IMPAQT

Intelligent Management System for Integrated Multi-trophic Aquaculture

The demonstration of the sustainability of multi-trophic aquaculture systems under a holistic perspective: LCA and Ecosystem Services Assessment

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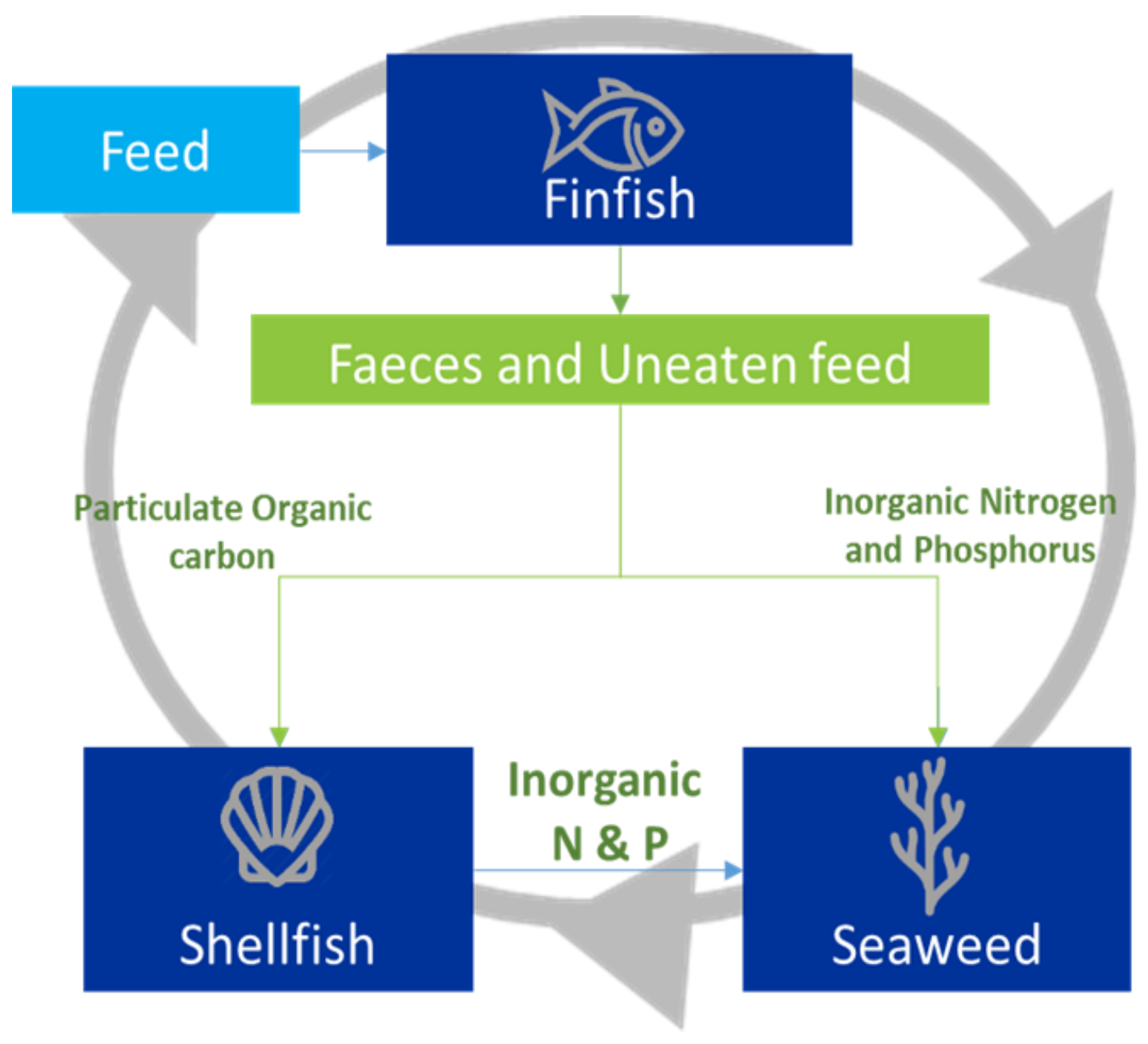
INTRODUCTION

The Horizon 2020 project IMPAQT aims to support Integrated Multitrophic Aquaculture (IMTA) by developing modelling tools, as well as new and emerging technologies, which enable economically, environmentally and socially sustainable aquaculture development throughout the EU.

