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Variability and uncertainty in water demand and water footprint assessments of fresh algae cultivation based on case studies from five climatic regions

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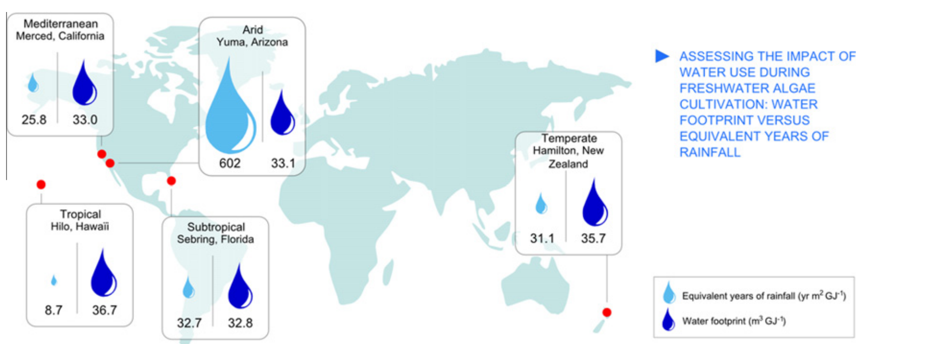
HIGHLIGHTS

- ▶ The water demand (WD) of algae cultivation for five case studies was quantified.
- ▶ Considerable variability and uncertainty regarding WD were found.
- ▶ The water footprint metric had poor geographical resolution and was biased towards high-productivity arid locations.

GRAPHICAL ABSTRACT



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ABSTRACT

Using case studies from five typical climatic locations, this study revealed that current quantification of water demand (WD) and water footprint (WF) of freshwater algae cultivation in raceway ponds suffer from uncertainty and variability in the methodologies and assumptions used. Of particular concern, the WF metric had an intrinsically poor geographical resolution and could be biased towards high-productivity arid locations because local levels of water stress are not accounted for. Applying current methodologies could therefore cause the selection of locations that are neither economically viable nor environmentally sustainable. An improved methodology should utilize more accurate evaporation models, determine realistic limits for the maximum hydraulic retention times and process water recycling ratios, and apply weighting to the WF to reflect localized water stress or use an alternative metric such as the equivalent years of rainfall required to support a productivity of 1 GJ m^{-2}.

1. Introduction

Despite the vast potential of algae biotechnologies to provide food, animal feed, bioactive compounds, biofuels, and new capabilities for pollution control (Dismukes et al., 2008; Spolaore et al., 2006; Singh et al., 2011), commercial algae cultivation remains expensive and difficult to scale up due to issues such as nutrient availability, CO_2 supply and delivery, land availability, process stability, biomass separation, and environment impacts (Murphy and Allen, 2011; Clarens et al., 2010; Singh and Olsen, 2011). Therefore, if algal biofuels are to become a commercial reality, the fundamental issues associated with large-scale algae cultivation must be addressed. Since more than 1 metric ton of process water must be handled for each kg of algae biomass produced (Murphy and Allen, 2011), water use represents a challenge of particular significance.

Water use can be assessed in terms of the water demand (WD) required for operating the process, which has direct economic and technological relevance, and the water footprint (WF), which reflects the amount of freshwater resource that the ecosystem is deprived of and which is essentially a policy tool. Different methods and assumptions have been used in the literature to estimate the amount of water used during algae cultivation (S1) and these differences may have led to conflicting conclusions. For example,

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