Sketch of March 20, 2012, by Mark Capron, PODenergy, MarkCapron@PODenergy.net

Draft Outline of Marine Agronomy Article

Possible title: (the SciAm editors will select a title that sells magazines.)
Can We Save the Oceans and Sustain Humans?
Marine agronomy could save the oceans while sustaining 9 billion humans with the additional food and energy we will need by 2050.

What is our cover graphic? Or let the SciAm professionals decide on a cover graphic?

In Brief (At 140 words, this draft may be too long. The SciAm editors are likely to write the brief in any case.)

Current human approaches to produce food and energy will cause mass extinctions of sea life regardless of how many marine sanctuaries are created. The effects could double in intensity as the population increases from 7 billion to the forecasted peak of 9 billion in 2050. Marine Agronomy melds increasing knowledge of our oceans with concepts of terrestrial agriculture and forestry. It can reverse human impacts by managing the removal and recycling of plant nutrients to: 1) 30% more world food production with the excess plant nutrients from human activities; 2) Double world energy production with the excess plant nutrients expanding sustainable forests of macro-algae; and 3) Remove carbon dioxide from the air to reduce ocean acidification, warming, and sea level rise. Recognizing Marine Agronomy as an adaptation, mitigation, and ocean-benefiting development will improve national economies while increasing ocean primary productivity and biodiversity.
See spreadsheet, still being refined. Appears difficult to double food production with seaweed grown only with the current mass of human activity nitrogen. Better numbers appreciated. However, consider that we will put more nitrogen into the land-sea-land-sea cycle. Or dare we suggest adding seafloor nutrients to the mix in a draft not yet reviewed by potential co-author NGOs? Or is marine agronomy's production of fish so much more efficient we can double the protein for people a third more seaweed production?

Introduction

Human population will be peaking at about 9 billion people in 2050. Our human need to alleviate hunger and poverty suggests we will strive to double food and energy production in spite of the consequences to our environment. Oceans are particularly at risk from an excess of plant nutrients and increasing greenhouse gases. Excess plant nutrients overwhelm natural systems, causing dead zones where the dissolved oxygen is depleted by decaying plants. Increased atmospheric carbon dioxide concentrations cause ocean acidification, which prevents many creatures from building their protective shells. It also warms the ocean, killing coral and causing mass migrations of species. The excess of plant nutrients comes from artificial agricultural fertilizers, inadequately treated or recycled municipal and livestock wastewater, and burning fuels. The carbon dioxide comes from burning fossil fuels.

Oceans cover almost three times as much area as does land. Ocean surfaces receive almost three times as much sunlight as does land. However, most of the ocean surface is a nutrient desert, thwarting or delaying the natural result of solar energy powering a cycle where life creates the conditions for more life. There are no wastes. The wastes of animals and fish are the nutrients for plants. The waste of plant photosynthesis is the oxygen we breathe. The waste of microbes digesting biomass becomes carbon dioxide and other nutrients for plants, or energy in the form of methane.

