Preventing global famine in case of sun-blocking scenarios: Seaweed as an alternative food source

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Key findings

This research suggests that in a sun-blocking scenario which could lead to an agriculture collapse, seaweed can be scaled up within 3-6 months to meet global food demands. The resulting retail price would be less than 2 $/kg making it affordable for the global population, potentially contributing to saving hundreds of millions from starvation. To achieve the task of feeding everyone, hundred thousands of square kilometers or less than 0,2% of the ocean surface would need to be covered with these farms. The limiting factor for expansion is expected to be the twisting of synthetic fiber into rope, since seaweed farms consist mainly of twine. The global rope production would need to be increased by a factor of 400.

Disclaimer

This is a draft of an ongoing research project. Findings may vary from final publication.

1. Why humanity needs quickly scalable alternative foods

Humanity is vulnerable to extreme scenarios such as asteroid impacts, super volcanoes, or even full-scale nuclear war. Although the initial death toll could total hundreds of millions, most of the danger lies with indirect consequences. The resulting fires and eruptions would launch soot into the atmosphere where it could block most of the sun's radiation for up to a decade, cooling the planet and limiting photosynthesis. These nuclear or volcanic winters would render conventional agriculture ineffective. The ensuing famine could cost billions of lives and cascading effects could cause irreparable damage to the long-term future of humanity. Current food storage provides only a few months' leeway to solve this problem and would be expensive to expand.

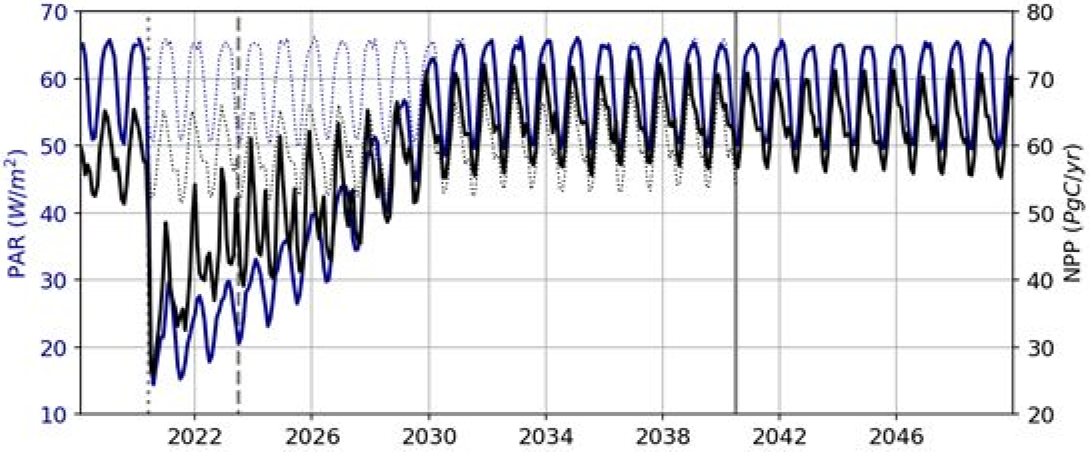
2. Modelling scale-up in nuclear winter

To see if seaweed is a promising alternative food source in sun-blocking scenarios, a Global Earth System model was taken to provide environmental parameters, which were then taken to calculate seaweed production rates. The material requirements for the seaweed farms are compared to industrial capacities. A Geographic Information System (GIS) analysis shows the available ocean area.

2.1 Global Earth System

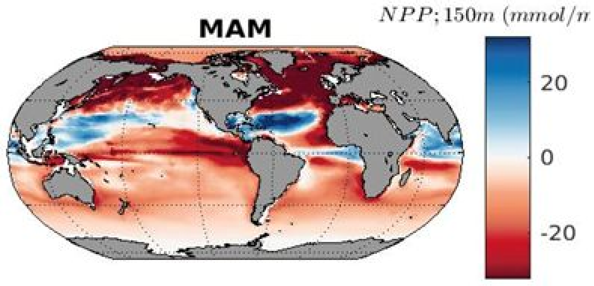
It is estimated that a full-scale nuclear war between the US and Russia could inject 150 teragrams (Tg) of soot into the atmosphere. The 1st May of 2020 was chosen as starting point. This would be particularly bad timing because at this time of the year the food storage is low and the following harvests of that year could be destroyed.