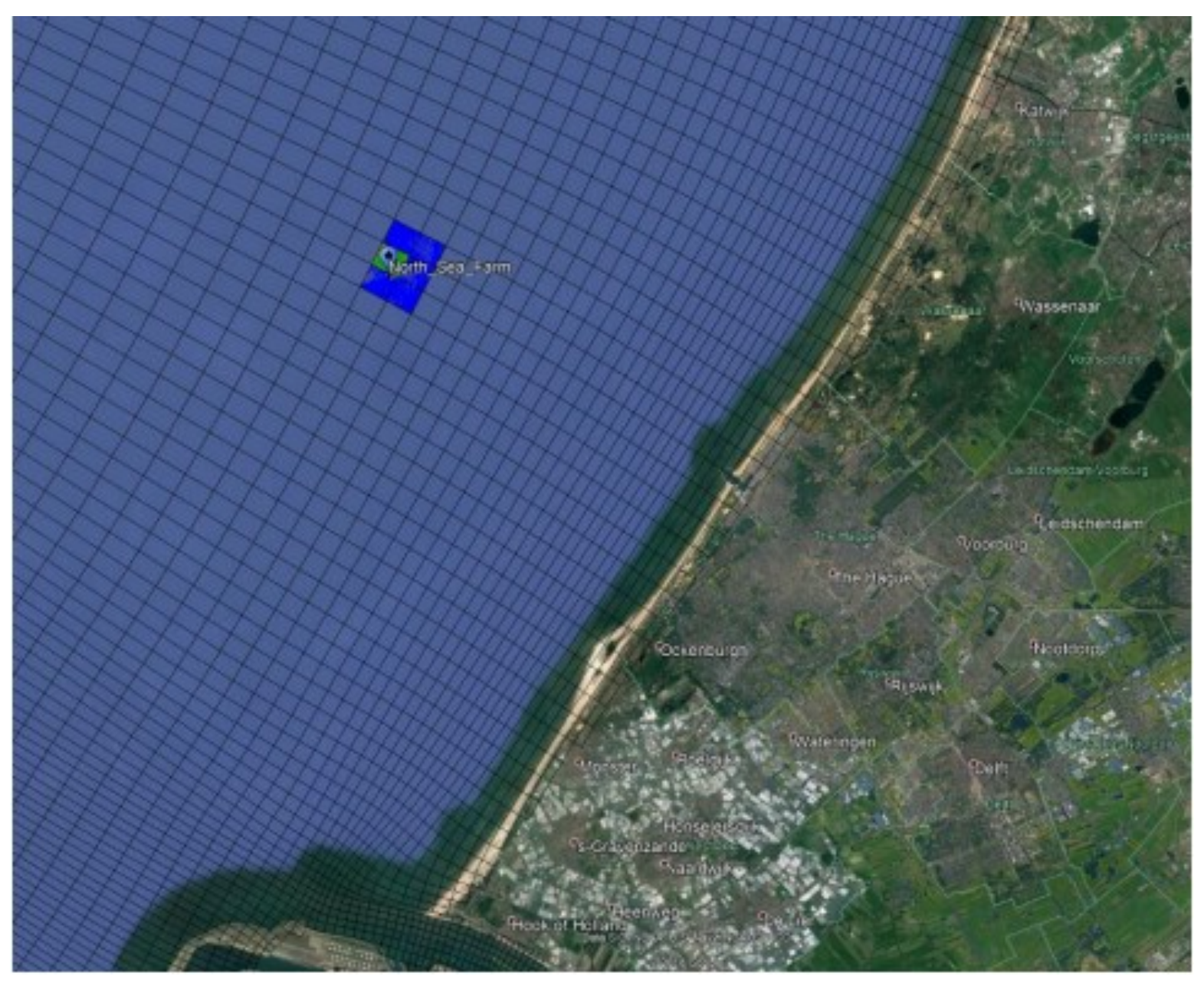
IMTA is expected to improve circularity and reduce the environmental footprint of conventional aquaculture, thus contribute to the optimization of Ecosystem Services (ES) such as food, clean water, flood protection or cultural heritage.



