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Saline Agriculture to Address the Climate, Food, Water, Ecosystem and Econometrics U.N. SDG Issues

Dennis M Bushnell*

Chief Scientist & Independent Researcher, NASA [Retired], USA

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***Corresponding author:** Dennis M. Bushnell, Chief Scientist & Independent Researcher, NASA [Retired], 228 North First Street, Hampton, VA, 23664, USA, Email ID: dennisb557@gmail.com

Abstract

The U.N. SDG societal issues of climate, population, ecosystem, water and energy are increasingly altering agriculture in real time. These alterations are in the context of the extant, limited capacity, fresh water agriculture. However, as these societal issues become more severe, both with respect to capacity and cost, there is a major available alternative - the huge capacities and profitable opportunities provided by saline water agriculture and halophytes. This paper summarizes the major saline agriculture opportunities to profitably address land, fresh water, food, energy, climate and ecosystem issues at scale. Overall, halophytes are a critical portion of the frontiers of the responsibly imaginable for agriculture going forward. Saline agriculture can address the increasing scarcity and increased costs of fresh water/ arable land, population growth, and the adverse climate and ecosystem impacts of freshwater agriculture. Saline Agriculture could reduce costs, increase profits, increase available fresh water, provide huge increases in food and fodder production and seriously mitigate climate.

Keywords: Climate; Population; Ecosystem; Water; Energy; Ecosystem impacts; Freshwater agriculture; Green-house emissions, Temperature; Land conversion and erosion

Introduction

The U.N. SDG societal issues of climate, population, ecosystem, water and energy [1] are increasingly altering agriculture in real time. Agriculture is considered the worlds' largest industry [2], using some half of the habitable land for crop production and pasturage [3]. Agriculture provides food, fuel, fiber and animal feed. Currently, this basic industry that literally feeds the world is beset by increasingly serious issues. Current agriculture is freshwater agriculture. Its' issues include the increasing impacts of climate [droughts, extreme weather, flooding, green-house emissions, temperature increases], an increasing population to feed, land conversion and erosion, ecosystem impacts [pests, fertilizer runoff, pollution] and cost increases across the board [4]. The overall effects of these and other issues have resulted in nearly a billion people lacking sufficient food [5]. The bottom line wrt freshwater agriculture appears to be that, going forward, to successfully feed the world the basic requirements are cost reductions/ increases in profits, serious increases in capacity, which requires both additional arable land and fresh water, and, considering the increasingly dire climate situation, climate/ ecosystem mitigation. Unfortunately, appreciable amounts of additional arable land and fresh water are not available. Fresh water agriculture already utilizes some 70% of the planet's available fresh water [7], which is running short for other uses and is only a very small percentage of the planet's total water. Some 97% of the planets water is saline ground water and salt water in the oceans, sea and salt lakes.

Fortunately for humanity, there is a "food and water 2.0", agriculture, a readily available massive capacity adjunct to freshwater agriculture – saline agriculture. There are halophytes, salt plants, some 6,000 plants that can grow on deserts and wastelands [the dry lands] using saline water and many of these are food plants, usable for food and fodder, along with providing essentially all other plant functionalities. Saline agriculture could utilize the some 44% of the land that is dry lands, and the 97% of the water that is saline, seawater, a truly major overall capacity increase in agriculture. Overall, cheap land and cheap water. In addition to food and forage production, huge additional biomass production using these currently barely used resources proffers low cost, major capacity bio/ SAF fuels and chemical feed stocks. Also, halophytes sequester some 18% of their CO_2 uptake in their deep desert roots, at scale sequestering some 4 gigatons of CO_2. Overall, this agriculture 2.0 would provide huge increases in productive land, free up to the some 70% of the fresh water now used for freshwater agriculture for direct human use, produce all the food needed going forward for centuries, provide low-cost biofuel energy in quantity and serious CO_2 sequestration from the atmosphere. In the process Saline Agriculture will reduce costs, increase profits, increase available fresh water, provide huge increases in food and fodder production and seriously mitigate climate [7-33]. Halophytes would also reduce pollution. as ocean water contains some 80% of the nutrients plants need, including trace minerals we have depleted from arable land over the years [34]. That is, halophytes seriously address the current major issues associated with freshwater agriculture.

