

Identification of the seaweed biostimulant market (phase 2)

Deliverable 1.1.2.

Part of Bio4safe WP1 Market analyses

Executed by Stichting Noordzeeboerderij / North Sea Farm Foundation

July 2018

Identification of the seaweed biostimulant market (phase 2)

Table of content

1. [Introduction & methodology](#)
2. [Seaweed species used for biostimulants and their applicability](#)
3. [Insights in seaweed biostimulant market drivers and barriers](#)
4. [SWOT analysis of global, European and 2-SeasRegion seaweed based biostimulant market](#)
5. [Conclusions & recommendation](#)
6. [Bibliography](#)

Identification of the seaweed biostimulant market (phase 2)

Preface

This report is part of the Interreg 2 seas project Bio4safe. The project is coordinated by PCS Ornamental Plant Research (Belgium) and includes 7 other partners including Research Station Proeftuin Zwaagdijk (NL), North Sea Farm Foundation (NL), Yncréa Hauts de France, establishment ISA Lille (France), Vegetables Pole Region North (France), NIAB (UK) and Dove Associates (UK) and Ghent University (Belgium). The Bio4safe-project runs for a period of four years, started in 2017 and is funded by Europe via the Interreg 2 Seas Programme.

Contact information

Questions and remarks about the report and the project can be shared with Marlies Draisma (marlies@noordzeeboerderij.nl) from the North Sea Farm Foundation.



Interreg 
EUROPEAN UNION

2 Seas Mers Zeeën

Bio4safe

European Regional Development Fund

NOORDZEE
BOERDERIJ 

Disclaimer:

All data collected is used for purposes of the Interreg 2 Seas Programme and only to the extent it is necessary to fulfill those purposes. North Sea Farm Foundation tries to work with accurate information. However, North Sea Farm foundation does not give any warranty or other assurance as to the content of the material appearing on this report. No rights can be derived from this publication.

Identification of the seaweed biostimulant market (phase 2)

List of terminology and abbreviations

D	Deliverable
SWOT	Strength, weaknesses, opportunities and threats
WP	Work package
Interviews	Correspond to numbers [1-9], [17-18],[26-27] in the list of literature

Identification of the seaweed biostimulant market (phase 2)

List of tables and figures

Tables

Table 1: Overview of the biostimulant supply chain, North Sea Farm Foundation, July 2018

Table 2: Overview of the bioactive compounds and their mode of action present in seaweed based biostimulants [10], [15], [19], [21], [22].

Table 3: Overview of the application methods of seaweed based biostimulants, mode of action per application method, corresponding possible mechanisms and the used species of seaweed per application method [16] (and interviews).

Table 4: Overview of industry categories the seaweed species used in related biostimulant products, based on interviews

Table 5: Overview of market drivers and barriers of the general biostimulant market and seaweed in specific, North Sea Farm Foundation, 2018

Figures

Figure 1: Example overview of seaweed species for biostimulants

Figure 2: *Ascophyllum nodosum* nature print by Henry Bradbury (1860), adapted from <https://commons.wikimedia.org>, July 2018

Figure 3: *Ascophyllum nodosum*, adapted from www.waterwereld.nu, July 2018

Figure 4: Market drivers for the biostimulant market, adapted from D 1.1.1 [30]

Figure 5: SWOT analysis example, derived from <http://www.uvlsrcp.org>, July 2018

Figure 6: SWOT analysis of seaweed biostimulant market (General & Global and European & 2 Seas Region level), based on the interviews.

1 | Introduction & methodology

Introduction & methodology

Introduction to the project and report

This market study is part of the Bio4safe Interreg project for the European Union. This project aims to reduce water use and fertilizer use in horticulture by using biostimulants and innovative tools. This combination will result in up to 20% reduction of water and 10% of fertilizer usage, depending on the crop. By specifically including biostimulant based on seaweeds, economic opportunities for seaweed producers will be explored and developed.

The project comprises of 6 work packages:

- Work Package 1: Market study: development of business models for producing biostimulants from seaweeds
- Work Package 2: Demonstration, implementation and adoption of biostimulants and sensor tools
- Work Package 3: Collecting and analysing cross-border data to develop information database and apps to access the information
- Work Package 4: Policy protocol
- Work Package 5: Project management
- Work Package 6: Communication

This report (D 1.1.2) is part of Work Package 1: Market study: development of business models for producing biostimulants from seaweeds and as such constitutes to the WP1.1 - Determination of existing market of biostimulants.

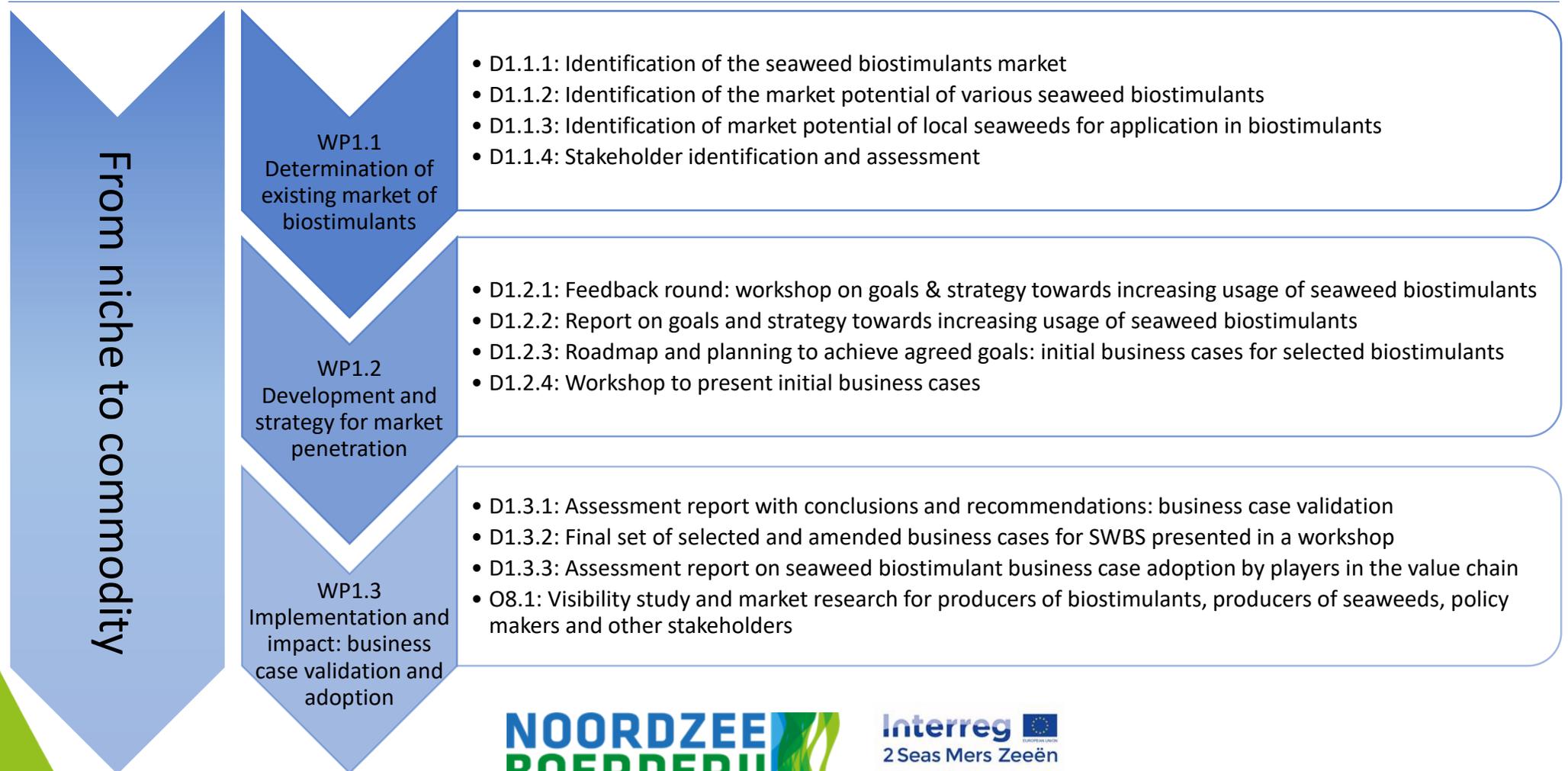
The following sheets briefly demonstrate the relation between these various elements and provide an overview of D1.1.2 and D1.1.3 in relation to the biostimulant supply chain.

