

Where to find or cultivate algae for biofuels?

Deliverable 1.6

Mapping of natural resources in artificial,
marine and freshwater bodies



diacel



UNIVERSITEIT
GENT

Dr Annick Verween
Dr Griet Casteleyn

Algae for biofuels



Natural occurrence



Cultivation

Natural blooms: microalgae



Microalgal bloom off the southern coast of England in 1999

- Freshwater
 - Cyanobacteria
 - Dinoflagellates
- Marine
 - Diatoms
 - Dinoflagellates
 - *Emiliana huxleyii*
 - *Phaeocystis*
- Occurrence dependent on:
 - Environmental conditions (light, temp, sal, ..)
 - Biological conditions (f.e. grazing by zooplankton)
 - Physical conditions (f.e. transport by currents)
 - Antropogenic influences (excess in nutrients, overfishing, global warming,..)

Natural blooms: macroalgae



- Freshwater
 - *Cladophora*
- Marine
 - Green MA (“green tides”)
 - Brown MA
 - mainly littoral zone

Macroalgal bloom during the Olympic Games in China in 2009

- 2 types:
 - Standing stock, mainly brown MA
 - Blooms, mainly *Ulva* and *Cladophora*
- Occurrence dependent on:
Environmental, biological, physical, antropogenic factors

Natural blooms: monitoring & mapping

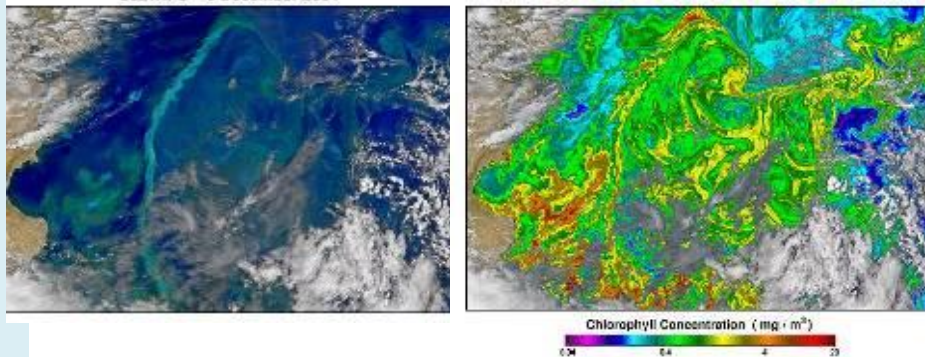
Microalgae

- Phytoplankton monitoring (EWFD)
- Satellite observations → chl a
- Ocean color imaging spectrometer
- Computer models
- EU: Near real-time algal bloom detection service

Macroalgae

- = biological quality elements (EWFD)
- Ground-based surveys
- Remote sensing
- Satellite observations

SeaWiFS 6 December 2004



SeaWiFS view of the phytoplankton blooms in the Malvinas current region. The enhanced natural color image shows actual differences in water color while the pseudocolor image shows chlorophyll concentration.



Menesguen, A. (2003) LES "MAREES VERTES" EN BRETAGNE, LA RESPONSABILITE DU NITRATE.

Natural blooms: applicable?

- **Important remark:**

- Growth phase
 - Duration
 - Intensity
- } Vary from year to year

- **Useful for biofuels?**

- Not a continuous source of biomass
- Harvesting?
- Composition and amount?
- Prediction of occurrence?
- Ecosystem disturbance
- Paradox between ↓ eutrophication and ↑ blooms

Integrated cultivation of algae

- Factors for successful growth of algae
 1. Climate
 - Solar irradiance
 - Temperature
 - Other elements
 2. Water availability
 3. CO₂ availability
 4. Nutrient availability
 5. Land availability
 6. Others