Fresh Water Agriculture Issues

The overall health of freshwater agriculture is not robust. It is contributing much to climate change [including some 26% of green-house emissions] and ecosystem issues and is directly impacted by climate in terms of droughts and more extreme storms which contribute to erosion and higher temperatures which decrease yield [4,35]. Arable land has reduced some 33% in extent since 1961 due to land conversion and erosion. There have been increases in nonfood agriculture demands for such as biofuels and chemical feed stocks. Land costs have increased much. There is an increased need for food due to population increases, including increases due to substantive advances in life expectancy. Close to a billion people suffer from hunger. Due to long term ground water withdrawal, the water table has fallen appreciably in many areas, including very productive regions and rainfall changes have put at risk some dry land farming. The increased use of agricultural chemicals, herbicides, pesticides and fertilizers have caused extensive pollution including runoff into rivers, streams and ground water. Aquifers becoming salinated, causing increasing irrigated arable land salination. Mitigations for these freshwater agriculture issues include regenerative agricultural practices to increase the richness of the soil, and developments in vertical farming, along with increasing robotics to improve efficiency and reduce costs. There does not appear to be a way to seriously solve most of the increasingly serious freshwater issues going forward at scale. The biology revolution writ large has, and probably will going forward increase yields, and possibly enable nitrogen uptake from the atmosphere, but serious increases in capacity for freshwater agriculture going forward are problematic. However, there is a possibility, as the cost of energy continues to decrease due to development of renewables and the new nuclear weak force nuclear batteries with no radiation [36], that desalination might become inexpensive enough to be used for agriculture. Overall, Apparently, there may be a need going forward, strengthened by the negative trends in climate, ecosystem, freshwater availability and land use, to augment at scale and perhaps eventually mostly replace freshwater agriculture.

There are two major freshwater agriculture augmentation-to-replacement solution spaces that scale for requisite capacity and are low cost. One is a compendium of industrial/laboratory foods, insects, fungi and dark foods, foods not produced by photosynthesis. The other, with truly massive capacity with first order impacts upon land, water, food, energy, climate, the ecosystem and profitability is Halophytes.

The Major-to-Massive Alternative, Saline Agriculture / Halophytes

Per references 7 to 32, halophytes are plants that grow on deserts and wastelands [dry lands] using saline and seawater. There are some 6,000 varieties, covering the spectrum of most freshwater plant functionalization with many being food plants. As an example of their usefulness, growing halophytes on a goodly portion of the Sahara could provide sufficient biomass/ biofuels to replace fossil carbon fuels with almost 90% less net CO_2 emissions, provide chemical feedstock and requisite food, while returning much of the 70% of the freshwater now used for conventional agriculture to direct human use. As an example, the Sahara has sizable saline aquifers, including the Nubian aquifer in the eastern Sahara. Then there is the Atlantic Ocean to tap, along with the Mediterranean and the Red Sea, depending upon locality. Deserts, wastelands are typically sunny, so there is inexpensive solar energy to pump saline water, and the halophyte biomass provides chemical feedstock to manufacture requisite piping. Dryland [deserts, wastelands] real estate is typically inexpensive. Some 22 nations, several with saline agriculture/ halophyte research institutes, have conducted halophyte studies. There has long been a halophyte agriculture in coastal India for food and fodder. Saline irrigation in dry lands regions typically produces an unstable atmosphere and freshwater rain downwind. Saline agriculture farming does not require new technology, but does need additional saline/salt water, some 30% additional is necessary to flush the salt down into the sandy soils. As stated, seawater contains some 80% of minerals plants need, therefore less added fertilizer/ consequent pollution. Also, there is research to enable plants other than alfalfa etc. to extract/ utilize nitrogen from the air. The 85% less CO_2 emissions solution to aircraft climate emissions utilizes biofuels, SAF fuels. Producing the requisite biomass for these biofuels by saline agriculture would reduce their cost and increase their availability. Halophytes can have yields equal to Glycophytes, freshwater plants. Halophytes cover the plant product spectrum, seeds, fruits, roots, tubers, grains, foliage, "wood," oils, berries, gums, resins, pulp and some are rich in energy, protein, and fats. Halophyte utilization includes food, fodder, biomass/energy, chemical feedstock, wood, landscaping, ornamentals, CO_2 sequestration, land desalinization and wildlife habitat. Major areas especially suited for Halophyte cultivation include Western Australia, around the Arabian Sea/ Persian Gulf, the Middle East, the Sahara, the Southwest U.S. including West Texas, Atacama in South America and others

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worldwide. There is a long literature explicating and extoling the opportunities of saline agriculture. Until recently, much of this research was focused upon using halophytes to desalinate salinated land and for food and fodder. More recently there has been increasing interest in the climate and energy mitigation attributes of halophytes. However, switching to saline / halophyte agriculture engenders similar econometric issues that renewable energy faced when trying to compete with fossil carbon-based energy, the existing major energy industry. In the case of renewables, not much happened until their costs fell below fossil fuel energy, since then renewables have grown massively, and their costs have/are reducing much more. Profits, vice just climate or other major societal drivers are apparently necessary to create serious changes in major industries such as freshwater agriculture. Halophytes should, using cheap land and water and with their large-to-huge capacity along with their many and major climate and ecosystem mitigation actions be adopted going forward as the many and serious fresh water and arable land and cost issues become more dire. Major portions of the population lack adequate food and fresh water now. The current state of saline agriculture is many decades of scientific studies, field trials and increasing utilization. Quinola is a halophyte as an example. What is needed to seriously develop saline agriculture is markets, seed availability, cultivation protocols, and scientific optimization.