Stay informed:

Information about the reports and the project can be requested from Marlies Draisma (marlies@noordzeeboerderij.nl) from the North Sea Farm Foundation.

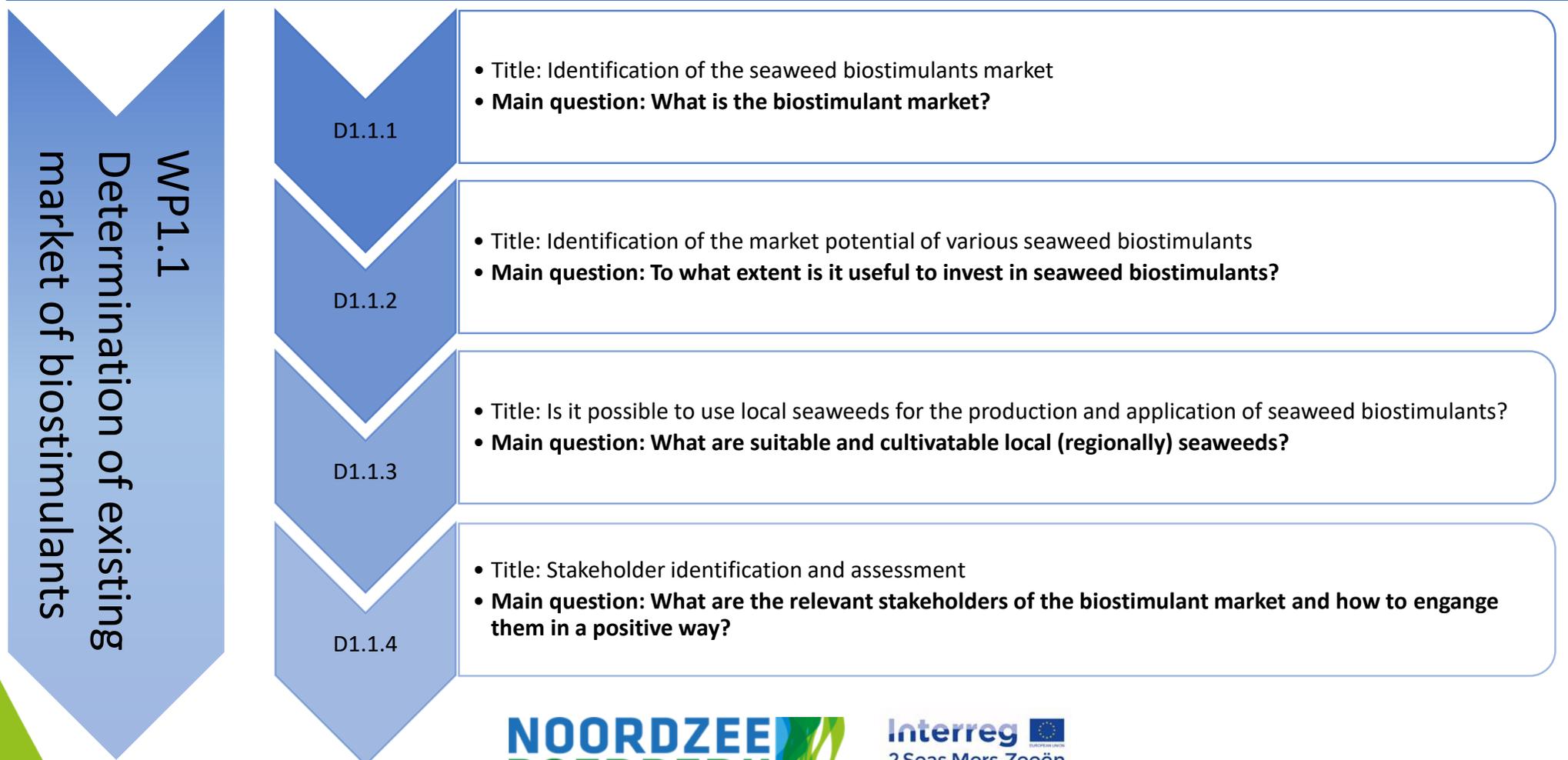
Introduction & methodology

Activities and deliverables for Work Package 1



Introduction & methodology

Deliverables and main questions for Activity 1.1



Introduction & methodology

Scope for Deliverable D1.1.2

D1.1.1: Identification of the seaweed biostimulants market

- **What is the biostimulant market?**
 - ✓ General description of biostimulants: definition, function and application
 - ✓ Broad identification of the biostimulants market: globally, EU wide and regionally
 - ✓ Identification of the seaweed based biostimulants as part of the total market
 - ✓ Assessment of the results, conclusions and recommendations for next steps

D1.1.2: Identification of the market potential of various seaweed biostimulants

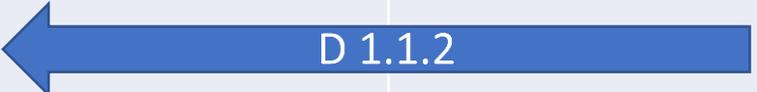
- **What is the market potential of seaweed biostimulants?**
 - Identification of commonly used seaweed species for biostimulants and their applicability
 - In depth analysis of industry categories objectives and needs – specifically related to seaweed biostimulants
 - Detailed overview of market drivers and barriers in the seaweed biostimulant market (logistics, knowledge, regulations, etc.)
 - Description and SWOT analysis of seaweed based biostimulant market: global, European, regional
 - Assessment of the results, conclusions and recommendations for next steps

Introduction & methodology

Overview of seaweed biostimulant supply chain

The seaweed biostimulant supply chain is summarized in the table below (table 1). The arrows in this table provide an overview of the approach for D 1.1.2 and D 1.1.3. D 1.1.2 starts at the end of the supply chain and D 1.1.3 at the beginning.