PILOT NORTH SEA FARM (NL)

The North Sea Farm (NSF) is located 15 km off the coast of The Hague, The Netherlands. It is a multidisciplinary test site for sustainable innovations. Seaweed has been cultivated at this site since 2016. In the coming years, this will be complemented with tests involving floating solar panels, shellfish cultivation and shellfish bank restoration as well.

Saccharina latissima is cultivated in the baseline conditions, being *Mytilus edulis* added as part of the multi-trophic system.



METHODOLOGY

LCA methodology (in line with ISO 14040 and 14044) is used as reference for the environmental assessment of six aquaculture pilots (four in Europe, one in Turkey and one in China). However, this poster entails the case study of North Sea Farm in Netherland.

Phase 1: Goal and Scope
Phase 2: Life Cycle Inventory (LCI)
Phase 3: Life Cycle Impact Assessment
Phase IV: Interpretation of results

The goal and scope have been defined considering all the inputs and outputs with a cradle to gate perspective. The reference unit considered for the inventory flows calculation are 1 ton seafood dry weight (seaweed in the baseline and seaweed and mussels in the multi-trophic system). During phase 3, the impact assessment calculates the environmental potential impacts associated with the Functional Unit (1 kg of edible protein). The method chosen is the Environmental Footprint (EF) Methodology (in the context of the Recommendation (2013/179/EU)). The results are finally breakdown for each impact category, in terms of the nutritional characteristics contained in the IMTA products in comparison with the baseline scenario (monoculture conditions).

One method to combine the many qualitative and quantitative features of ES assessment is a **Bayesian Network** (BN). These networks are statistical models functioning on the basis of causal dependencies between system elements of interest.

The aim of this study was to develop a methodology in order to assess how the two different farming approaches (monoculture vs. IMTA) would affect resulting ES.

First a conceptual model was developed, where the existing monoculture system (i.e. seaweed) was taken and connected to all delivered marine ES according to the CICES classification. In a second step, a new species (i.e. mussel) was introduced to the system and the exercise in step one was repeated (*Figure 1*). Based on this conceptual model, a BN was produced, selecting two provisioning ES (green) and two regulating and maintenance ES (blue) (*Figure 2*).

