

Mapping and Monitoring 'Blue Carbon' Ecosystems at Scale with Copernicus Sentinel-2 Imagery

A use case from Sweden

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Acknowledgements:



Swedish Agency
Marine and
Water Management



Blue Carbon is carbon that is removed from the atmosphere by ocean systems

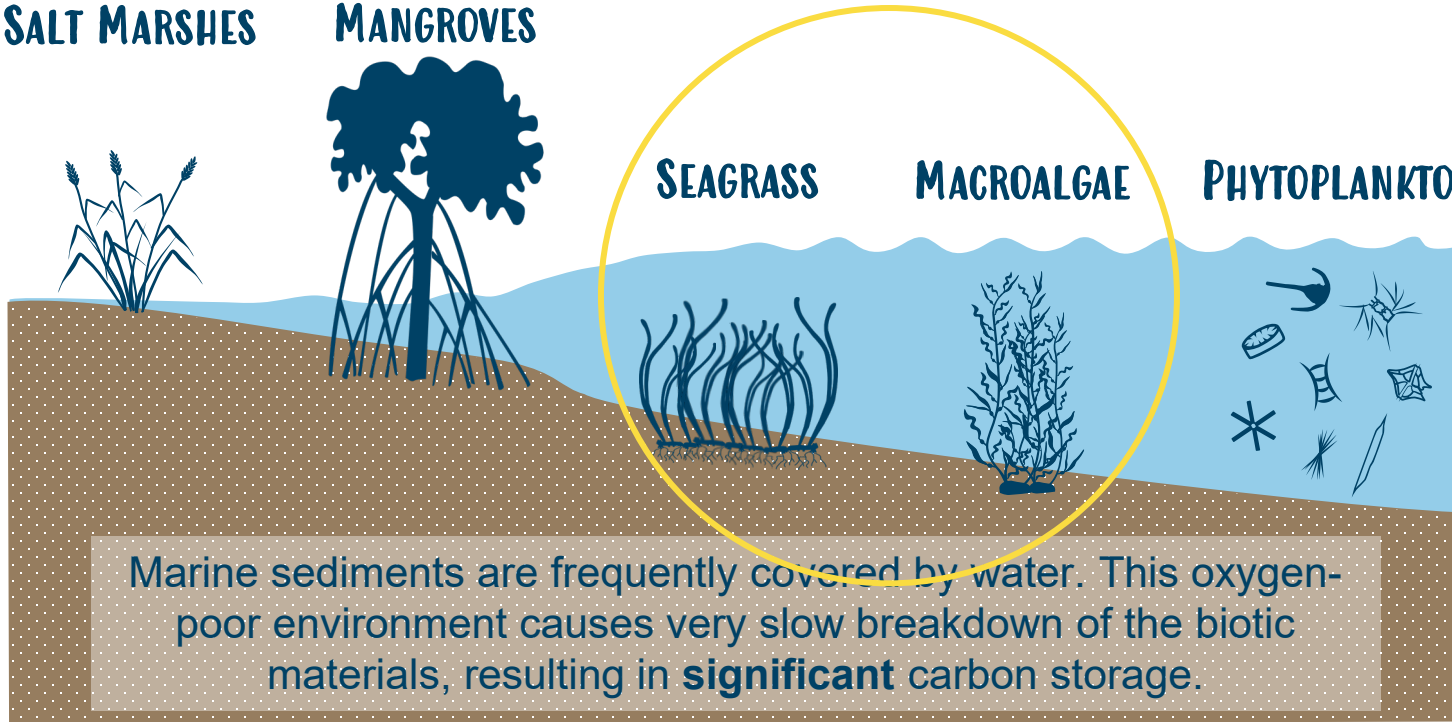
SALT MARSHES

MANGROVES

SEAGRASS

MACROALGAE

PHYTOPLANKTON



In biotic elements...

... and in sediments

Why is submerged vegetation so important?