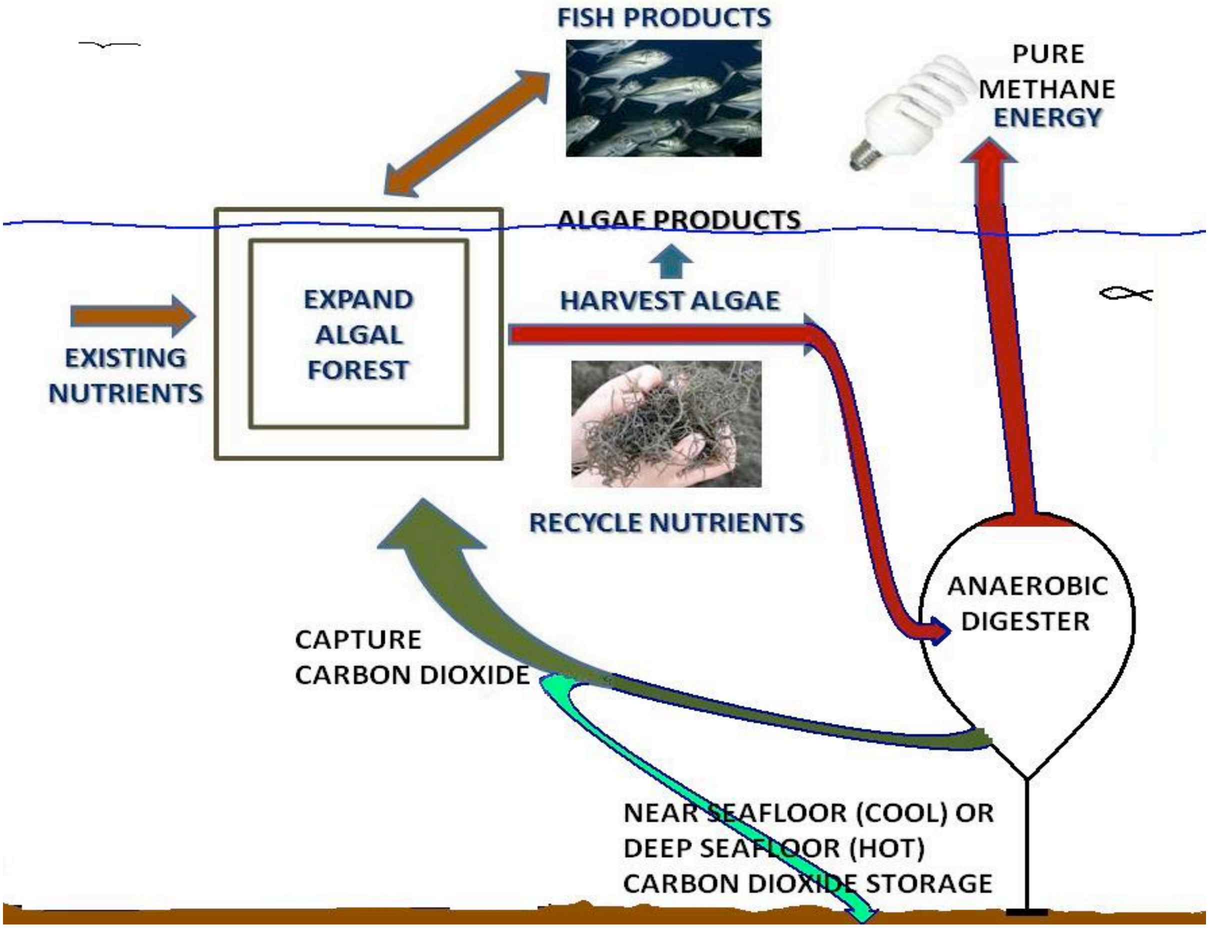
Problems result from unbalanced or rapidly changing nutrients. Excess nutrients from human activities flow into rivers, lakes, and oceans to cause microalgae blooms. When the algae die and sink, microbes deplete all the oxygen on the floor of the water body, creating a "dead zone." Burning the energy from long-dead microbes and plants (in methane, oil, and coal) causes a sudden increase in atmospheric carbon dioxide concentrations, which destabilizes climate.

The oceans can be saved by balancing the nutrients to create more life.

"More to Explore" articles related to the introduction:
Jonathan A. Foley, Scientific American, November 2011
US Marine Biomass Program, Duarte (2009) and others.

We should have a world map with dead zones and possible marine agronomy production areas. Our numbers about dead zone size and marine agronomy production might be in that graphic and not in the text.

The Marine Agronomy Ecosystem



This figure shows how existing nutrients in the ocean can grow a macroalgae forest, part of which nurtures fish while part is harvested for production of energy from biomethane. The nutrients remaining after anaerobic digestion are recycled to expand the algal forest. The gas produced in the digester is about 60% biomethane and 40% carbon dioxide. The carbon dioxide could be stored in or on the ocean floor to reverse climate change.

Note: SciAm articles do not use figure numbers or otherwise identify the graphics. The graphics are like "sidebars." Incidentally, I believe we should leave more technical terms such as "nutrient bio-extraction" or "Integrated Multi-Trophic Aquaculture" for our "more to explore" articles.

Humans have created sufficient excess plant nutrients in the ocean to double global food production by growing macroalgae and fish. We can eat the seaweed directly. In addition, we can leverage the excess nutrients to make more and higher value food with a loop of plant nutrients to fish nutrients to plant nutrients to fish nutrients …. Within this loop, fish are eating some seaweed products and the seaweed are growing on the fish wastes. Outside the loop, excess plant nutrients are leaving the water as sea vegetables and other algal by-products like carrageenan, plant-based animal feeds, fish-based animal feeds, and fish for human consumption.

We need a "sidebar" or a "more to explore" to explain the units and the numbers. For example: How to convert from tons of fertilizer to -N.

