Adaptive phyconomy for sustainable management of coastal ecoscapes in Indonesia

Iain C. Neish
Director, PT Sea Six Energy Indonesia, Bali, Indonesia

Email: ineish@sea6energy.com

Abstract. Adaptive phyconomy supports holistic, sustainable marine ecoscape development as a component of integrated coastal area management (ICAM). Phyconomy is the branch of applied phycology that comprises systems of art, science and technology applied to production systems that yield crops of algae. Through the macroalgae known as “seaweeds”, farmers turn seawater, sunshine, and effort into money. Adaptive marine phyconomy of tropical red seaweeds is an outstanding example of large-scale crop production that developed primarily from simple methods refined by farmers in the sea, but as of 2020 it is, still much more art than science. Phyconomy, ecoscape issues and market issues are intertwined in a way that demands holistic planning and management. Every phyconomy action is influenced not only by energy and materials issues, but also by issues among value chain stakeholder alliances. Ocean farming functions take place under conditions where environmental and socio-economic conditions are often uncertain, therefore adaptive approaches must be applied in a way that is resilient and sustainable. The present paper discusses how adaptive phyconomy art and science is being developed as a fundamental component of integrated coastal area management for sustainable marine ecoscape development in Indonesia.

1. Introduction
This e-document is a synopsis of Neish 2020, which was a video presentation that served as a plenary lecture at the virtual MARSAVE 2020 2nd Marine Resilience and Sustainable Development International Symposium, hosted by Hasanuddin University from Makassar, South Sulawesi, Indonesia, during October 2020. Please see https://www.youtube.com/watch?v=uRxCGRRA1vY to view the plenary video [1,2].

2. The concept of adaptive phyconomy in ecoscapes
‘Phyconomy’ comprises systems of art, science, and technology applied to production systems that yield crops of algae. ‘Adaptive phyconomy’, for purposes of this presentation, means practical seaweed farming as undertaken in tropical coastal communities.

Adaptive phyconomy in tropical seaweed farms is an outstanding example of large-scale crop production developed from simple methods refined by farmers in the sea. Phyconomy enables farmers to turn sunlight and seawater through seaweeds into money.

Adaptive phyconomy is undertaken within marine production ecoscapes where people live and work in the same communities. “Production ecoscapes” are “areas with dynamic mosaics of habitats and land and sea where the harmonious interaction between people and nature maintain biodiversity while providing humans with goods and services needed for their livelihoods, survival and...”
wellbeing.” [3]. Production ecoscapes are therefore essential components of integrated coastal area management (ICAM) and adaptive phyconomy has a key role in ICAM planning and development.

As a discipline, tropical marine phyconomy has been adaptive from its beginnings in the 1960s. Marine phyconomy of seaweeds in tropical ecoscapes is substantially based on trial and error (a.k.a. bricolage) and steps followed by virtuous cycles of adaptation are depicted simplistically in Figure 1. Bricolage is a process undertaken with the use of purpose-built test plots, but at the present state of adaptive phyconomy it is fair to say that farmers are installing test-plots every time they plant crops in the sea. If crops thrive, farmers are pleased. If crops produce average yields farmers are relieved. If crops fail, farmers are dismayed and frustrated. In every case, though, farmers are not sure why yields were as experienced, or what measures to take in response to harvest experiences.

![Diagram of virtuous cycles of adaptation](image)

**Figure 1.** Virtuous cycles of adaptation at the core of adaptive phyconomy

### 3. Seaweed crops farmed in Indonesia

All known commercial cultivars are thought to be derived from farmer-screening and selection of seaweed fronds from wild stocks as was certainly the case with *Kappaphycus alvarezii* var. Tambalang. Cultivars have been spread around the ASEAN region and around the whole world with few records being kept, so the provenance and identities of cultivars farmed in any given location is unknown. Figure 2 shows an overview of seaweed genera and species known to have given rise to commercially farmed cultivars in Indonesia.
Figure 2. Taxonomic tree for some genera of tropical seaweeds that are potential tropical crops
(Source: AlgaeBase.org)

4. Indonesian seaweed production geographical overview
Figure 3 is a map of Indonesian Provinces that shows locations where most seaweed was produced per
2019-2020 from industry consensus. About 50% of Kappaphycus was farmed in Kalimantan Utara. A
further 25% of Kappaphycus and about 80-90% of Eucheuma was farmed in Sulawesi. The remaining
25% of Kappaphycus and 10-20% of Eucheuma was farmed in areas throughout Indonesia. Most
Gracilaria was farmed in South Sulawesi and Central Java. Large areas of East Indonesia (enclosed in
a blue dotted line) can be tremendously productive, but logistics costs impaired links to value chains.
Other farmed seaweed genera listed in Figure 2 were not produced in large quantities.

Since 1986 seaweed farming has become an economic mainstay for tens of thousands of people in
Indonesian ecocapes. Confirmed data are unavailable but informed estimates cited in Figure 3 place
current production volumes of raw dried seaweeds from Indonesia in the range of about 300-360
thousand dry tons per annum per informal industry consensus. Per official government estimates,
however, current production volumes (all types) from Indonesia were estimated to be on the order of
over ten million wet tons per annum, and that translates to over one million dry tons. Such production
puts about half a billion USD (7,200 B IDR) per annum into the bank accounts of seaweed farmers
along the coastlines of Indonesia.

