (CNNs) as the most promising type of machine learning models for our project. CNNs are a cutting-edge form of “deep” machine learning particularly suited for image analysis that have recently been used by the natural and social sciences for such tasks as detecting reef fish in underwater videos, estimating reef fish abundance from images of coral cover, and predicting poverty from satellite imagery.

Through a collaboration with Dr. Kelly Caylor, UCSB professor and Director of UCSB’s Earth Research Institute, we successfully implemented a data processing and machine learning pipeline for training a CNN to detect aquaculture farms in satellite imagery. To date, we have tested our model on all four major aquaculture types (lines, cages, rafts, and ponds; Figure 3) and demonstrated our ability to accurately detect salmon farms in Chile (Figure 4).

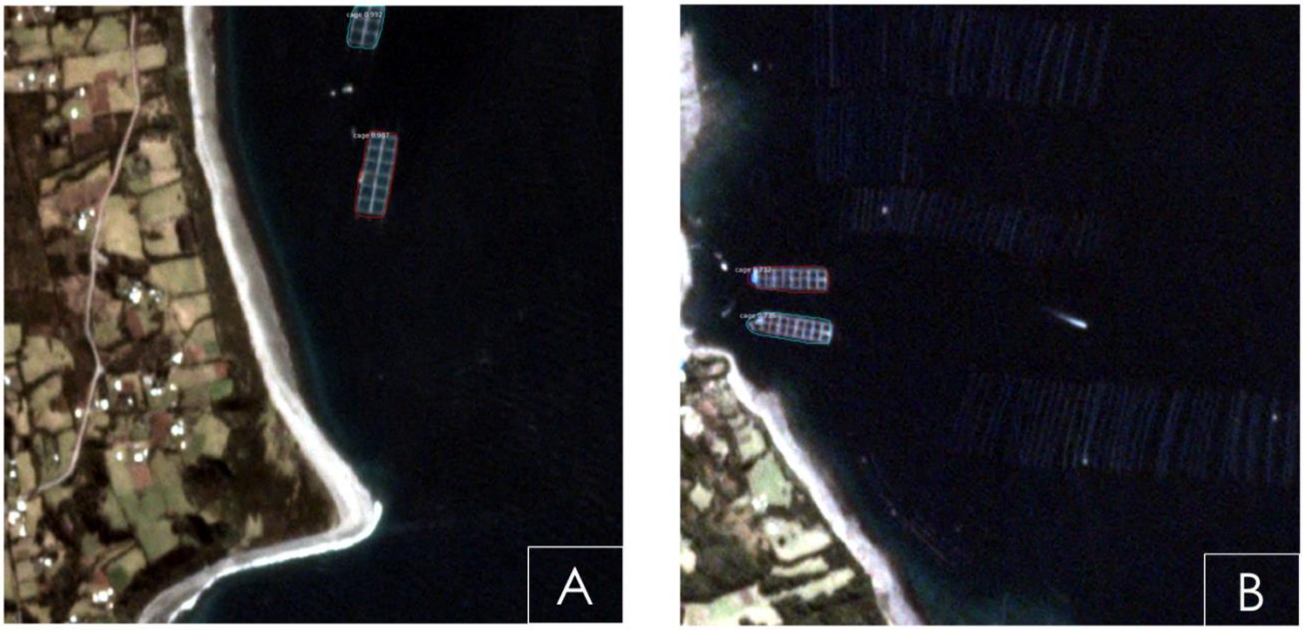

Figure 4: Example predictions from a convolutional neural network trained to detect salmon cages. The model correctly identifies both cages in each image with accuracies greater than 90% (A) and 73% (B).

We hope to leverage these promising initial results to improve our model's ability to detect other aquaculture types in different regions for the remainder of the year. Throughout this process, we will be able to use the national datasets that we compiled to expand our training dataset and validate our model predictions. We plan to synthesize these results into a manuscript for publishing in an academic journal. Lastly, we will develop proposals for new funding sources that will allow us to apply our model at larger scales beyond the scope of our current capacity using Planet Labs imagery.

Conclusion

There is a tremendous opportunity for sustainable aquaculture in U.S. waters to provide fresh seafood to domestic markets, create economic opportunities, and reduce our nation's reliance on potentially unsustainable seafood imports. With the nation's third longest coastline, California is particularly well-positioned to lead the development of a sustainable U.S. aquaculture industry. By developing an engaging and publicly available financial tool for stakeholder engagement, this project addressed a key challenge faced by a local initiative looking to expand California's sustainable aquaculture industry. Furthermore, the spatial data and models developed for this project are a step toward better understanding aquaculture's impacts and approaches for sustainably managing this sector. Looking forward, we hope our work on this project can be used by new aquaculture initiatives, as well as aquaculture managers, in California, the U.S., and abroad.

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