Table 1: Overview of the biostimulant supply chain, North Sea Farm Foundation, July 2018

					
Biostimulant supply chain	Seaweed cultivation/ Wild harvest	Logistics, processing & biostimulant production	Distribution & trading	Sales to end-users	End-users
					
Description	Seaweed for biostimulants is mainly wild harvest	The main processing step includes liquid extraction and/or drying & grinding. This is then used for the biostimulant end-product	Then the intermediate or final product is shipped to sales channels and/or rebranders	The products are then sold directly via B2B contacts, wholesalers and/or retail	End users include farmers, gardening professionals or consumers
Involved stakeholders	<ul style="list-style-type: none"> • Biostimulant raw material supplier 	<ul style="list-style-type: none"> • Biostimulant raw material supplier • Biostimulant end-product producer 	<ul style="list-style-type: none"> • Biostimulant end-product producer • End-product repackaging/rebranding • Biostimulant trader/agent 	<ul style="list-style-type: none"> • Biostimulant end-product producer • End-product repackaging/rebranding • Biostimulant trader/agent 	<ul style="list-style-type: none"> • Farmers • Gardening professionals • Household consumers

2 | Seaweed species used for biostimulants and their applicability

Seaweed species used for biostimulants and their applicability

Introduction & methodology

Introduction

In this chapter we will focus on different types of the seaweed species used for seaweed extracts in biostimulants. Seaweed extracts are part of a larger group of products used as source for biostimulants. Based on the analysis in deliverable 1.1.1 there are 7 relevant categories of biostimulants based on Du Jardin, 2015: (1) humic and fulvic acids, (2) protein hydrolysates and other N-containing substances, (3) **seaweed extracts** and botanicals, (4) chitosan and other biopolymers, (5) inorganic compounds, (6) beneficial fungi and (7) beneficial bacteria. In this chapter we will focus on the seaweed extracts, which species are used and how there are used.

Methodology

Literature research and several interviews have resulted in an overview of species of seaweed used for biostimulants. To be able to link production to seaweed species, multiple aspects and variables are gathered such as; relevant companies, seaweed species, market drivers and barriers, customer segments and others (example in figure 1). By providing this overview with information from the interviews and literature a simple and solid structure was developed which is used for further analysis and gathered information is presented in several tables in this deliverable.

About seaweed

Seaweed is an overarching name for macroalgae that live in salt water, brackish water or freshwater. All over the world one can find seaweeds. There are three groups of seaweed: green, brown and red seaweed. The color is determined by the composition and the amount of pigment in the seaweed. There are about 10.000 species (red, brown and green) worldwide, about which 30 of them are commercially relevant. Seaweed species are divided into families. Every family has its own name and characteristics, colors and thrives under different circumstances and locations. The various seaweed species can be gathered by wild harvest. A growing number of seaweed species is being cultivated for commercial purposes.

Seaweed name	Seaweed family	Application	Used for biostimulants	Pictures	Natural distribution	Production locations
Brown Count: 7						
1. <i>Acicophyllum nodosum</i>	Brown	Row crops	Yes		United Kingdom, Norway, United Kingdom, France, France, North America, Norway, Ireland	
2. <i>Durvillea</i> spp.	Brown		Yes		New Zealand	
3. <i>Ecklonia maxima</i>	Brown	Ornamentals (incl. greenhouse)	Yes		Africa - Southern	
4. <i>Fucus vesiculosus</i>	Brown		Yes		France	United Kingdom, Ireland, France
5. <i>Macrocystis pyrifera</i>	Brown		Yes			
6. <i>Padina</i> spp.	Brown		Yes			
7. <i>Sargassum</i> spp.	Brown		Yes			

Figure 1: Example overview of seaweed species for biostimulants

Seaweed species used for biostimulants and their applicability

Types of seaweed biostimulants

Seaweed species in biostimulants

Based on the interviews with several biostimulant producers and users it was striking to find that only a handful of seaweed species are being used in the seaweed biostimulant market. Most of these species are wild harvested.

Main seaweed species used in biostimulants:

1. *Ascophyllum nodosum*
2. *Laminaria hyperborea*
3. *Ecklonia maxima*
4. *Soliera chordaris*
5. *Fucus vesiculosos*

Ascophyllum nodosum (Figure 2) is used by 90% of the interviewed biostimulant companies. All gathered from areas with 'government controlled' wild harvest. The other four species are used sporadically in a few biostimulant products. Those species, *Laminaria hyperborea*, *Ecklonia maxima*, *Soliera chordaris* and *Fucus vesiculosos* could be cultivated. In the literature we found many more species which can be used in biostimulants [10]. Commercial products of these species from literature haven't been identified during this research.



Figure 2: *Ascophyllum nodosum* nature print by Henry Bradbury (1860), adapted from <https://commons.wikimedia.org>, July 2018

Composition of seaweed

The composition and the bioactive compounds present in seaweed species might well be linked to the mode of action [10]. Currently, it is unclear if seaweed biostimulants have the same function when using whole seaweed or using purified compounds of the seaweed.

Another way to add functionality in seaweed biostimulants is to combine multiple seaweed species in a biostimulant product. Several companies are looking into the opportunities of combining multiple seaweeds to improve the effects of their products.

To gain insights in development of the business case for cultivated seaweeds for biostimulants it will be important to research the bioactive components in specific species and their possible effects.

Seaweed species used for biostimulants and their applicability

Mode of action

Main biostimulating effects of seaweed extracts

Battacharyya et al (2015) describes 5 important modes of action of seaweed extracts on plants. However, there is still a lot unknown about the efficacy of seaweed extracts on plants [16].

1. Promoting plant growth

Seaweeds are interesting as a biostimulant mainly due to fact that some species contain large amounts of plant growth hormones. The growth and development of higher plants is regulated by plant growth hormones (phytohormones). Therefore, seaweed extracts can have a growth promoting effect on plants. In addition, phytohormones play a vital role in nutrient transport and the development of fruits and flowers. The most important plant growth hormones in seaweed extracts are: auxins, cytokinins and gibberellins [16], [22].