Comparing cereal or vegetable reported harvest weight with seaweed reported harvest weight….

During 2010, ___ tons of fertilizers from human activities flowed into the world's oceans creating 200,000?? hectares of ocean dead zones. The fertilizers are mostly inorganic nitrogen and phosphorus compounds. Marine agronomy would absorb the excess nutrients while producing ___ tons of sea plant foods. If we leverage the excess nutrients with the plant-fish-plant-fish nutrient loop, the excess nutrients can produce ___ tons of sea plant foods and ___ tons of fish foods. The ocean surface area needed to double food production is about ____ square kilometres, ____% of ocean surface, or nearly the same as the 200,000?? square kilometres of seasonal dead zones.

We need to find referenced numbers for the spreadsheet to ensure our calculations are reasonable. Also, we must ensure the comparison is apples to apples. When marine agronomists report "dry" weight, they mean desiccated. I suspect terrestrial foods are reported as what we would consider "wet" weight. Consider 700 million tons of milk could not be a dry weight. That wet-dry reporting difference is larger than a factor of ten.

Each year humans produce about 7,500 million metric tons of food, almost all from farms on 24% of our terrestrial habitat.[1] Our ocean harvest is about 85 million tons from capture fishing and 36 million tons from marine aquaculture.

The ocean biomass needed to meet humans' demand for energy is about 100 times greater than to meet our food requirements. It cannot rely on excess nutrients, and it does not need to. The larger seaweed energy forests are sustained by recycling the plant nutrients from the energy conversion processes. The energy conversion can be as simple as microbial anaerobic digestion to produce methane or as complex as microbial ethanol production. Either will separate the energy (carbon and hydrogen molecules) from the plant nutrients (nitrogen, phosphorus, iron, etc.). An energy production operation has two sub-loops running: plants-to-fish-to-plants and plants-to-energy-to-plants. Again, the sun shining into the water is the original source of energy.

Include an energy calculation: Harvest 20 dry weight tons per hectare per year of macro-algae (whatever is available at the specific location). Produce about 50 MWh per hectare per year of methane or liquid fuel. World used about 12 x 10^{10} MWh from fossil fuels in 2010. So need 2.4 x 10^{9} hectares of marine agronomy to produce 100% of 2010 energy demand. Ocean surface is 3.6 x 10^{10} hectare. So 7% of world's ocean will produce 100% of demand. This energy would all be carbon neutral, so it would stop adding CO_2 to the atmosphere. In addition, if 10% of the macro-algae production is diverted to food for people and increasing ocean biodiversity, that would produce 20 wet tons per hectare per year or 4.8 x10^{10} wet tons, about 5 wet tons of food per person per year for 10 billion people. Ideally, numbers will be a graphic or a sidebar with truckloads or other ways people can relate.

---

[1] Millennium Ecosystem Assessment, 2005 (SciAm won't use footnotes, but they are useful in drafts.)

Energy from marine agronomy could be produced on a globally significant scale. Perhaps 7% of the world's ocean surface could produce 100% of the world's 2010 energy demand. The large scale energy conversion process must be robust, accepting of any biomass while requiring little energy for growing, harvesting, processing, and recycling the nutrients. A robust process does not require a mono-culture and can tolerate or even be more economic with multiple products, "volunteer" seeding, and "loose" harvesting. That is: energy production from marine agronomy will increase ocean primary productivity and can be designed to increase ocean biodiversity.

Even if we are not burning fossil fuels in 2050, our current trajectory will leave us with too much atmospheric carbon dioxide dissolving into the ocean and continued warming. Marine Agronomy provides the opportunity at relatively small incremental cost to reduce atmospheric carbon dioxide concentrations.

When the energy conversion process is anaerobic digestion, it produces biologic carbon dioxide directly. Biogas is generally 60% methane and 40% carbon dioxide. The two gases are easily separated and the carbon dioxide can be permanently and safely stored (see more to explore for details).

Some of the following three paragraphs might move to "move to explore," particularly if we can find or we make a good reference.

The oil industry routinely uses membrane separation of the methane and carbon dioxide. We can use membranes or locate the digester a few hundred meters deep and employ differential dissolution. At depth, relatively little methane dissolves, so the gas output is 90% methane. Most carbon dioxide remains in solution until it bubbles out when the nutrients are returned to the ocean surface. We capture the 90% carbon dioxide bubbles. Compress that gas to 50 bar (pressure equivalent to 500 meters depth). Cool the compressed gas below 8°C, a typical temperature for that ocean depth and recover the methane as the carbon dioxide condenses to liquid.

