Aquaculture and Coastal Habitats Report No. 4

Mapping Vulnerability and Risk of Mangrove Conversion to Pond Aquaculture in Myanmar

J. Ronald Eastman, Stefano Crema, Katherine Landesman

Clark Labs, Clark University

Introduction

On behalf of the Gordon and Betty Moore Foundation, Clark Labs has been engaged in a series of projects to map aquaculture and coastal habitats. This report summarizes the procedures used and the results of a mapping of vulnerability of mangrove areas to conversion to pond aquaculture in Myanmar in 2014 and the risk of conversion by 2050. For information on the broader objectives of the program, please refer to Eastman et al., (2015). Vulnerability is a statement of the degree to which an area of mangroves has the right qualities for conversion, while the risk is a statement of probability of conversion for a specific date.

The goal of this stage in the project was to develop a comparable mapping of vulnerability and risk to that developed for Vietnam, Cambodia and Thailand (see Cunningham et al., 2015). In that previous project, vulnerability was empirically modeled using a Multi-Layer Perceptron neural network based on locations of known conversion from 1989 to 2014 and a set of explanatory variables. However, there is so little pond aquaculture in Myanmar that it was impossible to establish an adequate sample of historical examples of change. As a result, vulnerability was mapped using a special form of multi-criteria evaluation known as Dempster-Shafer Theory. The vulnerability was then transformed to risk using the same procedure as in the previous study.

Procedure

Given that an empirical modeling could not be achieved for Myanmar, it was decided to use a multi-criteria evaluation (MCE). The most common approach to MCE is to use a weighted linear combination of standardized supporting variables. However, after researching the issue in the field, we found that some variables supported the possibility of conversion while others argued against conversion (i.e., persistence of mangroves). For example, being far from the coast supports persistence, but being near to the coast does not support conversion. The two are not reciprocal. Dempster-Shafer theory is ideal for aggregating lines of evidence of this nature.

Dempster-Shafter (DS) theory (Gordon and Shortliffe, 1985) is named for a technique that combines Shafer's theory of evidence with Dempster's rule of aggregation. It plays a prominent role in medical diagnosis expert systems. It is a development from Bayesian statistics that explicitly recognizes the existence of ignorance and uncertainty in the state of evidence to support a hypothesis. In this respect it allows for the aggregation of partially diagnostic evidence and produces estimates of belief, plausibility, belief intervals and ignorance. Belief is the degree to which the evidence supports a hypothesis while plausibility is the degree to which the evidence does not argue against a hypothesis. The belief interval is the difference between them and expresses the uncertainty about a hypothesis. Ignorance is the total composite uncertainty over all hypotheses.

In the implementation of DS theory in Clark Lab's TerrSet system (Eastman, 2014), lines of evidence are supplied as fuzzy sets measured on a 0-1 scale. Further, it is necessary to indicate whether each line of evidence supports a hypothesis or the negation of that hypothesis. It then provides options to produce maps of belief, plausibility, belief intervals and ignorance.

From our field work, four lines of evidence were determined:

1. Mangrove intactness
2. Distance from existing pond aquaculture
3. Distance from airports
4. Distance from coast

The first of these relates to a statement in FAO (2003) that indicates:

> *Primary mangrove areas are protected under jurisdiction of the Ministry of Forestry and not available for aquaculture and are essentially forest reserve. Significant jurisdiction of secondary mangroves seems to be devolved to the Department of Fisheries for availability to conversion for aquaculture. The delineation of Primary and Secondary status does not appear to be well publicized nor the criteria to define these geo-ecological zones.*

Field work did not clarify this distinction. However, variations in the intactness of mangroves is very evident in remotely sensed images (Figure 1). Rather than classifying mangroves into intact/degraded, we used a Mahalanobis classifier (Foody 1992) that outputs the probability that each pixel belongs to a dense mangrove class. By masking with a previously created mapping of mangroves, the result can be interpreted as a mapping of intactness (on a scale from 0-1). Intactness was used to support a hypothesis of persistence.