2. Improving availability of soil nutrients and plant nutrient uptake

Plants take up nutrients via the roots and via the leaves. Seaweed extracts can change soil properties by means of physical, biochemical and biological processes, which can have positive effects on the nutrient availability for plants. It is known that in for example brown seaweed *e.g. Ascophyllum nodosum* alginates and fucoidans have soil improving properties. Furthermore, alginates can play an important role in the growth of the plants. Another example is *Ecklonia maxima*. Compounds present in this seaweed, a derivative of vitamin K1, can make the plant lower the pH of the soil, which makes iron bioavailable for the plant. It has been shown that various seaweed extracts (not mentioned which) can have a positive effect on the regulation of genes which play an important role in nutrient uptake [16].

3. Improving coping with abiotic stress

Abiotic stress (e.g. salt, heat, and water stress) in plants causes considerable losses in crop production around the globe. It has been estimated that abiotic stress lowers the production yield to less than 50%. Bioactive substances present in seaweed extracts help the plant to better perform during stress conditions. It is known that the seaweed species *Ascophyllum nodosum* contains various compounds i.e. cytokinins which have a positive effect on the plant during stress situations [16].

4. Improving plant metabolism

Seaweed extracts can have a positive effect on various metabolic and physiologic processes in plants, which can lead to a reduced effect of both biotic and abiotic stress. It enhances the synthesis of enzymes involved in the process of N-metabolism, which is important because plants cannot directly use nitrogen from the air, it needs first to be metabolized before it can be utilized by the plant. Furthermore, seaweed extracts can help the plant to increase the amount of chlorophyll, which enhances the photosynthetic capacity of the plant [16].

5. Promoting plant health

Seaweed extracts also can have a positive effect on the quality and shelf life of plants and crops, especially when seaweed extract are applied after the plant is harvested (post-harvest treatment). Plants treated post-harvest with seaweed extract had a higher concentration of health promoting substances like flavonoids and phenolics, which in turn prolonged shelf life of the plants. Furthermore, the quality *e.g. nutritional value* of harvested fruits, flowers and vegetables was better when seaweed extracts were applied [16].

Seaweed species used for biostimulants and their applicability

Bioactive compounds in seaweed based biostimulants

The most common bioactive compounds in seaweeds are depicted in table 2. The table gives a general description of the bioactive substances present in seaweed. The major groups of biological active compounds are present in the majority of the seaweed species. Generally speaking it can be concluded that the specific substances are present in each seaweed species. Although the quantity and combination of compounds varies greatly between species. All species of seaweed have a unique chemical composition. Which means that the amount and the type of bioactive substances differs per seaweed species. It is difficult to determine which bioactive substances are present in which seaweed species because only on a few species extensive research has been done on their chemical composition *e.g. Ascophyllum nodosum*. The exact chemical composition of a lot of seaweed species is still unknown, and can vary between location, period of harvest, etc. The majority of the interviewed biostimulant producers indicate that the concentration and presence of plant growth hormones, mainly auxins and cytokinins, in seaweed are an important driver to use a species of seaweed for the production of biostimulants.

Table 2: Overview of the bioactive compounds and their mode of action present in seaweed based biostimulants[10], [15], [19], [21], [22].

Major groups of biological active compounds	Specific substances per major group found in seaweeds species	Mode of action
Polysaccharides	Galactans, fucoidan, laminarin, alginates	Growth promoting, health improving, antiviral, antimicrobial, antifungal, and antioxidant
Proteins	Lectins	Essential source for amino acid formation, increase in biosynthesis, increase carbohydrate concentration in leaves, antimicrobial and antiviral
Pigments	Carotenoids	Protection from chlorophyll degradation and antioxidant
Polyphenols	Tannins, flavonoids	Antibacterial, deterrence of herbivores, protection from UV, release and suppression of growth hormones
Vitamins and minerals	K, Mg, Ca, Cu, Mn, Fe, I	Essential for plant life cycle, increases crop quality and crop yield
Plant growth hormones	Auxins, cytokinin's, gibberellins, betaines	Initiate root formation, initiate seeds germination, antiaging, enhances growth, enhances development of flowers and fruits. Enhances nutrient accumulation, stimulate shoot elongation, increases efficiency of water uptake. Effective to reduce effects of abiotic stress <i>e.g.</i> water-, drought- and salt stress

Seaweed species used for biostimulants and their applicability

Application methods of seaweed based biostimulants

Table 3: overview of the application methods of seaweed based biostimulants, mode of action per application method, corresponding possible mechanisms and the used species of seaweed per application method [16] (and interviews).

Application method	Mode of action	Possible mechanisms	Main seaweed species used in biostimulants
Aerial application	<ul style="list-style-type: none"> Foliar spray Post harvest treatment 	<ul style="list-style-type: none"> Abiotic stress tolerance Enhanced growth and nutritional quality Improved shelf life 	<ul style="list-style-type: none"> <i>Ascophyllum nodosum</i> <i>Laminaria spp</i> <i>Ecklonia maxiama</i> <i>Fucus vesiculosus</i>
Soil application	<ul style="list-style-type: none"> Furrow application Hydroponics system Soil drench Seed treatment 	<ul style="list-style-type: none"> Improved soil quality Reduced soil born pathogens Better rooting 	<ul style="list-style-type: none"> <i>Ascophyllum nodosum</i> <i>Ecklonia maxiama</i> <i>Fucus vesiculosus</i>

Table 3 shows how seaweed based biostimulants can be applied. The application method is mainly determined by the form and phase (liquid or solid) of the biostimulant product. The majority of the interviewed biostimulant producers produce liquid biostimulants, which can be applied both via air and on the soil. Only Laminaria is purely used for aerial applications. None of the interviewed biostimulant producers produces biostimulants for post harvest treatment.

Seaweed species used for biostimulants and their applicability

Application of seaweed based biostimulants per industry category

Table 4: Overview of industry categories the seaweed species used in related biostimulant products, based on interviews

Industry category	Seaweed species used in biostimulants
Row crops	<ul style="list-style-type: none"> • <i>Ascophyllum nodosum</i> • <i>Ecklonia maxima</i> • <i>Soliera chordalis</i> • <i>Fucus vesiculosus</i> • <i>Laminaria spp</i>
Horticulture (incl. greenhouses)	<ul style="list-style-type: none"> • <i>Ascophyllum nodosum</i> • <i>Ecklonia maxima</i> • <i>Soliera chordalis</i> • <i>Laminaria spp</i>
Ornamentals (Incl. greenhouses)	<ul style="list-style-type: none"> • <i>Ascophyllum nodosum</i> • <i>Ecklonia maxima</i> • <i>Soliera chordalis</i> • <i>Fucus vesiculosus</i> • <i>Laminaria spp</i>
Pastures/pitches/gardens	<ul style="list-style-type: none"> • <i>Ascophyllum nodosum</i> • <i>Ecklonia maxima</i> • <i>Soliera chordalis</i>

Table 4 shows which type of seaweed in biostimulants is used per industry category. The data is based on the interviews with biostimulant producing companies. It is important to realize that we still miss some key players in the sector, so this information is the current status and needs to be updated and completed in time.