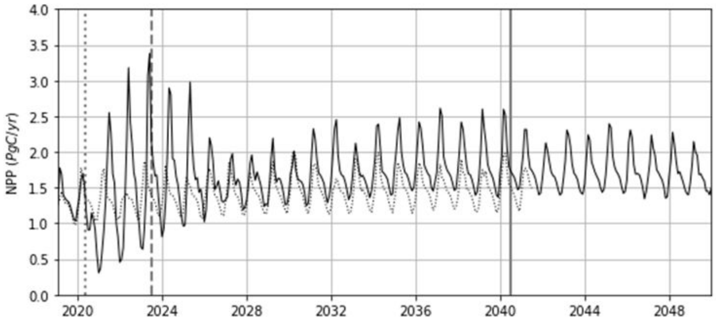
The graph below shows the global average Photosynthetically Active Radiation (PAR, blue line) that is hitting the earth's surface and the resulting Net Primary Production (NPP, black line). The dotted lines represent a control run in which no nuclear war occurs.



A strong link is visible between the amount of sunlight hitting earth and the production of biomass, represented through the amount of carbon fixed in plants. Following a 150 Tg event, a rapid fall in both PAR and NPP can be observed.

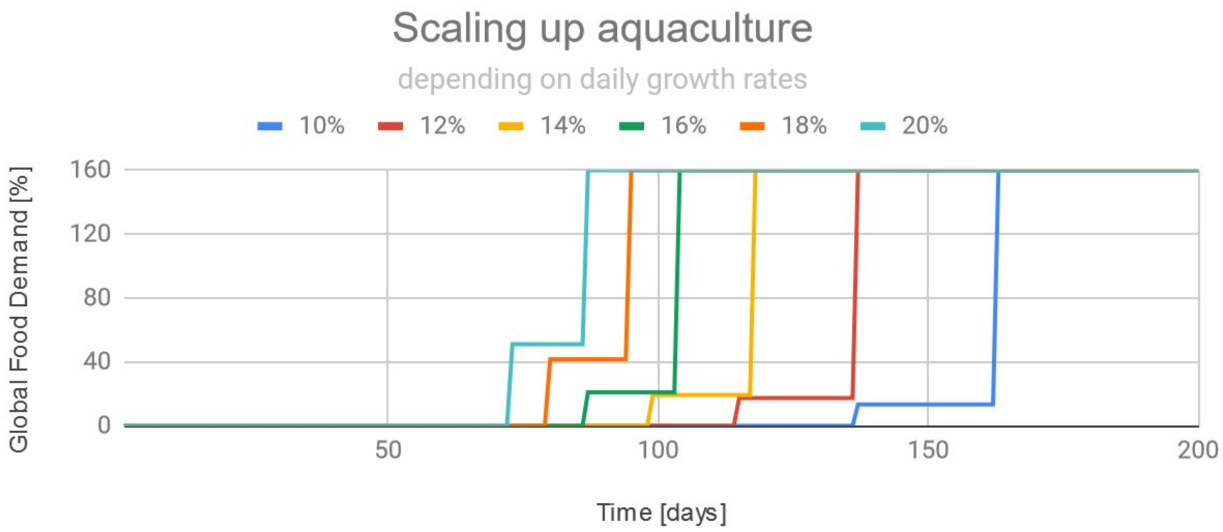
As a consequence of the sun being blocked the upper ocean layers start cooling (though slower than the surface on land). These colder layers increase in density and sink down, lifting up more nutrient-rich waters. Because of this deep ocean mixing some regions even experience an increase in NPP in a nuclear or volcanic winter despite the lack of radiation (blue areas in next image). The right graph displays the NPP of the Sargasso region (east of North America) where the deep ocean mixing supplies the region with nutrient rich waters for several years before normalizing (solid line depicts nuclear winter run and dotted line represents the control run).





2.2 Seaweed Growth Model

Ocean Surface Temperature, Salinity, PAR and Nutrient Levels are used to calculate the production rate of the seaweed species *Gracilaria tikvahiae*. The calculations show that growth rates of over 20% per day for the first 6 months can be achieved in several Large Marine Ecosystems (LMEs), allowing for quick scaling up. At these rates the global food demand can be covered by seaweed within 3-6 months, outcompeting all conventional high-yield crops like corn even in a nuclear winter. 160% of global food demand was chosen as the production limit to account for food waste and some animal feed.