A second line of evidence was developed based on distance from existing pond aquaculture. The logic is that areas of existing pond aquaculture are probably areas that are already served by infrastructure, knowledge and marketing support. By examining the radius of pond aquaculture clusters in Myanmar, it was determined that the typical radius was 15 km. Distance was therefore fuzzified to produce a map where the value is 1 immediately adjacent to existing ponds and dropped to 0 in a sigmoidal fashion at a distance of 15 km. This was used to support the hypothesis of conversion.

A third line of evidence was distance from airports (as an indicator of market access). This was fuzzified using a sigmoidal function range from 1 next to airports and 0 at a distance of 32 km in support of conversion.

Finally, distance from the coast was fuzzified from 0 next to the coast to 1 at 5.2 km in support of persistence. This was based on the maximum distance from coast of existing pond aquaculture. Figure 3 shows each of the lines of evidence.

Based on these four lines of evidence, TerrSet's Dempster-Shafer procedure was used to calculate the belief and plausibility of conversion. Given uncertainty in the model, these represent the lower and upper bounds on the estimated vulnerability. Typically, as more evidence is added, the interval between these is reduced until they meet (when uncertainty disappears). Given that uncertainty does exist, the best estimate of vulnerability is thus the mid-point between the two. Figure 4 shows this result.

Once the vulnerability image had been created, a risk map for conversion of mangroves to pond aquaculture by 2050 can be produced if the rate of conversion is known. In the empirical model developed for Vietnam, Cambodia and Thailand, rates were determined separately for each province based on the amount of change from 1989-2014. However, given that the amount of pond aquaculture in Myanmar is so small, only a national rate was calculated based upon the change from 1999-2014. This was then projected forward to 2050 using a Markov Chain model, allowing the final risk map to be created in the manner described by Cunningham et al. (2015). Figure 5 shows the result.