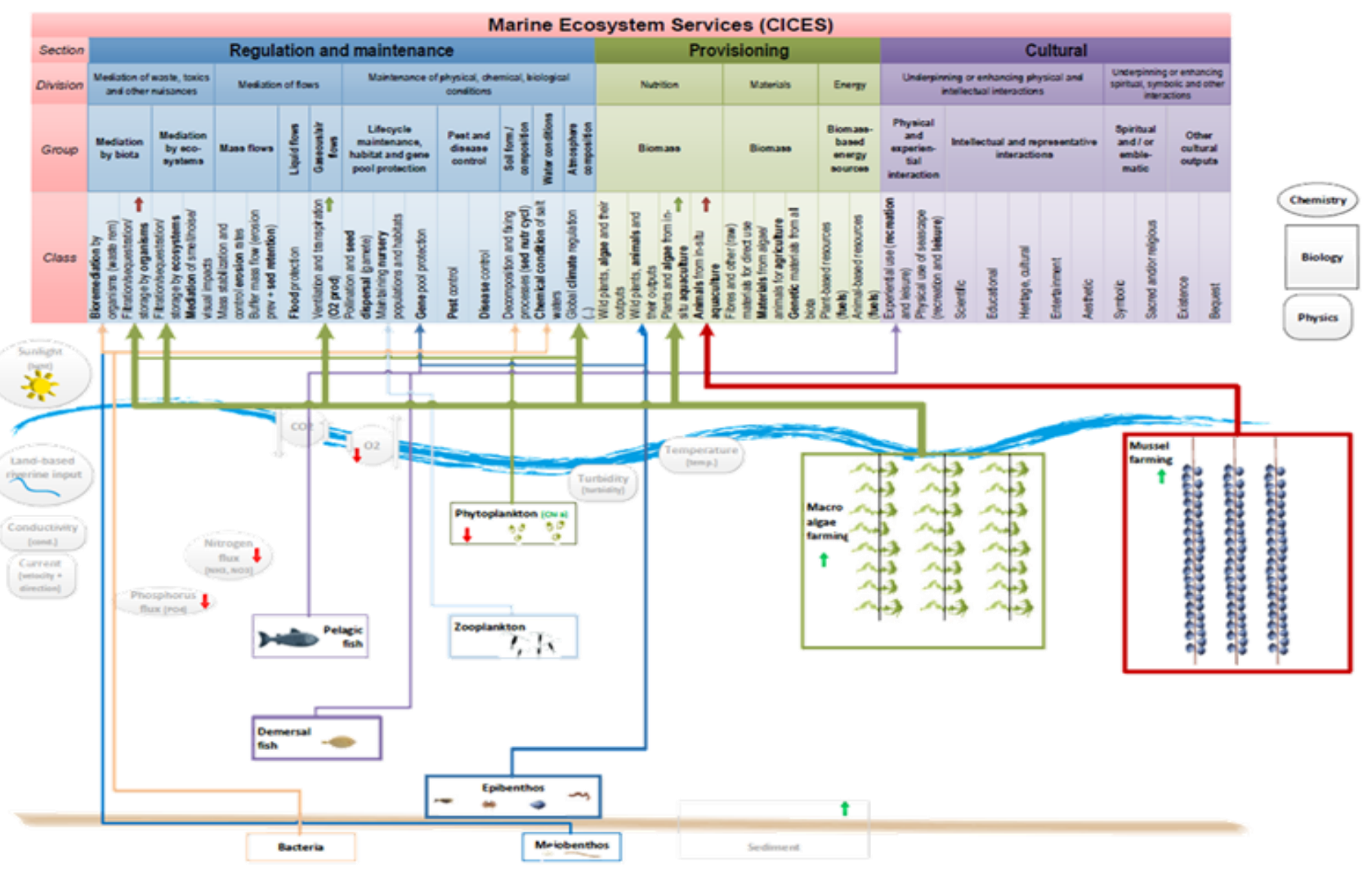


Figure 1: Marine Ecosystem Services Connected to Components

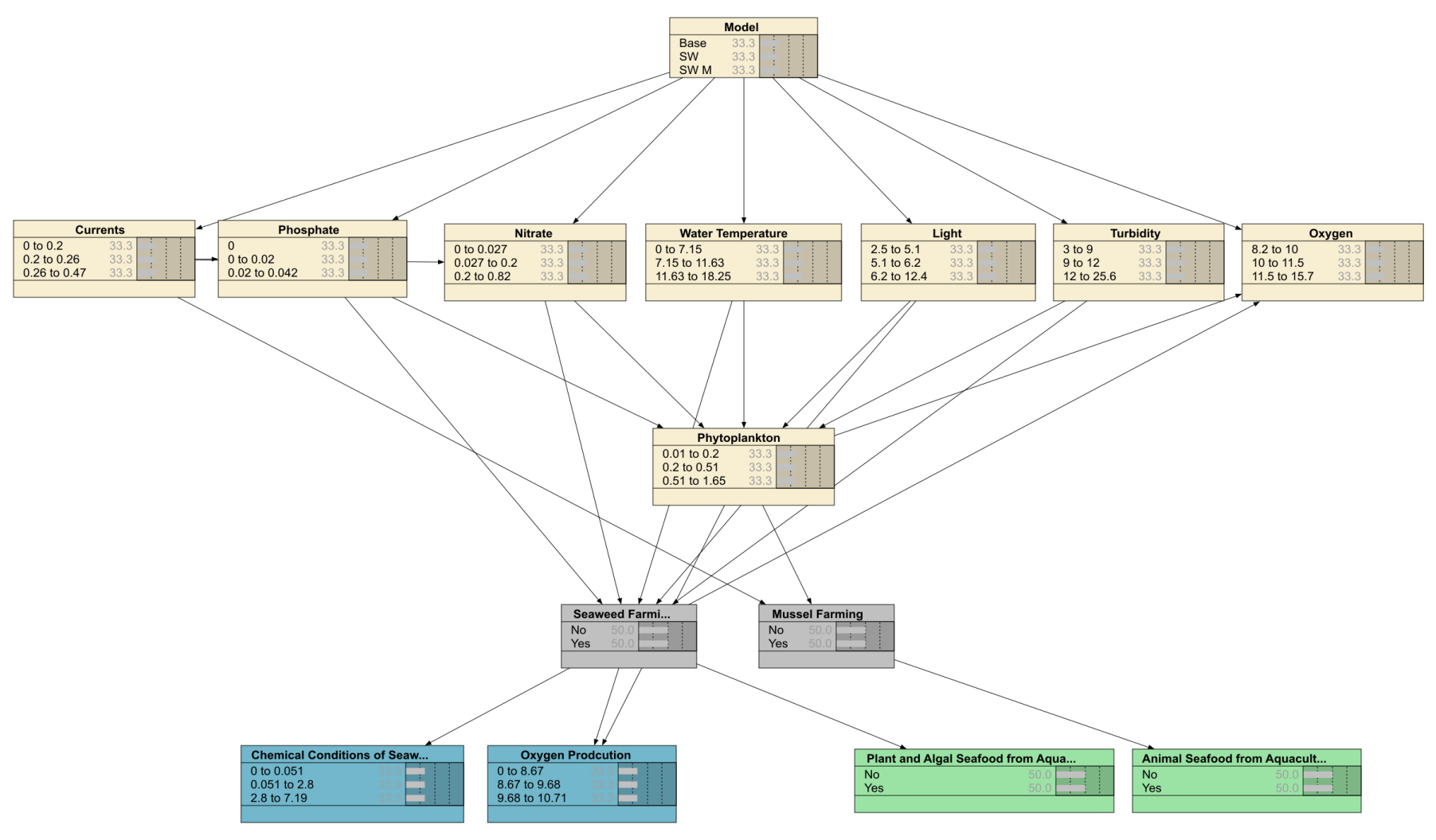


Figure 2: Developed Bayesian Network Depicting Provisioning (green) and Regulating and Maintenance Ecosystem Services (blue)