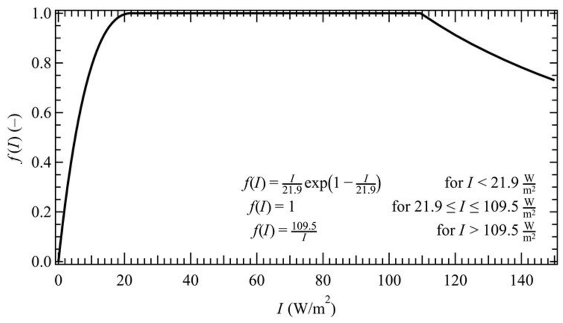
The impacts of the growth parameters on the production rate can be seen on the next page. One key aspect is the growth limitation depending on the incoming light. For this seaweed species, 20 W/m² is sufficient to reach maximum growth capabilities, which is approximately the lowest point in the 150 Tg model). This is the reason why various types of seaweed can be found flourishing several meters under the water surface and this makes them an ideal crop for low-sunlight scenarios like a volcanic or nuclear winter.

The density limitation shows the decrease in growth due to overshadowing. From this value the ideal harvest frequency is estimated and taken into labour considerations.

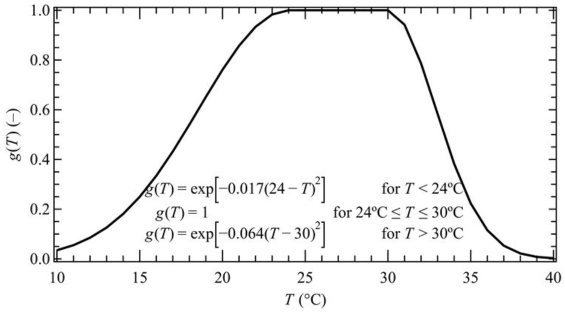
Production Rate

$$P = P_M * f(I) * g(T) * h(v) * i(S) * j(\rho)$$

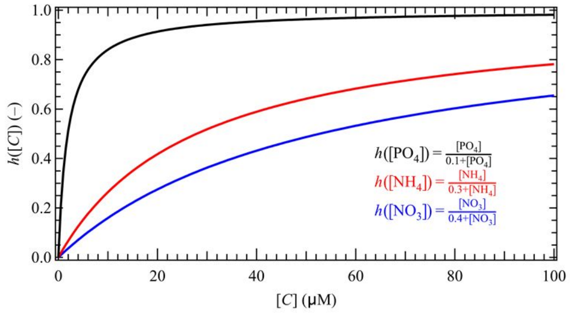
- P is the actual production rate (1/day)
- P_M is production (growth rate) under optimal conditions (1/day)
- $f(I)$ is the effect of non-optimal illumination $(0 \le f(I) \le 1)$
- $g(T)$ is the effect of non-optimal temperature $(0 \le g(T) \le 1)$
- $h(v)$ is the effect of non-optimal nutrients [e.g., P] $(0 \le h(v) \le 1)$
- $i(S)$ is the effect of non-optimal salinity $(0 \le i(S) \le 1)$
- $j(p)$ is the effect of self-shading due to increasing areal biomass density $(0 \le j(p) \le 1)$