Focus: MICROALGAL FARMING ON LAND

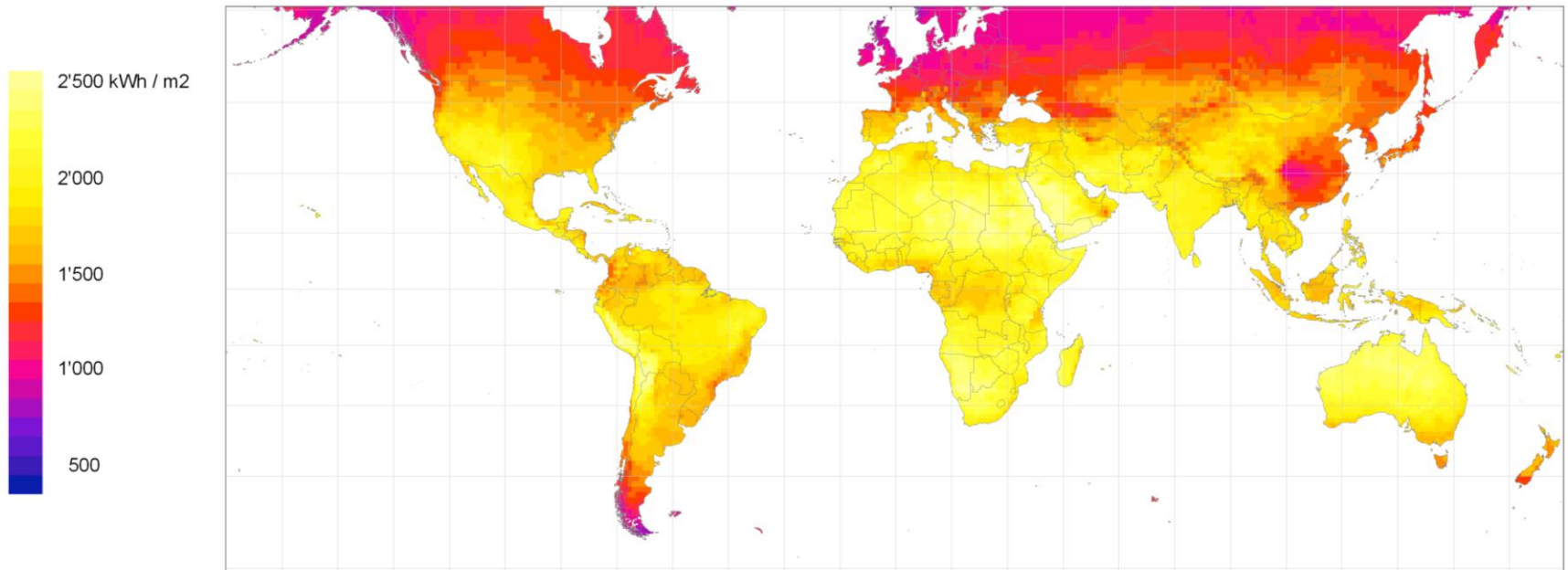
Marine macroalgal cultivation: McHugh (2003), Horn (2009)

Integrated cultivation of algae

1.1. Solar radiation

1500 kWh/m² * yr (Darzins et al., 2010)

Yearly sum of global irradiance



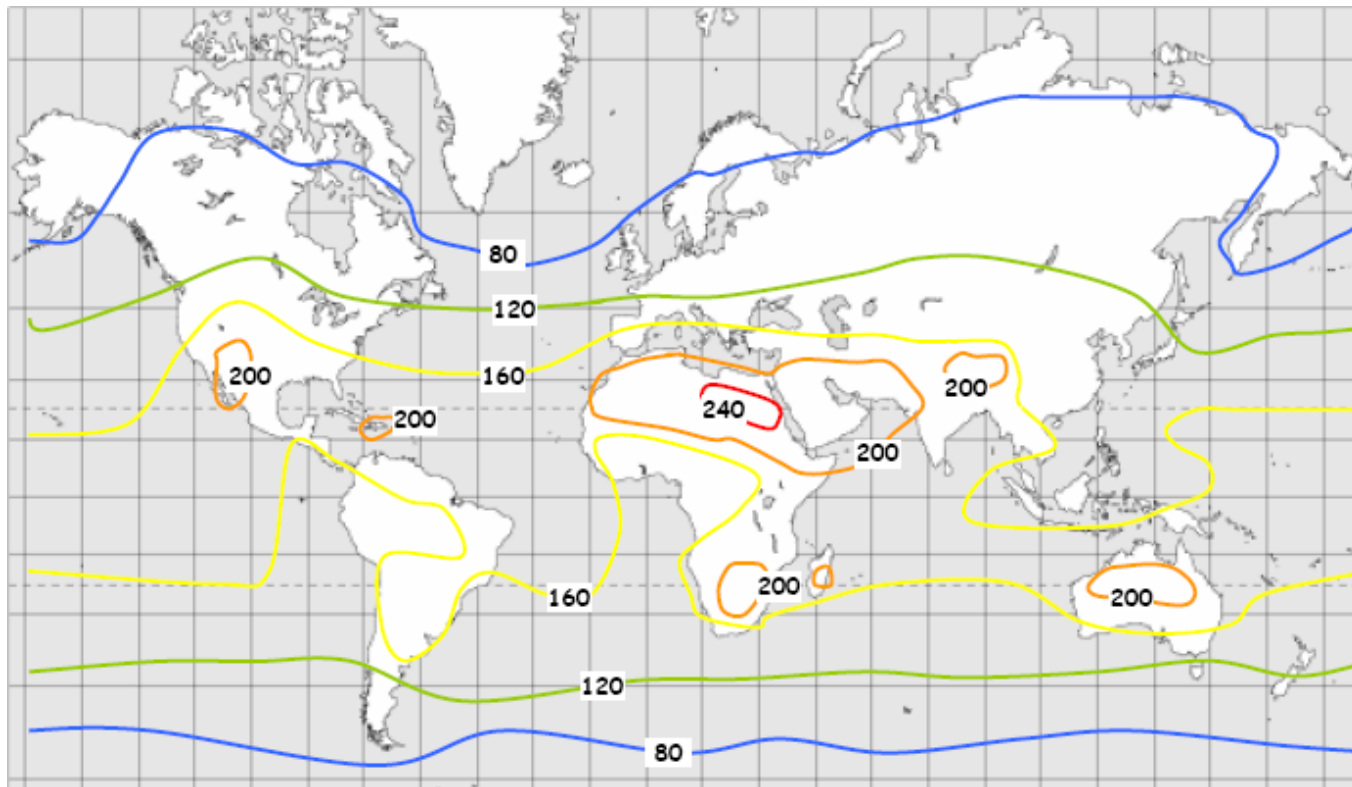
Yearly sum of global solar irradiance averages over the period of 1981 to 2000.