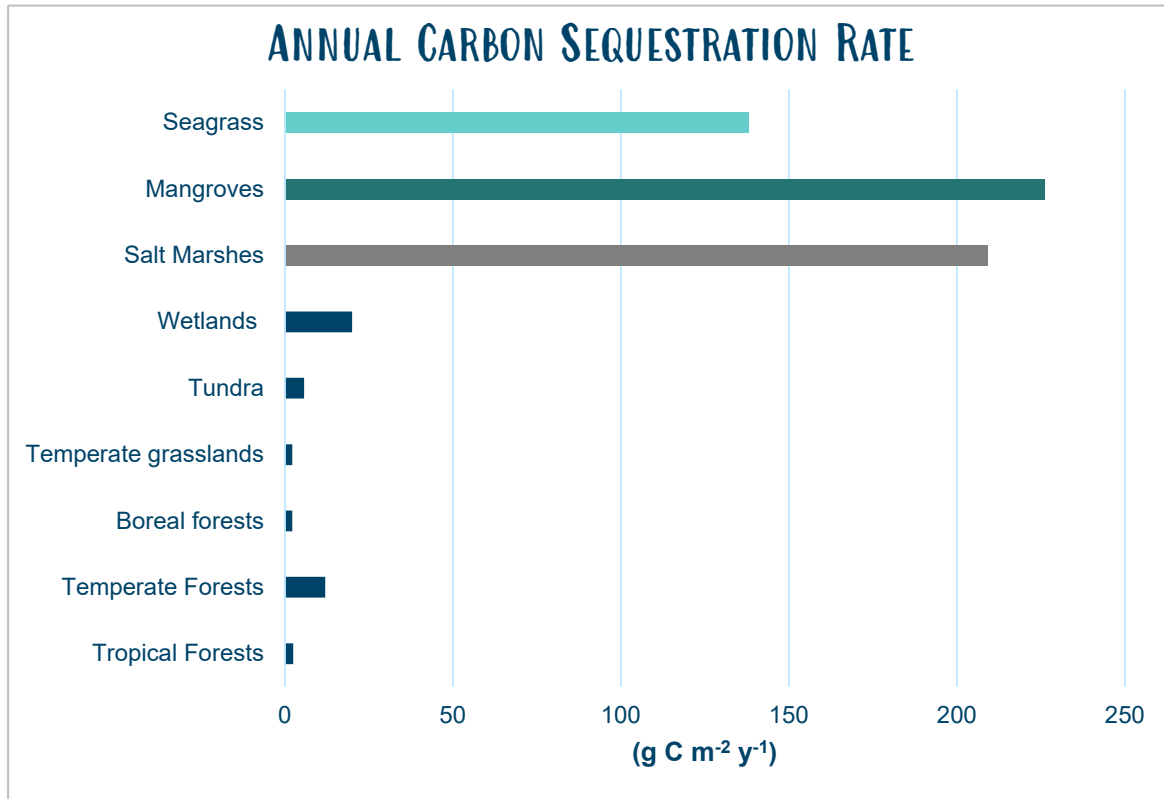
Atm. corrected Sentinel-2 image from 6 June 2019 showing Skanör south of Malmö (Sweden). The image reveals the fine structures of submerged aquatic vegetation as seen in 10 m satellite data.

© DHI



- Seagrass and seaweeds are among the most efficient natural carbon storage environments
- Seagrass is one of the key indicators of ecological status of coastal ecosystems