RESULTS

Ecosystem services assessment

Section	Division	Group	Class	Marine ES working name	Seaweed	Seaweed and mussel
Provisioning	Materials	Biomass	Plants and algae from in-situ aquaculture	Plant and Algal Seafood from	🟩🟩🟩	🟩🟩
			Animals from in-situ aquaculture	Animal Seafood from Aquacultu-	🟦	🟩🟩🟩
			Fibres and other materials from plants, algae and animals for direct use or processing	Raw Materials	🟩🟩	🟩
			Materials from plants, algae and animals for agricul-	Materials for Agriculture and	🟩	🟩
Regulation & Maintenance	Mediation of waste, toxics and other nuisances	Mediation of biota	Filtration/sequestration/storage/accumulation by mi-	Waste and Toxicant Removal and	🟩	🟩🟩
		Gaseous / air flows	Ventilation and transpiration	Oxygen Production	🟩🟩	🟩🟩
	Maintenance of physical, chemical, biological conditions	Lifecycle maintenance, habitat and gene pool protection	Pollination and seed dispersal	Seed and Gamete Dispersal	🟩🟩	⬜
			Maintaining Nursery Populations and Habitats	Maintaining Nursery Populations	⬜	⬜
		Soil formation and composition	Decomposition and fixing processes	Sediment Nutrient Cycling	⬜	⬜
		Water conditions	Chemical condition of salt waters	Chemical Condition of Seawater	🟩🟩	⬜
		Atmospheric composition and cli-	Global climate regulation by reduction of greenhouse	Global Climate Regulation	🟩🟩	🟩🟩
Cultural	Underpinning or enhancing physical and intellectual interactions *(through direct or indirect contact with marine biota and/or ecosystems, including in land-/seascapes [environmental settings])*	Physical and experiential interactions	Experiential use of plants, animals and land-/	Recreation and Leisure	🟩🟩	🟩🟩🟩
			Physical use of land-/seascapes in different environ-		🟩🟩	🟩🟩🟩
		Intellectual and representative interactions	Scientific	Scientific	🟩🟩	🟩🟩🟩
			Educational	Educational	🟩🟩	🟩🟩🟩
			Heritage, cultural	Heritage	🟩🟩	🟩🟩🟩
Environmental assessment (1 kg edible protein)						
Environmental impact	Global Warming Potential	Global Warming Potential calculating the radiative forcing of greenhouse gas (GHG) emissions over a time horizon of 100 years. It is based on IPCC (2013) method		From cradle to gate (infrastructure, on-growing, harvesting)	🟦🟦🟦	🟦
				On-growing phase:	🟩🟩🟩	🟩
	Ozone depletion	Ozone Depletion Potential (ODP) calculating the destructive effects on the stratospheric ozone layer over a time horizon of 100 years. It is based on WMO 2014) method		From cradle to gate (infrastructure, on-growing, harvesting)	🟦🟦🟦	🟦
	Water use	It is a midpoint indicator representing the relative Available Water Remaining per area in a watershed after the demand of humans and aquatic ecosystems has been met. It assesses the potential of water deprivation, to either humans or ecosystems, building on the assumption that the less water remaining available per area, the more likely another user will be deprived. It is based on AWARE (2016) method		From cradle to gate (infrastructure, on-growing, harvesting)	🟦🟦🟦	🟦
	Marine eutrophication	Expression of the degree to which the emitted nutrients reaches the marine end compartment (nitrogen considered as limiting factor in marine water). It is based on Recipe (2016) method		From cradle to gate (infrastructure, on-growing, harvesting)	🟦🟦🟦	🟦
				On-growing phase:	🟩	🟩🟩🟩

🟩🟩🟩	Much better	🟦🟦🟦	Much worse
🟩🟩	Moderately better	🟦🟦	Moderately worse
🟩	Slightly better	🟦	Slightly worse
⬜	Similar		

CONCLUSIONS

First results of the ESS assessment indicate that many of the previously available ecosystem services can increase in the magnitude in which they are harvested in a monoculture, and the service of animal seafood through aquaculture becomes available. However, a longer time and regional scale component is not included in the assessment, and the maintenance of physical, chemical and biological services could be decrease over time when no additional feed (nutrients) enter the system, but harvest (nutrients) is taken out.

The environmental assessment shows that all environmental impacts are reduced due the IMTA implementation, mainly due to more efficient infrastructure use. Whereas the environmental benefits in marine eutrophication for the on-growing phase are intensified in the IMTA scenario. Only Global Warming Potential has reduced its environmental benefit, since the incorporation of mussel are not contributing to increase the atmospheric carbon dioxide fixation. In line with ES assessment, these results are not considering the regional conditions.

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