June 2008



Integrated cultivation of algae

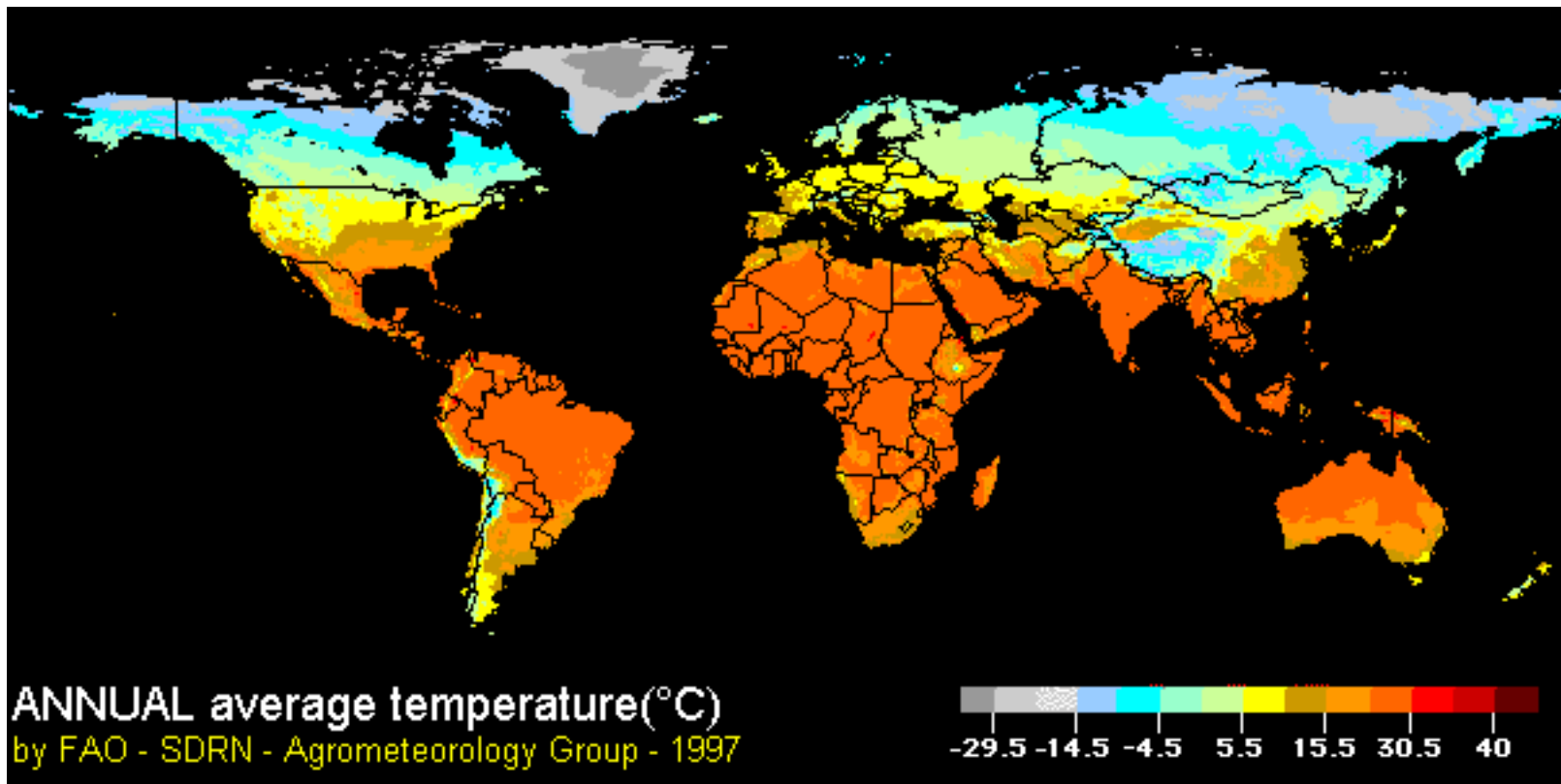
Productivity highest close to equator → less seasonal fluctuations
all year round production