Water and Dry/Salinated Lands Impacts of Saline Agriculture

Even before Climate change impacts became apparent there were increasing issues with freshwater scarcity, irrigated land salinization and emerging food shortages. Climate change is exacerbating these and adding additional issues. The scale of all these issues is immense, vast resources are required to address them in a meaningful fashion. As stated, two planetary resources that are nearly unutilized and at the scale of climate are saline/ seawater, some 97% of the water and deserts, wastelands, some 40% of the landmass. Providentially, there is a very sizable, some 6,000 varieties of plants, halophytes, salt plants, that can, uniquely, at scale, both greatly increase the value of deserts and wastelands and produce major solution spaces for societal issues. Some 1 billion Ha is already affected by salt, including some 20% of arable land [37]. As we continue to irrigate with increasingly saline aquifers, the percentage of salinated arable land will increase. For decades, research articles [7-33] have considered the benefits and capabilities of halophytes to address the increasing shortages of fresh water and food. However, switching from freshwater agriculture to saline AG at the planetary scale of the current freshwater agriculture is a major shift, of the same scale as the ongoing shift from fossil fuels to renewables. Soils suitable for saline agriculture include sandy soils and porous loam, which thus far over decades of experiments has less surface salt buildup. Less porous soils including clay which could produce salt buildup would require periodic salt harvesting for the minerals contained in saline/seawater. Ocean residue is harvested for such now. The arid lands so called drylands, deserts, wastelands are a major, at the scale of climate, largely unused planetary resource.

Water on planet Earth is some 97% saline/ salt water and some 3% fresh water. Of the fresh water, most is tied up in ice caps, glaciers, permafrost, the great lakes and lake Baikal and underground [38]. Currently, some 2 billion of the human population lacks access to safe drinking water. Some half of the human population have safe drinking water access issues for only part of the year [39]. Major reasons for these shortages include population increases, pollution, lack of updated water infrastructures, water use inefficiencies, and climate impacts, both droughts and evaporation. Overall, some 70% of the fresh water goes to agriculture, and some 15% each goes to industry and households. There are nearly a million deaths each year attributable to unsafe water access. As we have extracted ever more water from nominally freshwater aquifers they are becoming more saline, resulting in salinization of increasing percentages of arable land. "Conventional" Solutions to these freshwater issues include water efficiency/ conservation, water recycling, pricing and desalinization. One effect of climate change is increased evaporation. Solar PV panels are a major renewable energy approach and to decrease evaporation there are efforts to position them over open water. There are genomic and bioengineering efforts to reduce plant water use. Regreening land increases water retention, reducing flooding and water runoff into saline oceans. Overall, the need for fresh water "solutions" and their costs are rapidly increasing. One suggestion for water "get-well is to "transform agriculture". Replacing freshwater agriculture with saline, saltwater agriculture on deserts and wastelands using halophytes for food, fodder and most other utilizations of fresh water Ag products, an agriculture "transformation".

Reference [40] provides a superb overview of the earths' dry lands. Lands whose productivity is low due to lack of fresh water and low soil nutrients along with often poor water holding capability. Much of these lands are salt affected, salinated. Along with imbedded regions that could support biosaline agriculture some of these lands are snow covered, glacial covered, rocky, mountainous, eroded valleys and there are clay soils. Barren areas such as degraded forests and overgrazed pastures are included in potential biosaline agriculture regions. There are two ways of dealing with long term saline/ seawater irrigation with respect to residual salt. The best way is to utilize sandy soils and high porosity loams where an additional some 35% of irrigation water, from experience, allows the salt to percolate deep into the soil. Some decades of saline ag experiments indicate little appreciable salt buildup in sandy soils using this approach. The other possibility, for less porous soils where salt buildup can occur, is to periodically collect, mine the salt for minerals etc. In addition to these dry lands for halophyte agriculture there are sizable regions of fresh water irrigated land that is already and increasingly salinated

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which could be converted to bio-saline agriculture. Climate is on a massive scale, as are the increasing drought/fresh water/food issues. Saline/ salt water and dry lands are the last planetary resources that are not fully exploited and at the scale of the freshwater and climate issues. Society is extraordinarily fortunate that these resources are available with the happenstance of the richness of halophyte plants to develop, utilize these resources. Many of these dry land areas are on seacoasts. It is now possible to economically pump water over very long distances, instantiations of such are present in Africa. The maturation and cost reductions of solar energy greatly reduces the energy costs for long distance irrigation using saline aquifers or seawater. The costs of a Ha in the dry lands areas are lower than a Ha in developed arable lands used for fresh water agriculture.