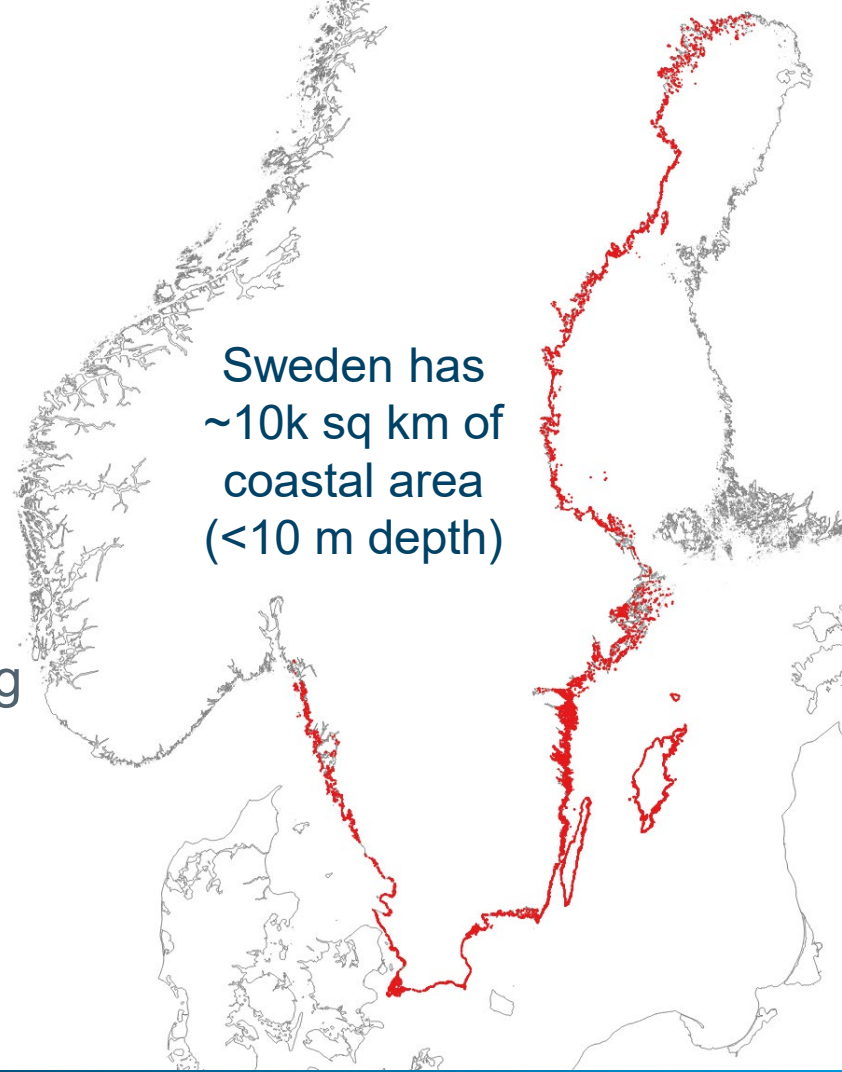
Comparison of carbon sequestration rates



- Marine habitats sequester more carbon annually compared to terrestrial ecosystems
 - Immense storage potential in marine soils
- Per m² of habitat, between 50 – 100 times more carbon captured annually by seagrass and mangroves compared to tropical forests

Motivation

- Tremendous coastal area with major gradients in env. conditions
- Incomplete information about areal distribution of submerged aquatic vegetation (SAV) growing on soft seafloor
- Need for regular, systematic monitoring of SAV at country-wide scale
- Limited budget and time



The Goal

- Supplement current monitoring with free EO data and create the first country-wide SAV map at 10m with ref. 2019/2020
- Wrap mapping workflow into a **cloud-based portal** (prototype) using ML methods and Sentinel-2 imagery
- Design the portal for non-EO specialists so that biologists with local expertise can perform mapping with timely data.



Portal Design

Combine the whole mapping workflow from Sentinel-2 image selection, pre-processing, ML model training, mapping, validation and visualization into a simplified GUI.

Submerged Aquatic Vegetation
Vegetation mapping in shallow marine areas of the Swedish coast

Layers

Range statistics

default percentile

std

R. 0 1000

G. 0 1000

B. 0 1000

Orthophoto

Infeasible area

Opacity: 100%

No habitat classification available.

Validation data

[Upload validation data](#)

[Download validation template](#)

Södra-Öresund
27-03-2020

Training data

Click on a habitat type and draw polygons on the satellite image to collect training data or upload training polygons. SAV (Submerged Aquatic Vegetation) and Sand are required, and in addition up to three other classes can be freely defined.