5. Seaplant ecosystem services in integrated coastal management ecocapes
Seaweeds are a subset of the overarching set of organisms known as seaplants, which includes not
only macroalgae but also microalgae, and marine vascular plants such as mangroves and sea grasses.
As the world’s premier archipelagic state, Indonesia has upwards of 60% of global tropical coastline.
Seaplants are ubiquitous along all Indonesian coastlines, where they are a primary productivity
foundation. Figure 4 summarizes how seaplant ecological services relate to each other. Provisioning
services provide people with goods that they need. Regulating services are a basis for marine
ecosystems. They also provide us with oxygen, and they fix carbon. Cultural services support seashore
recreation but be aware of dis-services like beach fouling and red tides. As ICAM is applied it must
take into consideration the wide array of seaplant ecosystem services (Figure 4).
**Figure 3.** Indonesian provinces showing locations where most seaweed is produced per 2019-2020 from industry consensus

**Figure 4.** Ecosystem services from seaplants in marine ecoscapes
6. Integrated aquaculture in managed ecoscapes
Integrated aquaculture is embedded in production ecoscapes, where it combines with surrounding ecosystems in a complex mosaic of ecosystem services. Figure 5 is a diagram that depicts aquaculture that integrates into managed coastal habitats and also into terrestrial agriculture systems on adjacent ecoscape land [4]. Outstanding examples of managed seashore habitats include mangrove forests and seagrass beds. Metabolites, energy, and nutrients cycle within the system. They also blend into water flowing through the system. Photosynthesizing seaplants are a primary productivity foundation for the entire production ecoscape.

![Diagram](image)

**Figure 5.** Integrated aquaculture in managed marine ecoscapes

7. Classification of prospective seaweed farm development locations
Figure 6 shows a classification system for prospective seaweed farm development locations that guides actions of farm developers such as Sea6 Energy, the company where the author was employed at the time of writing. This classification resulted from four decades of experience where the author saw differing results in areas where seaweed farming fitted in to coastal planning scenarios. Many projects failed outright; some succeeded from the beginning; and all too many went through series of starts, failures and revivals.
Figure 6. Classification of prospective seaweed farm development locations

Among “green” locations, per the classes shown in Figure 6, holistic, sustainable development of production ecoscapes can embrace entire value chains, with process plants in coastal villages and seaweed farms along coastal seashores where value addition can commence at the farm. The challenge of seaweed value chain players in such systems is that there is much competition in developed areas and competitors move in as soon as pioneering developers start to get a return on efforts and investment that establish new seaweed sources. Thus, among locations classified as “yellow” zones in Figure 6, the fact is that substantial funds, effort and time must be invested before the developer knows whether they are in a green, a yellow or a red zone. In the early years of seaweed farm development the risk was often worth the reward, but in recent decades few developers have sunk funds and efforts into locations where their investments could not be protected. That has hindered industry expansion, even as uncertainty prevails pertaining to how seaweed farming is being blended into integrated coastal management mosaics.

Bali is an especially poignant example of how seaweed farming has fared with respect to ICAM. Seaweed farming first started in Bali, before spreading all over Indonesia and Bali had several green zones, especially in the South where tourism was also at early development stages in the mid-1980s. Seaweed farming became prosperous through the 1990s even as tourism grew, but by the turn of the 21st century, seaweed farming was being zoned out of existence at several locations and/or people were attracted to jobs in tourism rather than signing on to a life working on the farm. By the time Covid-19 arrived on the scene in early 2020 seaweed farming was gone at several formerly thriving locations and seaweed production of Bali was down to a small fraction of former levels. That changed, however, as people lost tourism-related jobs and rediscovered seaweed farming as a source of livelihood. Several locations had revived phyconomy in Bali ecoscapes by the time of writing.

8. Conclusion
Fitting in with Integrated Coastal Area Management planning is of critical importance to enterprises such as Sea6 Energy. One of the most rewarding aspects of our vocation is the collaborations we have with people in coastal ecoscape communities. The impact of Covid-19 on seaweed farming in Bali is an example of how seaweed must be factored in to integrated coastal management planning. We hope
and trust that Marsave 2020 will be another step toward effective integration of seaweed farming, processing, and utilization along Indonesian seashores.

References

[1] Neish IC, 2020 Art, Max, Vic and origins of tropical marine phyconomy; with special reference to India’s role in evolving marine phyconomy from art to science. Presented at the India International Seaweed Expo and Summit 2020, NIOT Chennai, 30-31 January 2020

[2] Neish IC, 2020 Adaptive phyconomy for sustainable management of coastal ecoscapes in Indonesia: How adaptive phyconomy supports holistic, sustainable marine ecoscape development as a component of integrated coastal area management (ICAM) Video presentation at MARSAVE 2020 2nd Marine Resilience and Sustainable Development International Symposium, Hasanuddin University, Makassar, South Sulawesi, Indonesia, October 2020

[3] Hurtado AQ, Neish IC & Critchley AT, 2019 Phyconomy: the extensive cultivation of seaweeds, their sustainability and economic value, with particular reference to important lessons to be learned and transferred from the practice of eucheumatoid farming Phycologia 58(5): 472-483

[4] JSSA 2010 Japan Satoyama Satoumi Assessment 2010 Satoyama-Satoumi Ecosystems and Human Well-being: Socio-ecological Production Landscapes of Japan – Summary for Decision Makers United Nations University Tokyo Japan