World map of algae biomass productivity (tonnes ha⁻¹ year⁻¹) at 5% photosynthetic efficiency considering an energy content of 20 MJ kg⁻¹ dry biomass. From Tredici 2010.

Integrated cultivation of algae

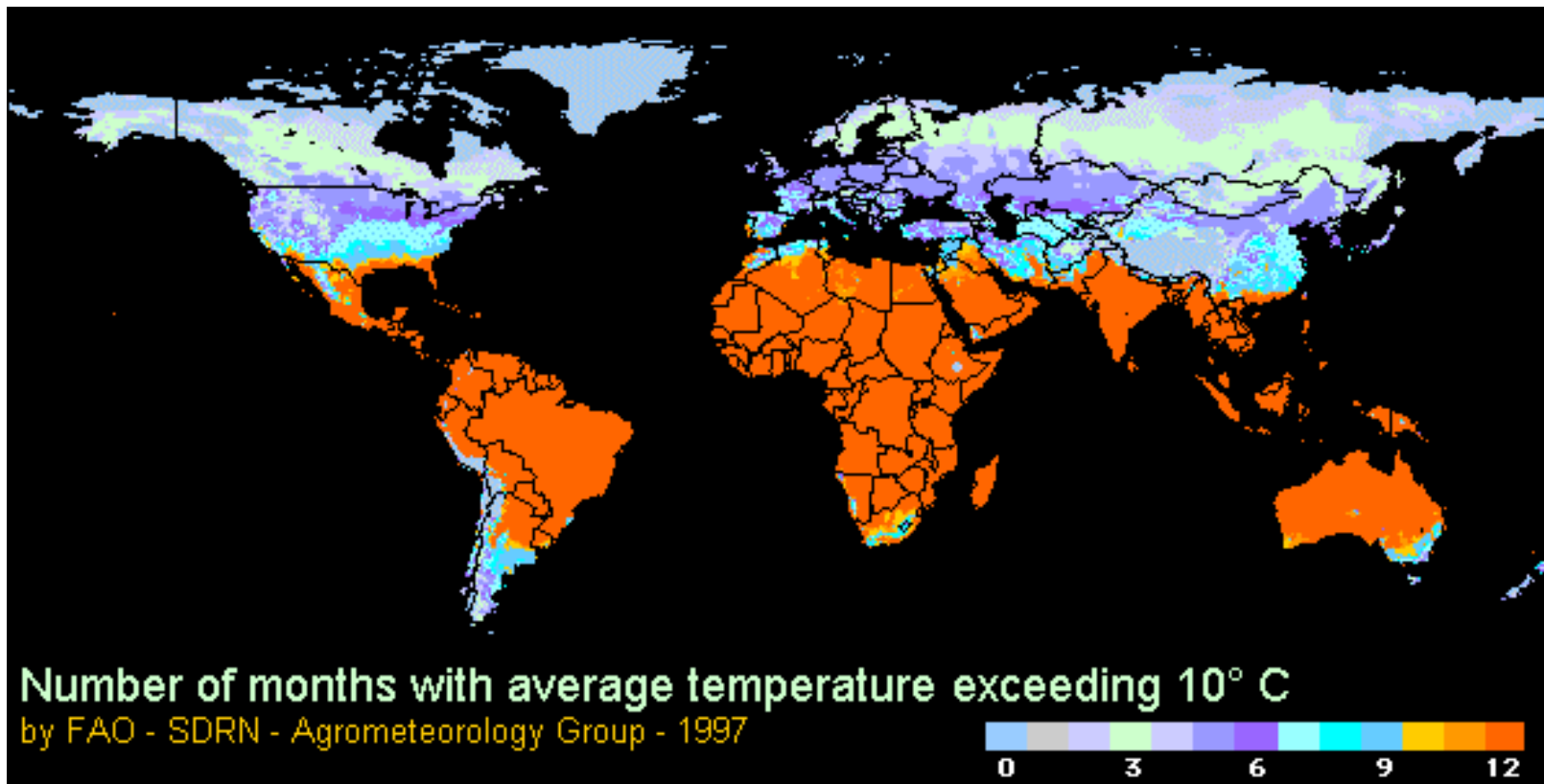
1.2. Temperature $20\text{ }^{\circ}\text{C} < \text{annual average} < 30\text{ }^{\circ}\text{C}$



Annual average temperature. Source: FAO (<http://www.fao.org/nr/climpag/climate/img/3temmin.GIF>)

Integrated cultivation of algae

All year round production → coldest month > 15°C



Number of months with average temperature exceeding 10° C.