Another way to reduce global carbon dioxide concentrations even more rapidly is to capture the exhaust from the biofuel combustion as it is producing electricity. Carbon dioxide exhaust capture technology is well demonstrated.

The carbon dioxide captured in either way can be permanently and safely stored in any manner appropriate for the local geography, hydrology, and geography.

Perhaps we ask the NGO's how we can fit more perspectives into the actual article while retaining their support: Marine Agronomy as Climate Change Adaptation for the Developing Country islands and coastlines (aka Small Islands Ocean Afforestation Initiative), business (if Marine Agronomy cannot create jobs or pay for itself, it will not be sustainable and jellyfish will inherit the oceans), future generations out to 2200 (Is Marine Agronomy a good "hump" technology for scaling back after 2050?)

Summary

Therefore, it seems possible to produce all or most of the additional food we need by managing the nutrients on less than ____ percent of the oceans' surface. This would use no freshwater, lack of which Foley highlights as a constraint to further growth in agriculture. It would use nutrients that are presently wasted and which cause nuisance blooms and dead zones in the world's coastal waters. No more terrestrial wilderness would need to be converted into croplands and the ocean plantations that would take their place would help to reduce ocean acidification by removing carbon dioxide while creating new habitat for marine life. Further, there is potential to reach beyond the production of food to consider biofuels and long-term carbon storage.

Marine Agronomy is on a steep learning curve, at about where terrestrial agriculture was 200 years ago. We could condense the experience of 200 years into 20 years with a smaller investment than one modern weapons system.

We need to request (or demand?) some action! But what action? SciAm obviously liked Foley's suggestion for rating foods on how they are produced, a form of LEED rating for foods. See model publication below.

Model publication: Can we feed the world & Sustain the Planet?
Jonathan A. Foley, Scientific American, November 2011

Model introduction: 1 billion chronic hunger. 2 or 3 billion more by 2050. Rising incomes. Land use. Three challenges: 1) Feed all 7 billion, 2) double food production, 3) become sustainable.

Model Barriers: No more land. Crop yields not increasing enough. Meat consumption is increasing. Agriculture's environment damage. Freshwater use and contamination. Flows of nitrogen and phosphorus cause dead zones. GHG emissions.

Model Solutions:

1) **Stop deforestation.** Use Deforestation and Degradation mechanism where rich nations pay tropical nations to protect forests.
2) **Close the "yield gap."** Mostly bring better seeds, fertilizer, and irrigation to the low producing farms in Africa, Central America, and Eastern Europe. Also, more reduced tillage, cover crops, and leave residues to decompose.
3) **Apply water and fertilizer more efficiently**. Drip irrigation in dry areas. Use less fertilizer in China, northern India, central U.S., and western Europe. Also, reduced tillage, precision agriculture, and organic farming.
4) **Shift diets away from meat**. At least away from grain-fed beef.
5) **Reduce food waste**. Rich countries waste at the consumer end. Poor countries have crop failures, pests, and delivery issues.

Model Summary: Networked food system. Silver buckshot, not silver bullet. Agriculture needs the equivalent of Leadership in Energy and Environmental Design (LEED) program. That is foods are awarded "points" based on nutrition, security, and environmental impacts. Read the LEED-Ag rating of food with your smart phone.

Model graphics:

a) The cover graphic is a full page apple with skin picked off to form a globe with Americas, Africa, and Europe as the remaining skin.
b) World map showing Type of Agriculture and Yield of Maize Farmland.
c) Area-related indications of Status Quo and Goal for red-Food Access, blue-Food Production, yellow-Environmental Damage.

Thoughts on why SciAm published the model article. What we need to imitate:

1. It asks a global question and gives a global answer. It isn't just one crop, one country, one industry. It is a question and an answer for all 7 billion.
2. It is a "Reader's Digest" of the science and includes five documents in "More to Explore." Do not include all facts and concepts, only the 3-5 of each most important.

3. It has a cool solution – the LEED-Ag. We can suggest this be broader: LEED-Food and LEED-Fuel.
4. It looks like good info to guide the United Nations Millennium Development Goals.
5. The text and two graphics cover four pages, an additional two pages are devoted to the title cover picture. Eliminate excess words.