Seaweed based biostimulants can be based on:

- Pure seaweed extract
- A mix of different seaweed extracts
- A mix of seaweed extracts with other biostimulating ingredients *e.g. Bacillus spp*

All of these seaweed based biostimulant versions have a different efficacy, while they all contain for example *Ascophyllum nodosum*. This is the reason why most of the seaweed species are applicable in multiple industry categories, as one can see in the table.

Based on our interviews only *Ascophyllum nodosum*, *Ecklonia maxima* and *Soliera chordalis* are applied in all four industry categories. The least amount of biostimulants are applied on horticultural crops in greenhouses. Mainly because the climate and other factors can more easily be regulated.

Seaweed species used for biostimulants and their applicability

Summary

At this moment only a few species of seaweed are used in the production of seaweed based biostimulants. Most of the (seaweed based) biostimulant producing companies use brown seaweed species of which *Ascophyllum nodosum* is commonly used. This seaweed species possesses unique bioactive compounds. Due to the fact that it occurs in tidal areas it contains substances which help the seaweed to cope with drought, salt and water stress. Biostimulants based on *Ascophyllum nodosum* (figure 3) can help to reduce the effect of abiotic stress on plants and crops.

Plant growth hormones are the most important bioactive compounds in the seaweed extracts used for biostimulants. The most important plant growth hormones are auxins and cytokinins, these compounds play an important role in plant growth, plant development, development of fruits and flowers and the resistance to abiotic stress.

Most of the seaweed based biostimulants are liquid, which implicitly means that they are mostly applied via foliar spray or via irrigation water. It is difficult to determine which seaweed species are specifically used per industry category. Most of the seaweed based biostimulants consist of a mix of seaweed and other biostimulating ingredients, these mixes differ per product. Generally it can be concluded that seaweed based biostimulants are applied in all of the industry categories.



Figure 3: *Ascophyllum nodosum*, adapted from www.waterwereld.nu, July 2018

3 | Insights in seaweed biostimulant market drivers and barriers

Insights in seaweed biostimulant market drivers and barriers

Setup of this section

Where the previous chapter gave a more technical overview of the seaweed biostimulant market. This chapter will elaborate on the more soft part of innovation. It focuses on general and seaweed specific drivers and barriers: knowledge, people and other forces that support and/or counteract development and growth of the seaweed biostimulant market.

This chapter also builds further upon the four general drivers referred to in the conclusion of the phase 1 report of this market analysis. Information coming from different stakeholder interviews and the Field Trial Visit of the Bio4safe program have been used to further develop the insights in seaweed biostimulant market drivers and barriers.

This section gives an overview of the market drivers and barriers that industry partners have related to the use of biostimulants in general and specifically to seaweed biostimulants (Figure 4). With the use of multiple open interviews insights are given into the specific needs that biostimulant companies have to further develop their businesses and the sector as a whole.

Next to this, a desk review has been performed to see whether there are notable differences in drivers, barriers and needs related to industry categories (ornamentals, forestry, etc).

The information in this chapter will be used as input for the SWOT-analysis in the next chapter.

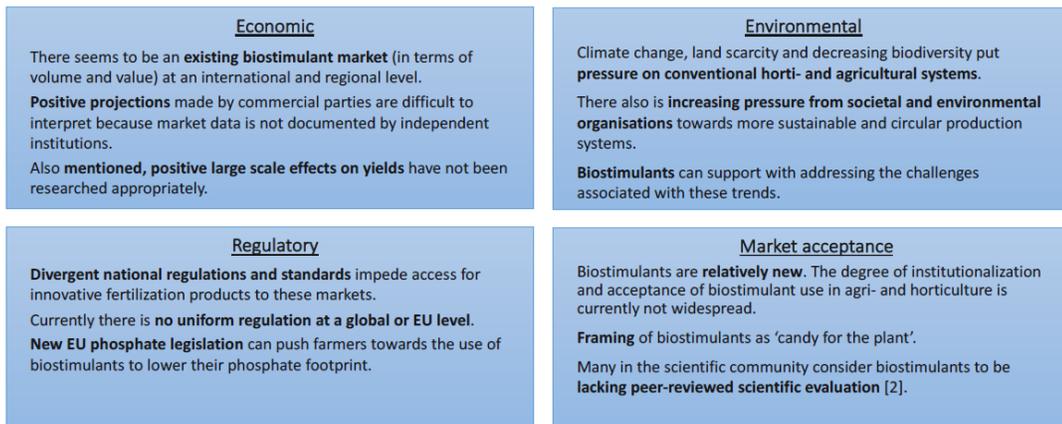


Figure 4 Market drivers for the biostimulant market , adapted from D 1.1.1 [30]

Insights in seaweed biostimulant market drivers and barriers

General biostimulant industry needs

Interviews with several stakeholders, biostimulant producers and users have been performed. The biostimulant producers described a number of needs for the biostimulant industry. These needs are summarized in this section.

Product claims of biostimulants

Claiming is to state something as a true fact. In the biostimulant sector some biostimulant manufactures, retailers and wholesalers claim certain effects of their products, which are not achieved in reality, also mentioned as 'overclaiming'. Currently there are products on the market claiming effects which are not achieving the effects written on the label. This results in a lack of credibility and is harming the biostimulant sector. Additionally, this issue may cause unequal competition. Legislation is needed, especially on labelling requirement, to help solve this problem.

Uniform legislation in relation to registration of biostimulants

Each country has its own legislation about biostimulants. This legislation covers the requirements to which a biostimulant product must comply, before it may enter the market. These requirements are based on a definition of biostimulants. Furthermore, the definition also determines in which legislative category (fertilizer or protection agent) the biostimulant can be registered, legislation differs per category and per country. If the product does not or partially comply to the legislative requirements it will not be registered as a biostimulant, which means the product cannot enter the market. Legislation on the registration of biostimulants is

an important issue. At the moment there are several different definitions for biostimulants present, which results in different legislation and registration requirements for biostimulants per country. This makes it difficult to bring new biostimulant products on the market. There is a need for a global uniform legislation on biostimulants.