Source: FAO (<http://www.fao.org/nr/climpag/climate/img/3temnum.gif>)

Integrated cultivation of algae

1.3. Other climatological elements

- **Precipitation**
Rainfall < 500 mm/yr
- **Evaporation**
Influenced by air humidity
- **Severe weather**
hail, tornadoes, cyclons, ... Damage infrastructure
-

Integrated cultivation of algae

2. Water availability

Freshwater → limited

Marine or brackish water

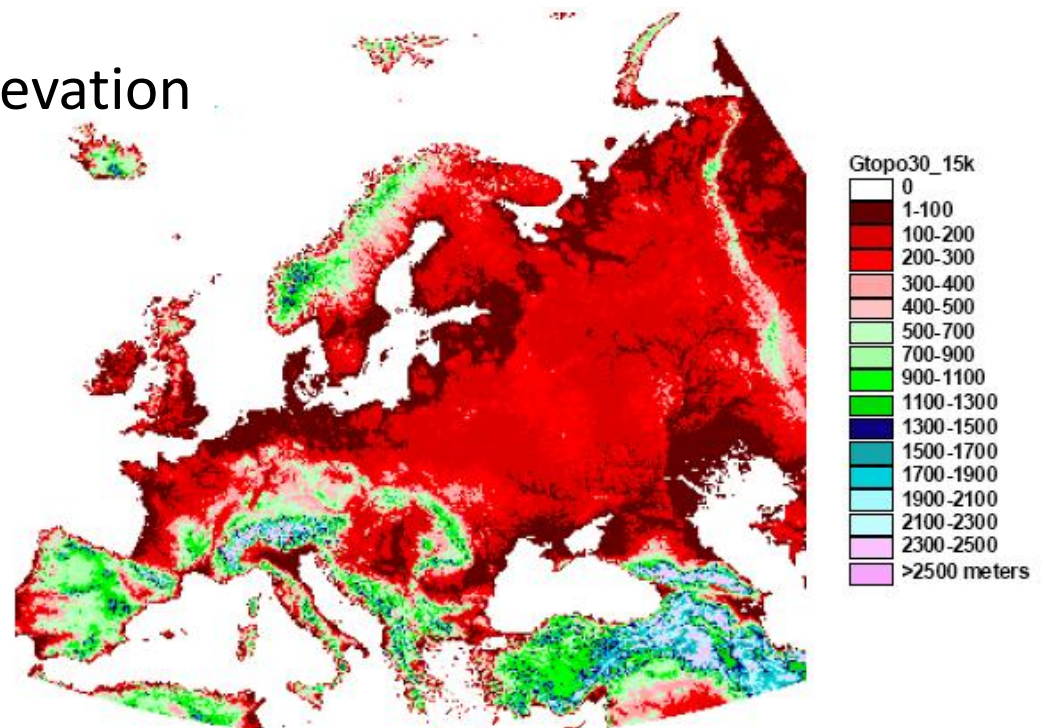
- Distance to the sea + elevation
- Saline aquifers