<input type="checkbox"/>	Name	Color	Area
<input type="radio"/>	SAV	●	-
<input type="radio"/>	Sand	●	-
<input type="button" value="⊕"/>	New class		

No training data available

[Delete polygons](#)

[Download polygons](#) [Upload polygons](#)

Post-processing

Choose sieving to remove isolated classified pixels smaller than the minimum object size (in pixels) and to replace them with the pixel value of the largest neighbour polygon. The sieving method looks at the neighbouring 4 or 8 pixels (connectivity) to determine if a pixel is grouped with pixels of the same class.

Sieve: 4 8

Connectivity: 4 8

Minimum object

mapbox © Mapbox © OpenStreetMap Improve this map

Web-tool for classification of shallow marine habitats based on Copernicus Sentinel-2 imagery and machine learning

Submerged Aquatic Vegetation
Vegetation mapping in shallow marine areas of the Swedish coast

Norra Göteborg
12-99-2020

Mapping

Training data

Click on a habitat type and draw polygons on the satellite image to collect training data or upload training polygons (SAV, Submerged Aquatic Vegetation). Note that training data needs to be provided for all habitat types listed below.

● SAV ● Sand ● Rock ● Delete

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72
73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96
97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144
145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168
169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192
193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216
217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240

Download polygons Upload polygons

Visualisation

Base map stretch

R: 0 0.1

G: 0 0.1

B: 0 0.1

Show habitat classification

Opacity: 100%

● SAV ● Sand ● Rock

18.51 km² 23.17 km² 6.84 km²

Show validation data

Upload validation data

Download validation template

Post-processing

Regions added successfully.

Training data received successfully!

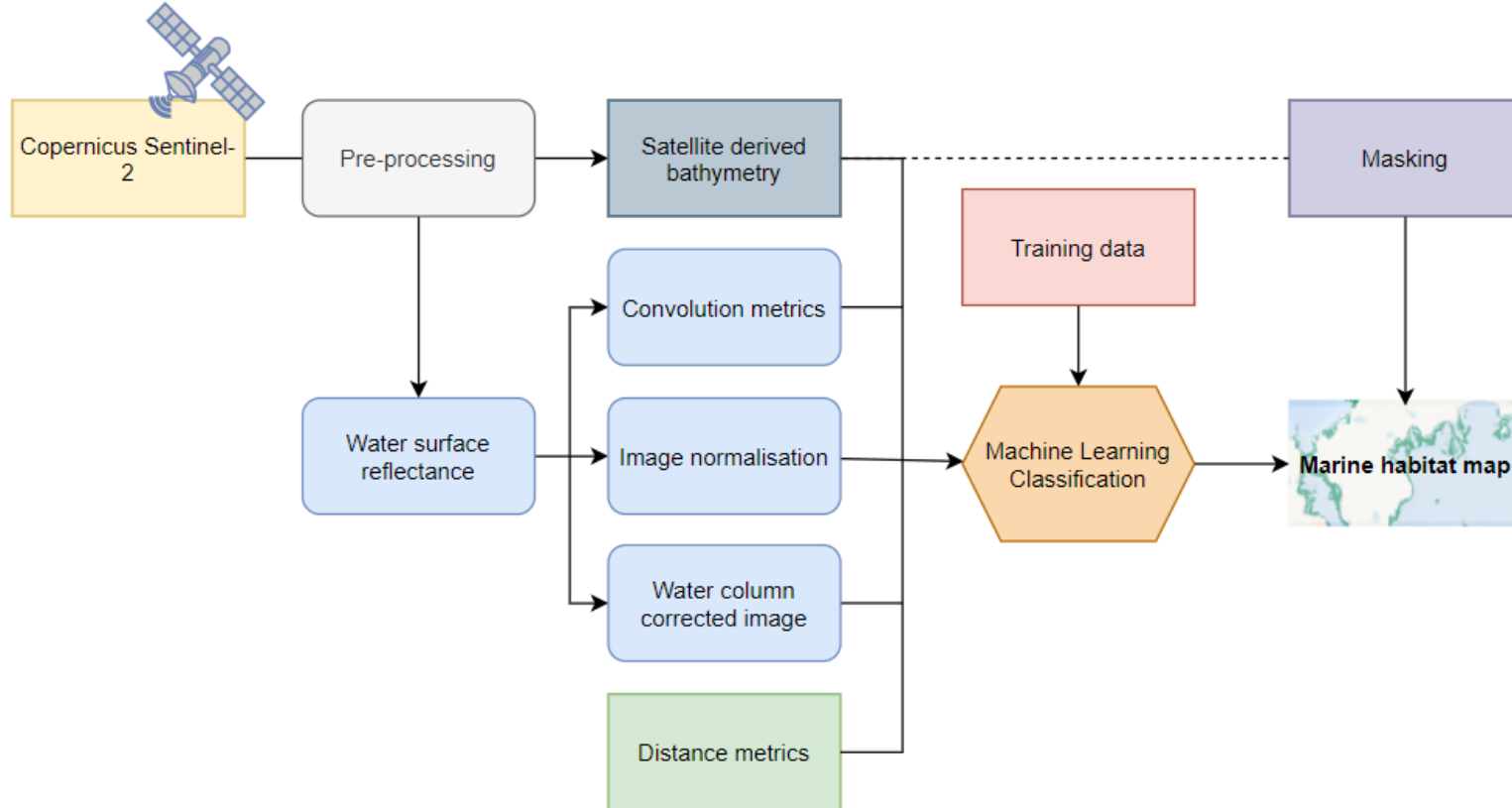
Pixel count received successfully!