Climate/Ecosystem Impacts of Saline Agriculture

Climate issues, due primarily to the increasing use of fossil fuels to power the industrial age and later, producing and emitting CO_2 into the atmosphere, are an acknowledged existential human societal threat [41]. Climate impacts include increasingly serious temperature rise, floods, droughts, storms, disease, sea level rise, species extinction, ocean acidification and ocean thermohaline circulation reduction, all occurring now with increasing severity. The ocean thermohaline circulators are slowing rapidly now with projection for effects even in the nearer term. Projected world costs of climate are $38T/yr. by 2050 [42]. Human activities also increased atmosphere aerosols, which have significantly reduced climate impacts due to CO_2 and methane emissions thus far, but we are cleaning up the air now. The climate impacts of aerosols that reflect and block the sun are similar in magnitude to CO_2 but opposite in sign. There are many positive climate-feedback, climate changes that make further climate change much more impactful. These are not yet all fully incorporated into the climate projections and include CO_2 and methane emissions from the warming tundra and oceans, the increasing acidity of the oceans from CO_2 adsorption, reducing CO_2 Ocean uptake and increased evaporation which is increasing atmospheric water content. The major climate impacts that create the unique, at scale, value of the halophytes/wastelands and desert /saline and saltwater nexus for climate mitigation include temperature increase, droughts, and sea level rise, all of which will adversely affect fresh water availability and efficacy of fresh water agriculture. In spite of disparate efforts thus far to mitigate climate change, it is becoming ever more serious. The projections now call for the need to not just stop CO_2 emissions, it is also necessary now to remove CO_2 from the atmosphere and increase the planets albedo. Furthermore, doing so needs to be profitable at the huge scale of climate change. Several Climate mitigation approaches which have been suggested have potentially serious issues including the possibilities of major adverse, unintended effects. These include cost, scale and adverse effects for some geo-engineering approaches, major cost, latency, scale and waste issues for fission and fusion nuclear, and cost, scale and leakage for non-bio-CO_2 sequestration.

Saline agriculture posits major climate mitigations, at scale and profitable, including sequestration of up to 4 gigatons of CO_2 in their deep desert roots, massive capacity production of lower cost biofuels, biomass to replace petroleum for chemical feed stock and reduced fertilizer use/ runoff.

Synopsis of Feasible Saline Agriculture Econometrics

a) Greatly increased agricultural capacity [far greater agricultural land area and water availability].

b) Lower land costs.

c) Greatly increased and stable agricultural water capacity [obviating effects of droughts and lowering the water table].

d) Sequestration, at scale, of some 4 gigatons of CO_2 from the atmosphere, reducing the huge and increasing costs of climate change.

e) Major capacity increase at lower cost for biomass to replace petroleum for chemical feed stocks.

f) Major capacity to produce lower cost biofuels for transportation.

g) Release of up to 70% of the available fresh water for direct human use, reduced health costs.

h) Reduced food costs.

i) Reduced Fertilizer costs [seawater contains 80% of the Minerals plants need].

j) Less chemical runoff, reduced ecosystem impacts.

k) Reclaiming and using assets stranded due to degraded irrigation areas, roads, canals, housing etc.

Conclusion

There are many increasingly dire and expensive-to-seriously-mitigate issues associated with conventional freshwater agriculture. Freshwater agriculture is both adversely effected by and contributes to climate and ecosystem issues. The scale of the requisite agricultural "get wells" is large and accordingly requires at scale mitigations. Experience with the adoption of renewable energy indicates these at scale mitigations need to be profitable to be adopted at scale in a timely fashion. An available profitable mitigation approach for freshwater agriculture going forward that is at scale and profitable is saline agriculture using halophytes, the 97% of the water that is saline/ seawater and the some 44% of the lands that are deserts, wastelands, plus land already salinated. There is a long list of feasible econometric and other benefits of saline agriculture including massive capacity to alleviate hunger, make available vast amounts of biofuels/ biomass, solve freshwater issues, provide CO_2 sequestration at scale, and alleviate some ecosystem issues. Saline agriculture has the capacity to, literally, green the planet. Halophyte varieties mimic the functionalities of freshwater plants. The increasing need to

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seriously include saline agriculture in the agriculture mix going forward is becoming obvious, much greater and more affordable agricultural capacity is essential to meet projected further needs and solve current shortfalls. Current agricultural mitigations are not at scale are mainly palliative vice curative. Saline agriculture can be curative and affordable-to-profitable, using/ enabled by massive hither-to unexploited planetary resources.

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