location & depth for US

Waste water

rich in nutrients

Too many sources to map



Detail of the global USGS GTOPO30 Digital Elevation Model for Europe

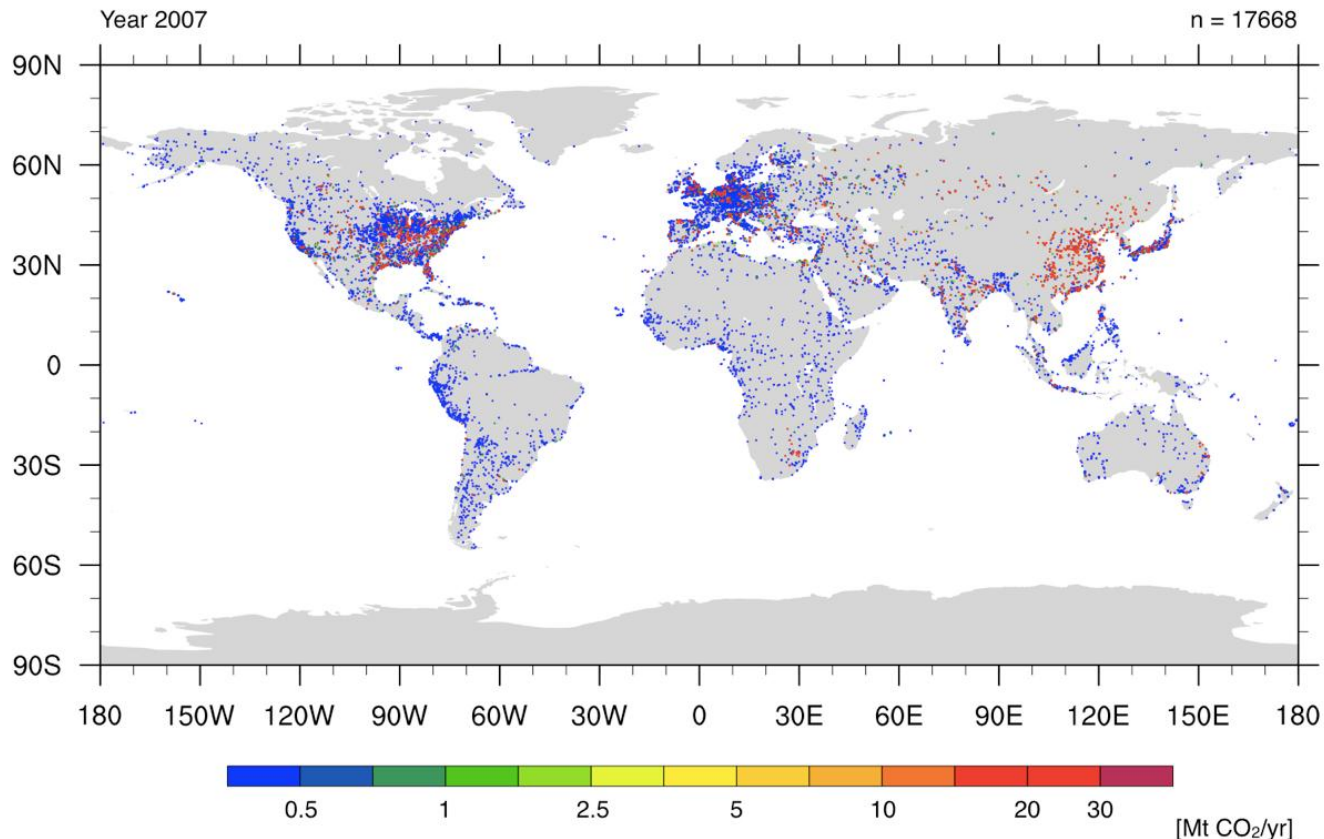
Integrated cultivation of algae

3. CO₂ availability

f.e. power plants

Nearness of large point sources

proximity of industrial & urban areas



Over 17.000 mapped power plants in 2007. Source: Carbon Monitoring for Action (CARMA).