© DHI

Mapbox © OpenStreetMap Improve this map

DHI GRAS

Methodological implementation



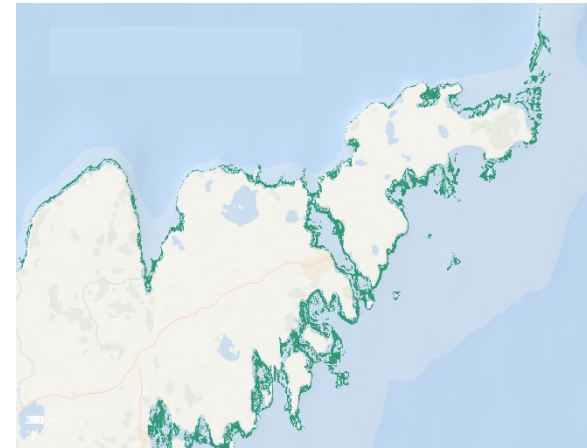
Country-wide SAV map derived with Sentinel-2 data 2019/2020

- In total it was feasible to map an area of 3,860 km² of the Swedish coast with S2 imagery.
- 1,550 km² (41 % of total area) were mapped as SAV
- Almost all (99 %) of the S2 derived data is from 0 to 6,5 m depth

How accurate are the SAV maps?

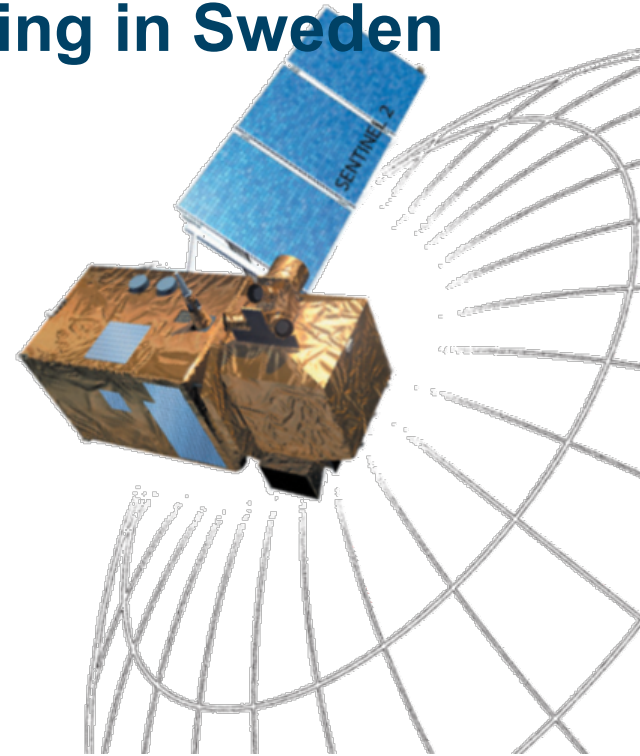
Comparison with independent field data from three different regions along the Swedish coast