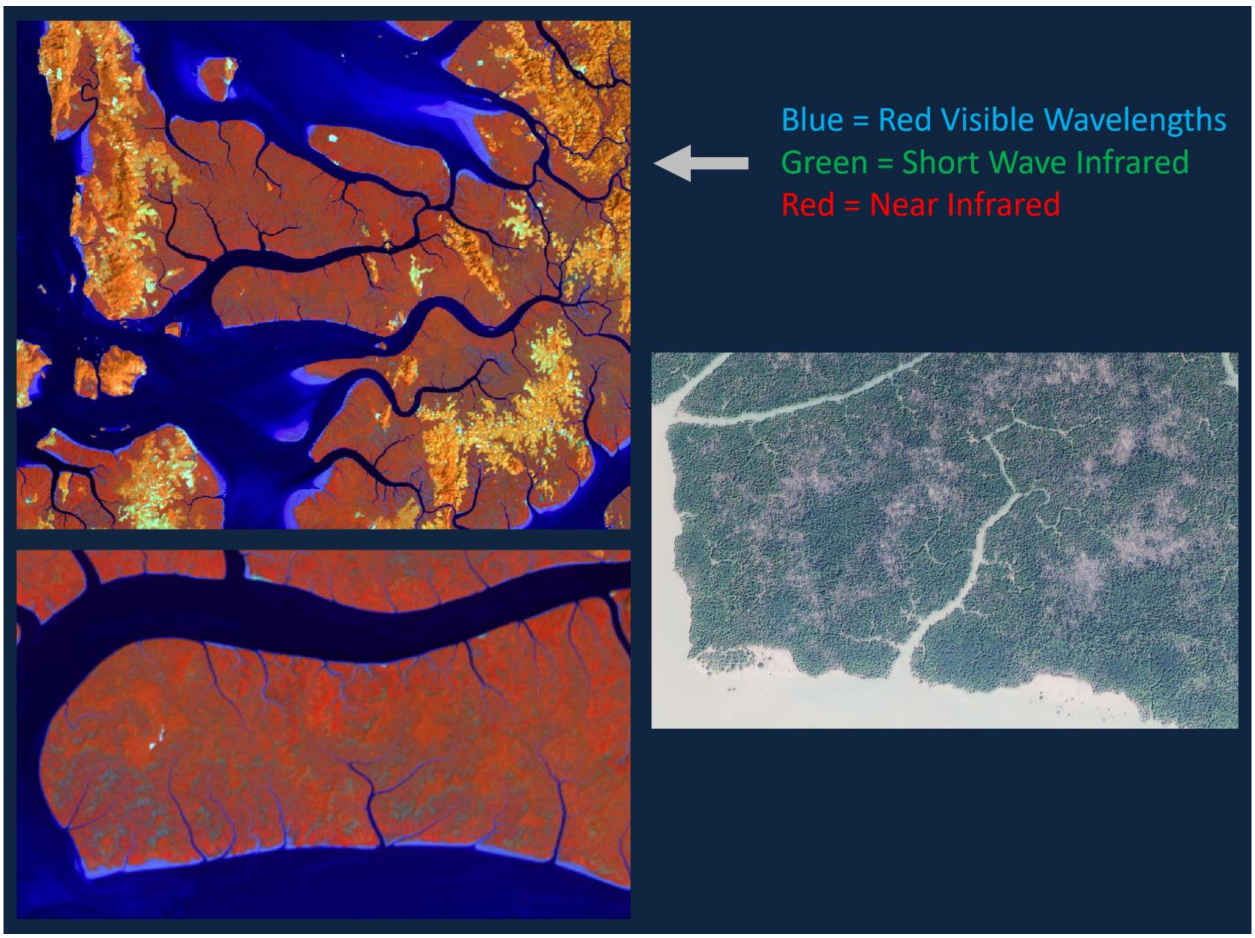

Figure 1 Landsat 8 false color composite (upper left). The reddish areas are mangrove. Darker gray-red areas are degraded mangroves (bottom-left). The right image shows a natural color composite from Google Earth for the lower left section of the island shown in the lower-left.