Efficient applications of biostimulants by end-users & Education of end-users in usage of biostimulants

For some end-users and even for providers of biostimulants it is not always clear what the exact efficacy of biostimulants is. Furthermore, they are not always properly informed about how to use the biostimulants in a proper way (dosage, application rate, when to apply etc.). This can have several causes; the manufacturer of biostimulants provides not enough information about the biostimulants or there is simply not enough information available. This lack in information may lead to misunderstanding. So it is important to inform and educate both the provider and the end-users in detail about the usage and efficacy of biostimulant products.

Insights in seaweed biostimulant market drivers and barriers

General biostimulant industry needs

Lack of knowledge on the exact mode of action

Biostimulants in general are complex products, in which a lot of components are present with each a specific effect. In order to make efficient use of the product, knowledge about the efficacy and composition is required. All effects of the ingredients of the biostimulant should be known. Due to the complexity of biostimulants it is not always clear what the exact efficacy of the biostimulant is. To cope with this challenge more scientific research is needed and more field trials (e.g. Bio4safe) should be performed to determine the exact mode of action of biostimulant products. Due to the complexity of the ingredients of biostimulants it may be possible to find new unknown modes of actions of biostimulants by means of scientific research. It is important to share new obtained knowledge with the consumers and end-users and keep them informed.

Soil conditions

Each individual field (agricultural, pasture, etc.) can often have its own unique soil characteristics, which can have an effect on the efficacy of the biostimulant on the crops. Different soil conditions should be taken into account for the production of biostimulants, because some ingredients of biostimulants may influence the soil characteristics. It is important to better align the biostimulant product with the soil conditions of the client.

Knowledge on market demands

Know-how on what the biostimulant market wants. Biostimulant producers briefly

describe that better insights are required in the market demands and in the development of the biostimulant market. A lack of knowledge on the market demands can be interpreted in several ways: currently the market is not easily accessible and transparent or biostimulant producing companies do not do enough in-depth market research themselves.

Climate change (opportunity)

In relation to climate change biostimulants are becoming more important in the entire agricultural sector (row crops, horticulture, ornamentals and pastures/pitches/gardens). Climate change may cause more extreme weather events in the near future (drought, salinization etc.) which can result in an increase in the level of abiotic stress plants experience. This increase in the level of abiotic stress may lead to an increase of the demand of biostimulants in near future. Additionally, due to increased levels of stress in plants, climate change also enhances new product development. Climate change should be recognized as a driver for biostimulants in general and for new product development.

Proof of return on investment (opportunity)

Business is an important driver to invest in biostimulants. Some biostimulant producers already promise 3:1 return of investment to the farmer. It is important to make the use of biostimulants more attractive for the end-users. Insights in the business case (as proof) builds a stronger case for using biostimulants.

Insights in seaweed biostimulant market drivers and barriers

Seaweed-based biostimulants industry needs

High quality of seaweeds

Many of the interviewed biostimulant producers mention that they prefer only to use high quality seaweed of the selected species, it is still unknown what “high quality” means. For some interviewees the presence of auxins and cytokinins in seaweed are an important driver to use a species of seaweed for the production of biostimulants. The quality determines if the seaweed is used for biostimulant production.

Surprisingly, most of the interviewed biostimulant producers prefer high quality seaweed instead of low priced seaweed. Most of them are willing to pay more for a high quality seaweed.

Sustainable production of seaweeds

All of the interviewed biostimulant producing companies use seaweed which is harvested from the wild. Most of the *Ascophyllum nodosum* is originating from Ireland and Scotland, while *Ecklonia maxima* is mainly from South Africa. Both seaweed species are harvested under the supervision of the governments. In order to prevent environmental damage and overharvesting, it is only allowed to harvest the seaweed from each utilized area once in a three to four year period.

Stable supply chain of seaweeds

Seaweed is a seasonal product, it is only harvested in specific periods per year. This means that there is no stable supply of raw seaweed throughout the year. The harvested seaweed is directly processed to enhance its shelf life. The processed seaweed is then used and sold throughout the year. Due to the fact that the environmental conditions are not the same during a year, the composition of the seaweeds may change during a year.

Insights in seaweed biostimulant drivers and barriers

Overview drivers and barriers (general and seaweed specific)

In sum, there are several needs for the general biostimulant industry and specific for the seaweed biostimulant industry. The needs are used as input for the following table (table 5). The table provides an overview of the drivers and barriers summarized per main category.

Table 5: overview of market drivers and barriers of the general biostimulant market and seaweed in specific, North Sea Farm Foundation, 2018

Category	<u>Economic</u> The competitive market demands, constant improvements in production revenues, cost reductions as well as avoiding additional cost in order to comply with regulations.	<u>Environmental</u> Climate change, land scarcity and decreasing biodiversity put pressure on conventional horti- and agricultural systems.	<u>Market acceptance</u> The markets on which biostimulants are traded need to be ready and willing to accept any new production approaches and cost models.	<u>Regulatory</u> Legislation associated regulations should enable application of biostimulant products for their intended use and create level playing field as well.	<u>Science & technology</u> Objective information available that verifies the product claims as well as further research to clarify mode of application and usage.
☺ Drivers	<ul style="list-style-type: none"> • High quality of seaweeds • Stable supply chain of seaweeds 	<ul style="list-style-type: none"> • Climate change • Sustainable production of seaweeds 			
☹ Barriers	<ul style="list-style-type: none"> • Market knowledge of producers • Proof of return on investment 	<ul style="list-style-type: none"> • Specific soil conditions at end-user level 	<ul style="list-style-type: none"> • Efficient applications of biostimulants by end-users • Education of end-users in usage of biostimulants 	<ul style="list-style-type: none"> • Product claims of biostimulants • Uniform legislation in relation to registration of biostimulants 	<ul style="list-style-type: none"> • Lack of knowledge on the exact mode of action

4 | SWOT analysis of global, European and 2-Seas region seaweed biostimulant market

SWOT analysis of seaweed biostimulant market

Setup of SWOT analysis

Strengths, weaknesses, opportunities and threats (SWOT)

A SWOT analysis provides competitive insight into the potential and critical issues that impact the overall success of an organization, individual or supply chain. In this case the primary goal of a SWOT analysis is to identify and assign all significant factors that could positively or negatively impact the success of the supply chain, providing an objective and in-depth look at the seaweed biostimulant market. Structured in four categories:

- **Strengths** – are positive attributes internal to the market or situation that are within the market control.
- **Weaknesses** – are also internal factors within control that may impede the ability to meet the objectives.
- **Opportunities** – are external factors that the market should (or could) develop.
- **Threats** – are external factors beyond control that could place the development of the market at risk.

SWOT of the seaweed biostimulant market

In this section the SWOT is used as a tool to analyse the seaweed biostimulant market. The analysis summarizes two levels: general & global and Europe & 2-seas region. Insights in the different categories: strengths, weaknesses, opportunities and threats of the market/supply chain (example in figure 5), can form the input for

a strategic plan for the seaweed biostimulant sector in the next phase of WP1.