Integrated cultivation of algae

4. Nutrients

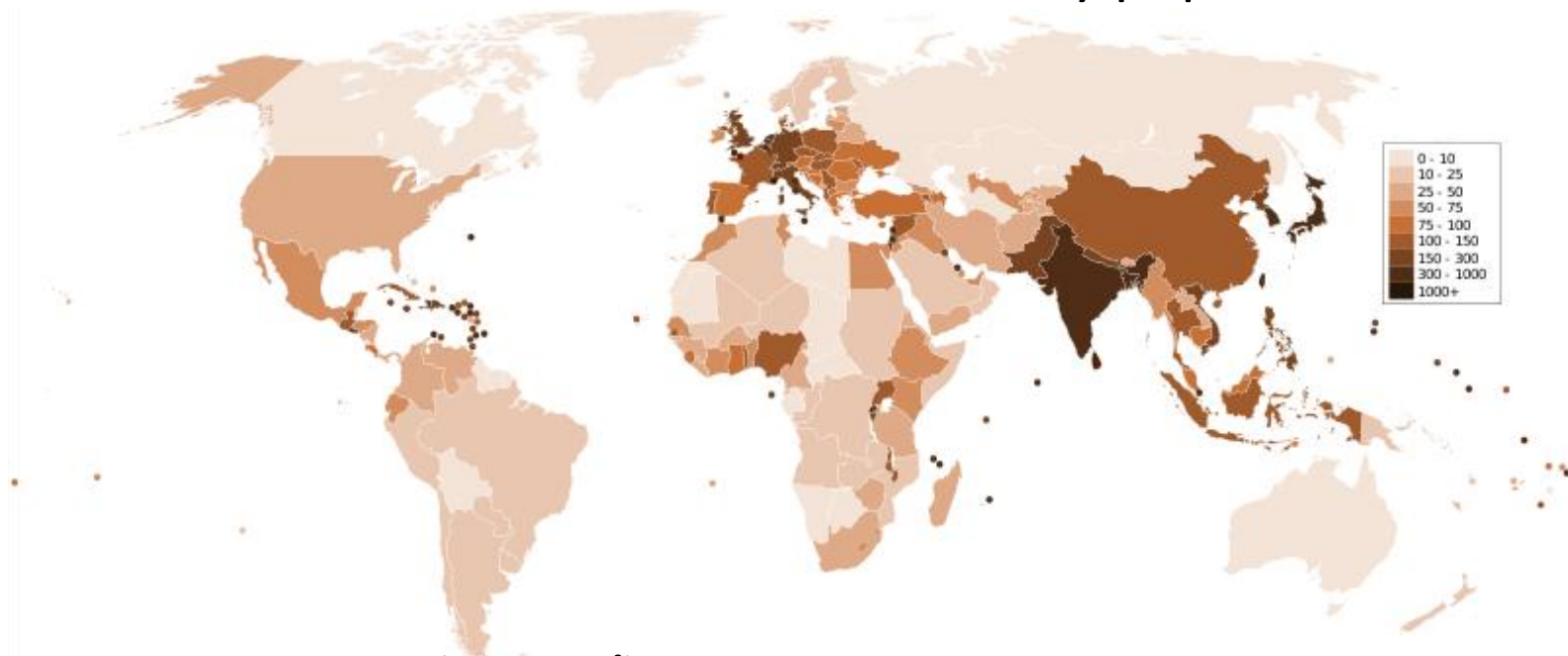
- Fertilizers

vs

Mainly N, P, K

Waste streams

- Highly concentrated vs diluted
- In densely populated areas

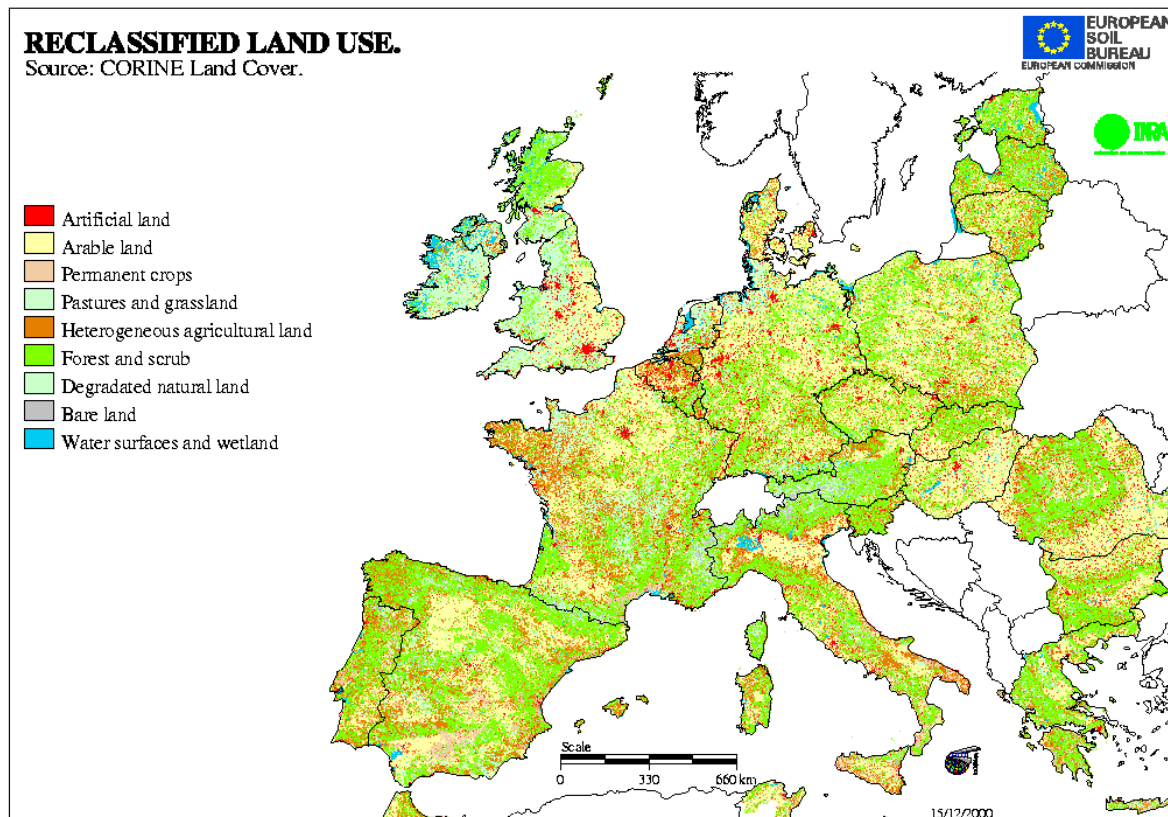


Population density (people per km²) by country, 2006

Integrated cultivation of algae

5. Land availability

- Biofuels: flat terrain not fertile A LOT



European land use. From
MESALES (Modèle
d'Evaluation Spatiale de
l'ALéa Erosion des Sols)