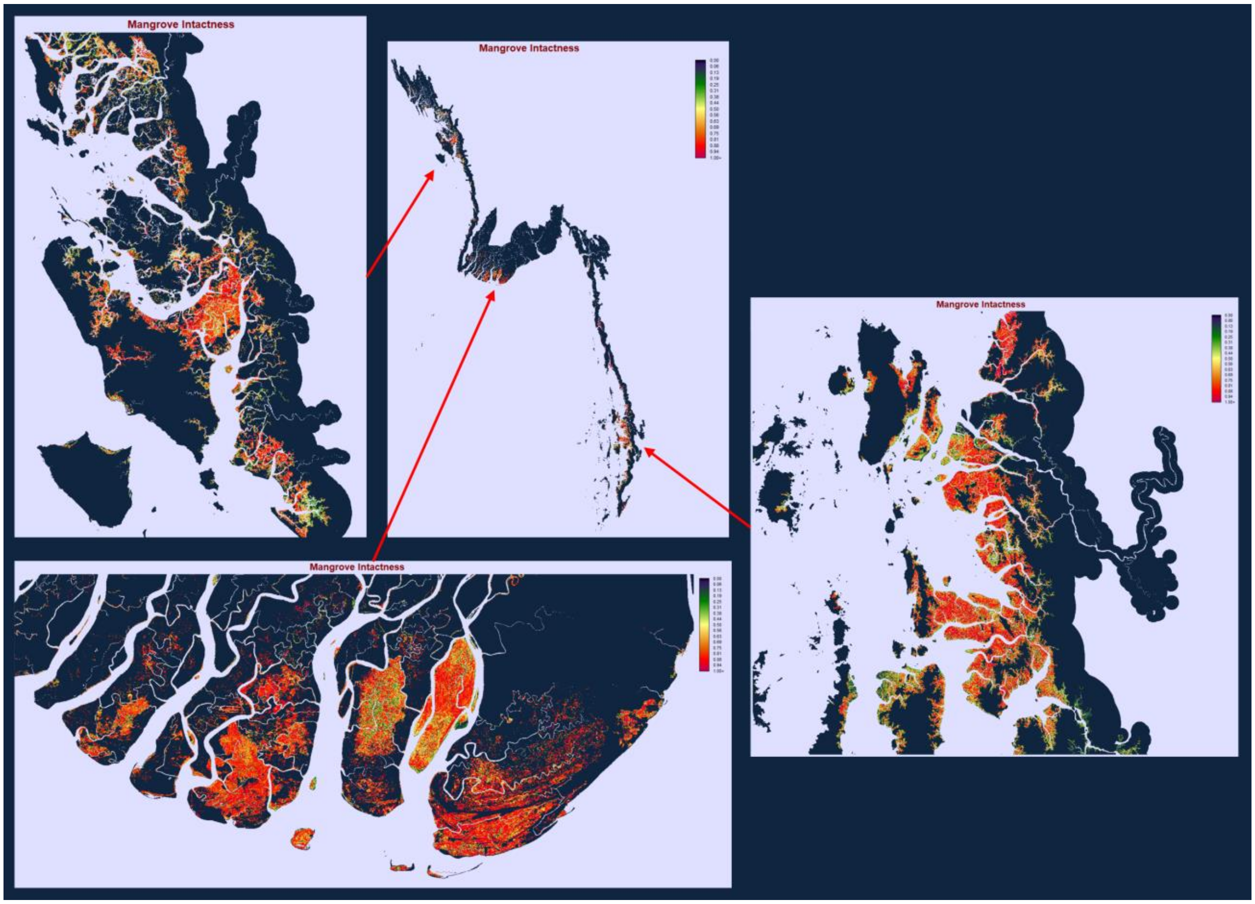

Figure 2 A map of mangrove intactness developed using a Mahalanobis classifier

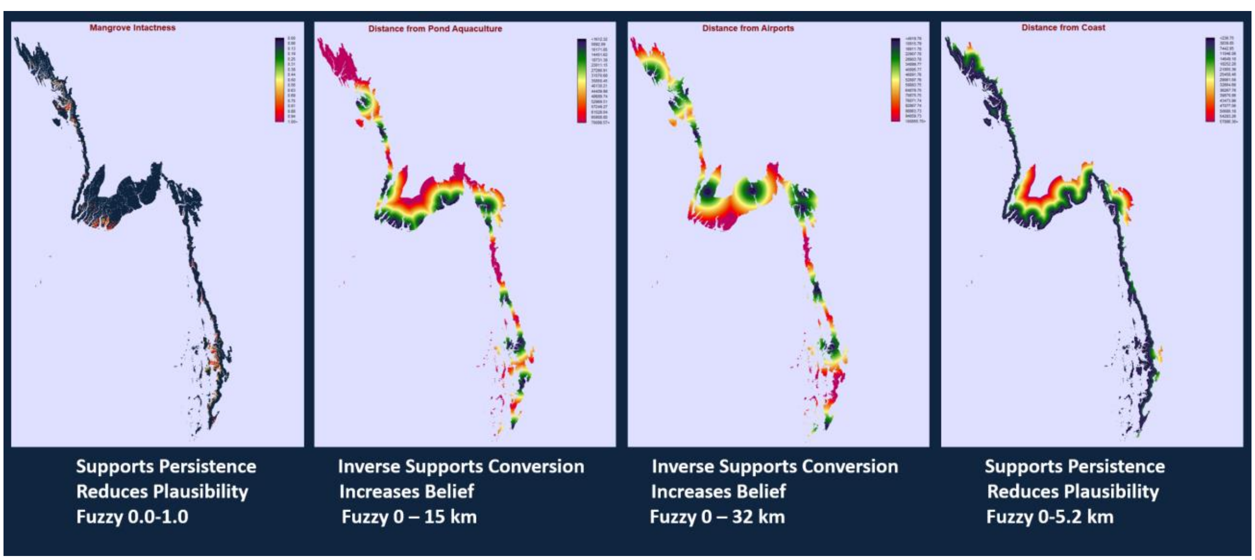

Figure 3 The lines of evidence, expressed as fuzzy sets, that were used in the Dempster-Shafer analysis