On the next page the SWOT gives a brief overview of the strengths and opportunities for the seaweed biostimulant supply chain, in green on the left side of the quadrant. On the right side of the quadrant, in orange and red, the threats and weaknesses of the supply chain.

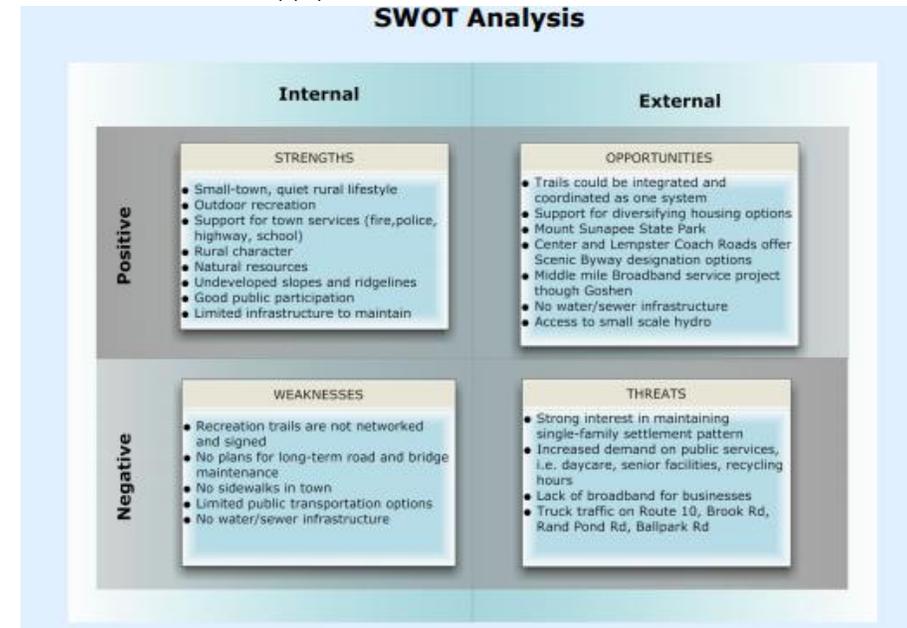


Figure 5: SWOT analysis example, derived from <http://www.uvlsrcp.org>, July 2018

SWOT analysis of seaweed biostimulant market

SWOT of General & Global and European & 2 Seas Region level

<p>General & global</p> <p>European & 2SeasRegion</p>	<p>Strengths (internal – positive)</p> <ul style="list-style-type: none"> New applications for biostimulants Increased demand for (seaweed based) biostimulants <ul style="list-style-type: none"> High quality seaweeds Sustainable production of seaweeds Improved market knowledge for biostimulant producers Improved product knowledge for providers and clients 	<p>Weaknesses (internal – negative)</p> <ul style="list-style-type: none"> Knowledge about mode of action is limited Regulation about requirements labelling is not adequate Proper application of biostimulants is prone to specific soil conditions of clients Low prices of seaweeds with lower quality <ul style="list-style-type: none"> Almost all seaweed biostimulants are based on one type of seaweed (<i>Ascophyllum nodosum</i>) Seaweed is being wild harvested → used species are difficult to cultivate Chance of unstable (quality/quantity) supply chain Limited seaweed harvest → seaweed is harvested from outside the 2-Seas Region
<p>General & global</p> <p>European & 2SeasRegion</p>	<p>Opportunities (external – positive)</p> <ul style="list-style-type: none"> Growing market demand Climate change and related abiotic stress Decrease in the (demand to) use agrochemicals Possible more seaweed species can be utilized for biostimulant production <ul style="list-style-type: none"> More extreme dry and wet periods, increase of abiotic stress, increased demand biostimulants Development of tools to show return on investments for clients 	<p>Threats (external – negative)</p> <ul style="list-style-type: none"> Market opportunism, products with false claims are entering the market Legislation is not consistent, different definitions and legislation of biostimulants per country <ul style="list-style-type: none"> New legislation will not benefit (seaweed) biostimulants

Figure 6: SWOT analysis of seaweed biostimulant market. (General & Global and European & 2 Seas Region level), based on the interviews

5 | Conclusion, recommendation & next steps

Conclusion, recommendation & next steps

What is the potential of the seaweed based biostimulant market?

Seaweed based biostimulant market

Approximately, a **third of the total biostimulant market consist of seaweed based biostimulants**. The presence of plant growth hormones in seaweeds, like auxins and cytokinins, are important bioactive substances which can help crops to cope with abiotic stress like drought. At the moment, only a few species of seaweed are used in the production of seaweed based biostimulants, of which the brown seaweed species *Ascophyllum nodosum* is mainly used. None of the currently used species are currently being cultivated. Most of the seaweed based biostimulants are liquid, which implicitly means that they are mostly applied via foliar spray or via irrigation water. Most seaweed based biostimulants consist of a mix of seaweeds and other biostimulating ingredients. These mixes differ per product. The **seaweed based biostimulant market is growing and most products are applied in all categories of the industry**. Currently no specific barriers or competitive advantages between the industry categories have been identified.

Drivers and barriers

Society is becoming more conscious about health issues and the environment. This development leads to a decrease in the use of agrichemicals and hence an increase in the demand for more sustainable products like biostimulants. Also **changing climates, more water and drought related stress, works as a trigger for end-users to start with (seaweed based) biostimulants** to make their crops and produce more resilient.

The supply chain in Europe is currently stable and providing enough seaweed material. Local wild-harvested seaweed species are being used in local biostimulant products. A pitfall of the current way of working is that the seaweed biostimulant market builds its foundation upon mainly one seaweed species that is only being wild harvested. In the future this could prove to become a great barrier for the seaweed biostimulant sector as it needs to keep on track with the growth of the biostimulant sector in general.

Producers of biostimulants also refer that legislation is an important barrier. **Ununified legislation per country in relation to registration of biostimulants withhold an overall EU market approach**. Also regulatory aspects such as labelling can help the biostimulant sector tackle products with incorrect product claims.

Lastly, the **knowledge base and market acceptance of seaweed based biostimulants need to be improved**. Lack of knowledge on the exact mode of action of seaweed compounds obstruct end-users to accept specific products. Education of end-users in accurate use of biostimulants (related soil conditions etc) can help those users to improve their return-on-investment.

Conclusion

Currently it is interesting to invest in the seaweed based biostimulant market as the supply chain is stable and the market is growing. For further growth, investors should also invest in developing the knowledge base, lobby for unified legislation, education of their end-users and a more diverse and resilient supply of seaweeds for their product.