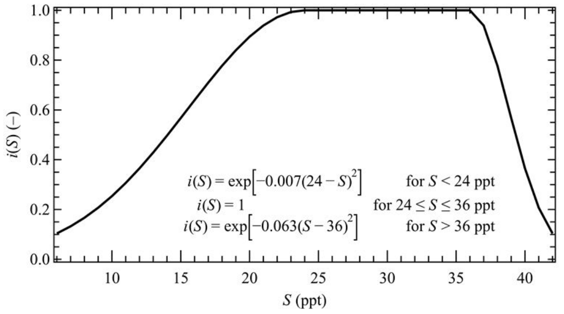
Light Limitation



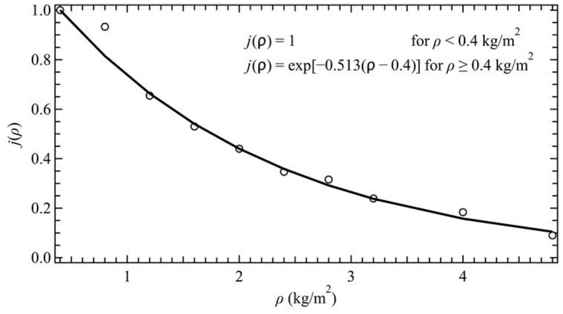
Temperature Limitation



Nutrient Limitation



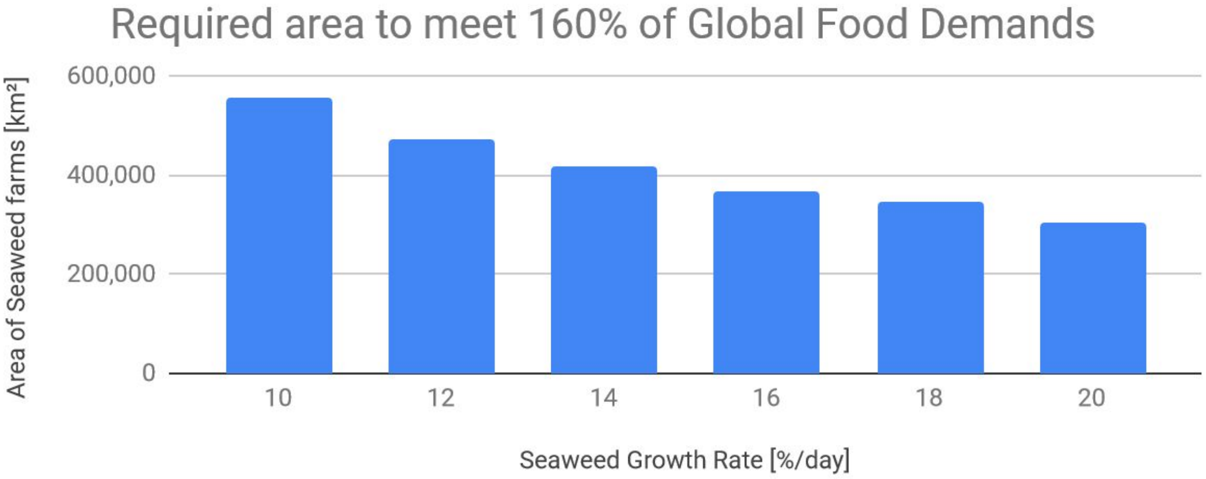
Salinity Limitation



Density Limitation

2.3 Geographical Information System (GIS)

Based on these growth rates the required areas of ocean surface can be estimated.



To calculate the suitable ocean area for these farms, a GIS analysis was done, with the limitations shown in the table below.

Area Limitation	Reasoning
Between latitudes 30°N and 30°S	Most promising Growth rates
46 km radius around harbors	Common range for economical aquaculture farming
2 km belt around coasts	Accessible area usable without port infrastructure
Less than 100 m water depth	Reduces the anchoring cost of the seaweed farms

The resulting ocean area spans over 1.9 million km², providing enough room to place the required 0.3 to 0.6 million km² of farms.

2.4 Industry scope

These seaweed farms' main components are ropes. To cover the area to meet global food demand, 6 to 12 million tonnes of rope need to be twisted and deployed. Current global production accounts for only 0.2 million tonnes of rope per year with the limiting factor being the twisting of synthetic fibers of which 66 million tonnes are produced globally each year. Since time is of the essence to prevent a global famine, rope twisting capacities need to be scaled up dramatically. To twist all of the synthetic fiber production ~320.000 twisting machines would be needed, thus increasing the rope production rate by a factor of 400. With increased demand and rapid tooling cost this requires ~$7 billion for the machines, an amount which is dwarfed by material and labour costs). This endeavour might seem tremendous but it would occur at a much smaller scale than the retrofitting of car manufacturers in World War 2 to produce planes instead.

3. Conclusion

The specific properties of seaweeds allow for rapid scaling up even in extreme scenarios like nuclear or volcanic winters. This is especially crucial for the long-term future of humanity to bridge the gap between a global agricultural collapse, after which we will rely on food storage which only lasts several months, and the switch to other alternative food sources that could take years to scale up.

Several assumptions have been made throughout this research project to achieve the holistic potential of seaweed. Please consider subscribing to the ALLFED newsletter to receive updates when the final and more detailed publications are online.

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Further questions?

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