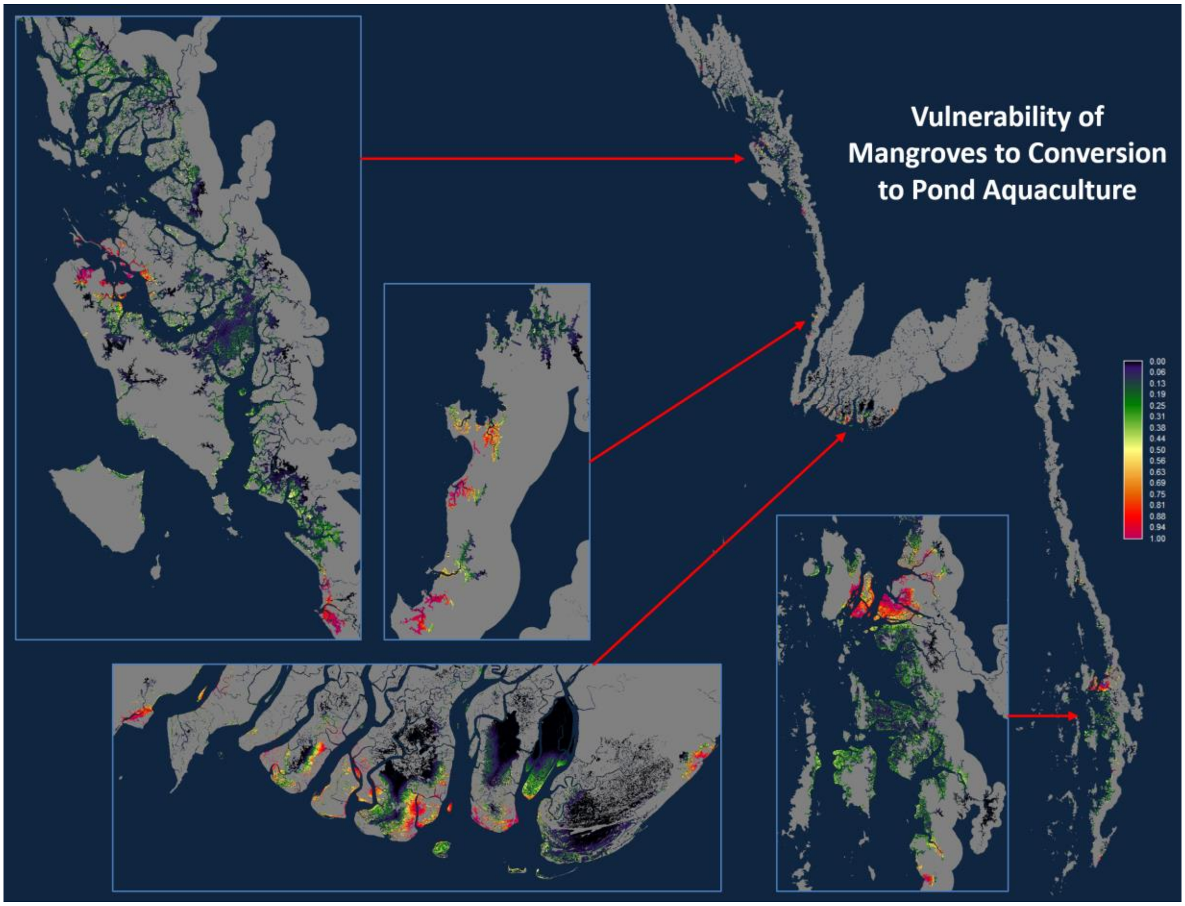

Figure 4 The map of vulnerability of mangroves to conversion to pond aquaculture in 2014