Conclusion, recommendation & next steps

Recommendations

Based on the above conclusions we have come to the following recommendations towards a seaweed based biostimulant market that is more sustainable, scalable and more resilient.

In general

- The biostimulant sector in Europe should invest in lobby to develop unified legislation related registration of biostimulants, as it is an important barrier for current and future growth.
- Also the development of calculations to showcase return on investment by end-users using biostimulant products should help as an economic driver to realize better market acceptance.

Short term seaweed specific

- It is key to develop more scientific insights in the way of working of seaweed based biostimulants. An answer to the question whether refined seaweed components (compared to whole seaweed extracts) can work as an effective ingredient for biostimulants will be essential in developing a strategy how the seaweed based biostimulant sector could be developed in the future.
- In interviews to be executed for D.1.1.4. it is interesting to question how biostimulant producers are perceiving the current supply chain of their seaweeds (mainly one species and wild-harvest only). A better understanding of their position shall help in developing a method to work towards a local seaweed cultivation supply chain for biostimulants.
- Related to this it will also be important to gain insights in the dependency of biostimulant producers on seaweed species and/or compounds.

Long term:

- With the current estimated growth of the biostimulant sector it will be essential to work towards an increased level of resilience of the (local) supply chain of seaweeds that can be used for the development of seaweed based biostimulants. A resilient supply chain could be a combination of both wild-harvested and cultivated seaweeds. Also a diversification of seaweed species used for biostimulants can strengthen the supply chain in case of pest, disease or other crises. Next to this breeding technologies can help in improving existing species to be used as a building block for seaweed based biostimulants.

Conclusion, recommendation & next steps

Summary of next steps

D1.1.2: Identification of the market potential of various seaweed biostimulants

- **What is the market potential of seaweed biostimulants?**
 - ✓ Identification of commonly used seaweed species for biostimulants and their applicability
 - ✓ In depth analysis of industry categories objectives and needs – specifically related to seaweed biostimulants
 - ✓ Detailed overview of market drivers and barriers in the seaweed biostimulant market (logistics, knowledge, regulations, etc.)
 - ✓ Description and SWOT analysis of seaweed based biostimulants market: global, European, regional
 - ✓ Assessment of the results, conclusions and recommendations for next steps

D1.1.3: Identification of market potential of local seaweeds for application in biostimulants

- **Potential of local (regional) cultivatable seaweeds for the production and application of seaweed biostimulants**
 - Overview of local produced seaweed in 2 seas region (species and producers).
 - Correlation of regional seaweed biostimulant market and local production of seaweed.
 - Detailed overview of local seaweed production market drivers and barriers in the seaweed biostimulant market (logistics, knowledge, regulation, etc.)

6 | Bibliography

Bibliography

List of literature (1/3)

1. Interview Bioatlantis, July 2018 by North Sea Farm Foundation, confidential interview report
2. Interview Tradecorp, July 2018 by North Sea Farm Foundation, confidential interview report
3. Interview ECOstyle, June 2018 by North Sea Farm Foundation, confidential interview report
4. Interview Biotechica, June 2018 by North Sea Farm Foundation, confidential interview report
5. Interview Danvos, May 2018 by North Sea Farm Foundation, confidential interview report
6. Interview Arramara, June 2018 by North Sea Farm Foundation, confidential interview report
7. Interview Lima Europe, June 2018 by University of Gent, confidential interview report
8. Interview Acadian, June 2018 by University of Gent, confidential interview report
9. Interview BMS micro-nutrients, June 2018 by University of Gent, confidential interview report
10. Yakhin, O. I., Lubyantsev, A. A., Yakhin, I. A., & Brown, P. H. (2017). Biostimulants in plant science: a global perspective. *Frontiers in plant science*, 7, 2049.
11. Overview of the seaweed industry by country; Iceland, France, Norway, Portugal, Spain, United Kingdom; A summary of the initial findings of the netalgae project regarding the current status of the seaweed industries in the participant countries, 2012, www.netalgae.eu
12. AlgaeBase, (search term: Laminaria), visited July 2018, <http://www.algaebase.org/>,

Bibliography

List of literature (2/3)

13. Wikipedia, (search terms: Gelidium & Lithothamnium), visited July 2018, www.wikipedia.org
14. Agar-Agar producer Mooragar, visited July 2018, <https://www.mooragar.com/history-of-agar>
15. Chojnacka, K., Saeid, A., Witkowska, Z., & Tuhy, L. (2012). Biologically active compounds in seaweed extracts—the prospects for the application. In The open conference proceedings journal (Vol. 3, No. 1, pp. 20-28).
16. Battacharyya, D., Babgohari, M. Z., Rathor, P., & Prithiviraj, B. (2015). Seaweed extracts as biostimulants in horticulture. *Scientia Horticulturae*, 196, 39-48.
17. Interview Koppert Biological Systems, July 2018 by North Sea Farm Foundation, confidential interview report
18. Interview Compo Expert, July 2018 by North Sea Farm Foundation, confidential interview report
19. Bulgari, R., Cocetta, G., Trivellini, A., Vernieri, P., & Ferrante, A. (2015). Biostimulants and crop responses: a review. *Biological Agriculture & Horticulture*, 31(1), 1-17.
20. Productfiches biostimulanten: overzicht van in 2018 per plant geteste biostimulanten op het PCS en specificaties van de verschillende types biostimulanten, Proefveldbezoek biostimulanten in de praktijk, 12 juli 2018, Proefcentrum voor Sierteelt
21. Pal, A., Kamthania, M. C., & Kumar, A. (2014). Bioactive compounds and properties of seaweeds—a review. *Open Access Library Journal*, 1(04), 1.
22. Tuhy, L., Chowanska, J., & Chojnacka, K. (2013). Seaweed extracts as biostimulants of plant growth: review. *Chemik*, 67(7), 636-41.
23. Tholhuijsen L. & Verstegen S., (2018). Doen biostimulanten wat ze beloven? Test ze zelf. www.Boerderij.nl.
24. EU project Biofactor, 2012-2017, www.biofactor.info

Bibliography

List of literature (3/3)

25. BIOFECTOR Summary Project activities 2015, (2015), EU project Biofactor 2012-2017, <http://www.biofactor.info/dissemination.html>
26. Interview Lallemand, July 2018 by University of Gent, confidential interview report
27. Interview Proeftuin Zwaagdijk, May 2018 by North Sea Farm Foundation, confidential interview report
28. Little. H., Understanding the benefits and modes of actions of seaweed extract-based biostimulants on enhanced nutrient uptake, (2018), Presentation Acadian Planthealth, US biostimulant summit 2018.
29. MACRO CASCADE project, 2016-2019, www.macrocascade.eu
30. Identification of the seaweed market (phase 1), (2018), North Sea Farm Foundation, D 1.1.1 project Bio4safe