- Average total accuracy per region 0.60-0.77.
- On average 31-50 % of vegetation growing in 3-5m not detected
- Only 6% of unvegetated substrate was classified wrongly as vegetated
- Poor performance in areas with fragmented sparse vegetation and poor water quality, e.g. Bothnian Bay



Some challenges with S2 SAV mapping in Sweden

- Highly variable water conditions (clouds, wind, waves..)
- Deeper and/or turbid waters
- Differentiation between optically deep and dark sea floor
- Lower growth limit of seagrass
- Areas with highly fragmented and sparse marine plants and algae
- Species differentiation



Conclusions

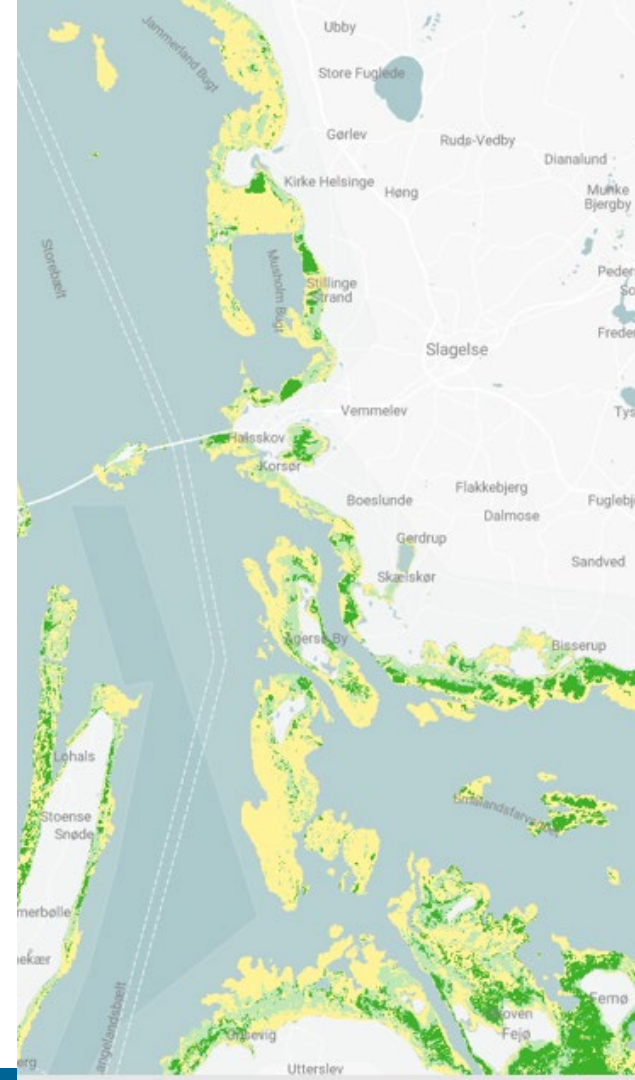
- Good approach to map vegetation coverage at **large scale**, systematically and regularly
- Good results in clear water down to 6m (best to 3m)
- Potential for improvement, as training data is key to achieve a good result and attribution of mixed pixels has a big impact on classification result.



Next steps

- Continuous improvement of web-portal with additional features, e.g. orthophotos
- Optimisation in satellite image pre-processing
- Testing of new ML approaches

Vision is to have a fully automated system in the coming 3-5 years, integrating various scales such as field inventory, drone and spaceborne sources.



Thank you!

For more information:

Huber et al., (2021) Novel approach to large-scale monitoring of submerged aquatic vegetation: A nationwide example from Sweden
<https://doi.org/10.1002/ieam.4493>

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