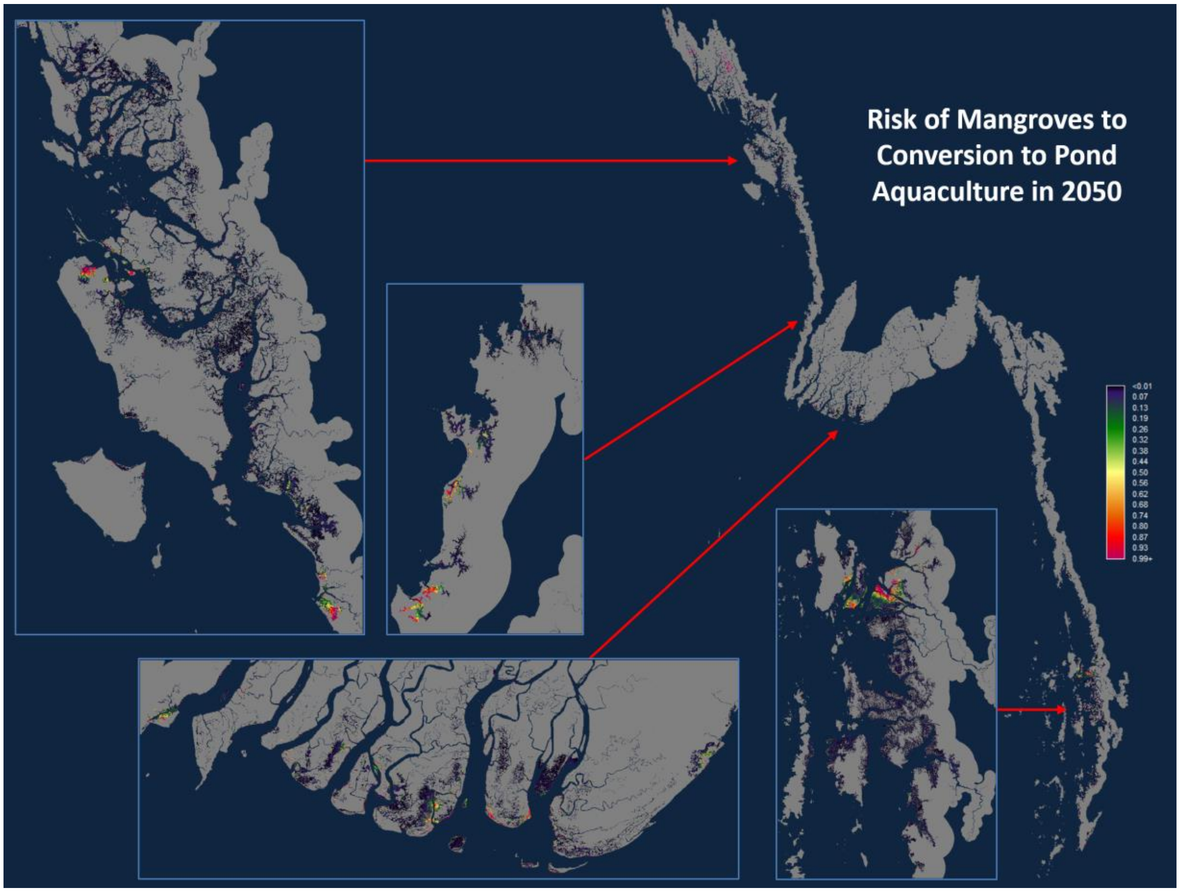

Figure 5 The map of the risk of mangroves converting to pond aquaculture in 2050.

References

Cunningham, S., Eastman, J.R., and Crema, S.C., (2015) “Aquaculture and Coastal Habitats Report No. 2: Mapping Vulnerability and Risk of Land Conversion for Pond Aquaculture in Thailand, Cambodia and Vietnam”, (Clark Labs, Worcester, MA).

Eastman, J.R., (2014) TerrSet Geospatial Monitoring and Modeling System (Worcester, MA: Clark University).

Eastman, J.R., Crema, S.C., Sangermano, F., Cunningham, S., Xiao, X., Zhou, Z., Hu, P., Johnson, C., Arakwiye, B., and Crone, N., (2015) “Aquaculture and Coastal Habitats Report No. 1: A Baseline Mapping of Aquaculture and Coastal Habitats in Thailand, Cambodia and Vietnam”, (Clark Labs, Worcester, MA).

FAO (2003) “Myanmar Aquaculture and Inland Fisheries”
http://www.fao.org/docrep/004/ad497e/ad497e00.htm#Contents

Foody, G.M., Campbell, N.A., Trodd, N.M., and Wood, T.F., (1992) Derivation and Applications of Probabilistic Measures of Class Membership from the Maximum Likelihood Classification, Photogrammetric Engineering and Remote Sensing, 58, 9, 1335-1341.

Gordon, J., and Shortliffe, E.H., (1985) "A Method for Managing Evidential Reasoning in a Hierarchical Hypothesis Space", Artificial Intelligence, 26, 323-357.