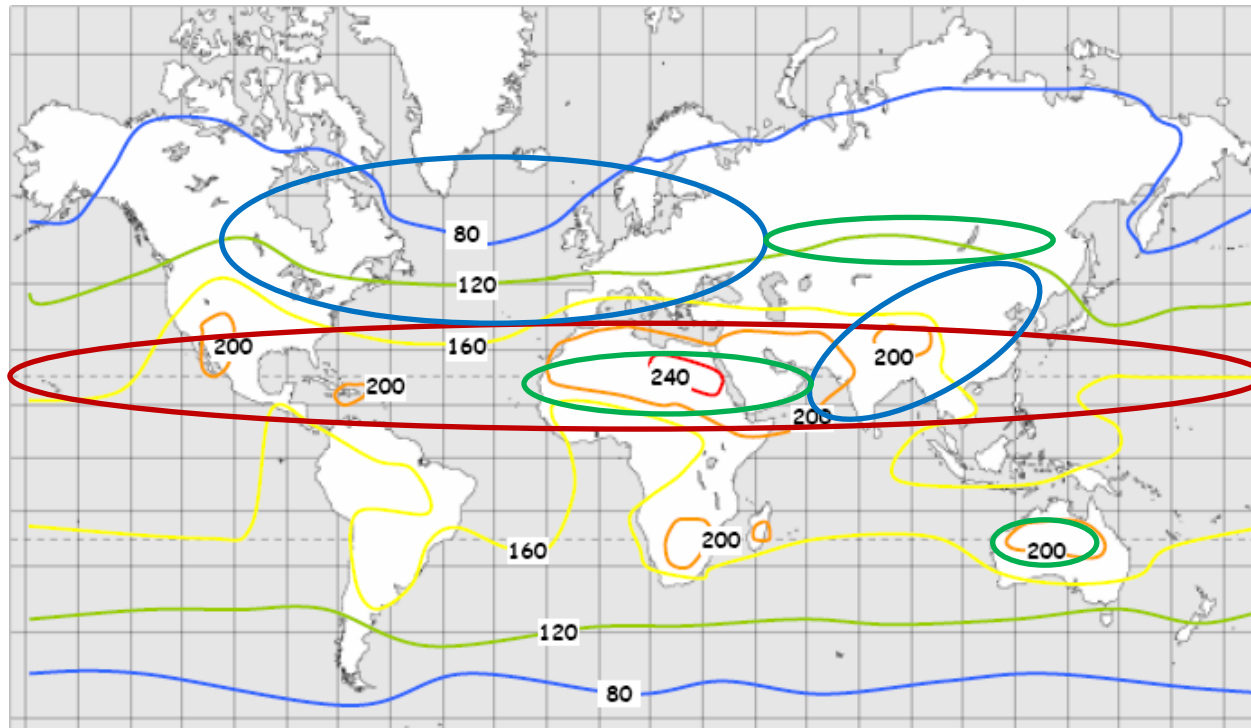
Integrated cultivation of algae

5. Other factors

- Skilled personnel
- Transport facilities
- Proximity to downstream processing
- ...

Mapping of optimal cultivation sites: Conclusion

- Lot of requested characteristics → in conflict



Nutrients & CO₂

Potential highest yields

Space

- Impossible to generalize: most sp have different optimal conditions, can differ according to requested end product

Mapping of optimal cultivation sites

	North Europe	South Europe	North America	South America	Africa	North Asia	South Asia	Australia
Solar irradiance	-	+/-	+/-	+	+	-	+	+
Temperature	-	+/-	+/-	+	+	-	+	+
CO ₂ availability	+	+	+	+/-	-	-	+	+/-
Water availability	Very dependent on the type of water source preferred, being natural fresh or salt water, waste water or aquifers							
Nutrient availability	+	+		+/-	-	-	+	-
Land/space availability	-	-	+	+	+	+		+
Skilled personnel	+	+	+		-		+	
Transport	+	+			-		+	

General indication of the different continents characteristics for algae cultivation on a large scale. Blue reflects positive aspects, red accounts for negative aspects, yellow corresponds to a dual result and for the white, not enough information was found (Griet Casteleyn).



diacel

Annick Verween
Technology Developer
+32 9 264 85 42

Annick.Verween@UGent.be
www.diacel.ugent.be