Institute on Science for Global Policy

Aquatic Plants for Sustainable Food and Protein Production: Implications for Global Food Security**

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Summary: As the 21st century global population expands toward 9 billion people and the demand for higher quality, protein-rich diets increases, a revolution in agriculture is needed to meet food requirements in an environmentally sustainable manner.

Crop diversification efforts that deliver increased biomass and/or protein yields with reduced environmental costs are slow to evolve. Promising, non-conventional crops and protein sources (e.g., algae and aquatic plants) occupy niche markets in nutritional supplements and animal feed but have yet to materialize as disruptive players in the protein sector. Recently, water lentils (i.e., aquatic plants in the duckweed family) have become a focus of commercial farming operations for protein-rich foods. Scientifically credible opportunities exist with water lentils, including: (i) "sustainable intensification"; (ii) obtaining high-quality, plant-derived proteins; (iii) expanding use of non-arable land; and (iv) crop production intrinsically resistant to disease and natural and/or man-made disasters.

Evidence from early-stage commercial water lentil farms indicates large-scale production of a sustainable, aquatic, plant-based protein is a real-world option. Challenges to widespread adoption of this alternative crop include customer acceptance and a lack of clarity and synchrony in the regulatory environment. Promoting novel protein crops such as water lentils can be part of a broader strategy to address the intersection of exploding global food and protein demand and environmental sustainability.

Current realities: The world's food needs are projected to nearly double by 2050, as global demand for environmentally costly high-protein diets (e.g., animal proteins) continues to increase. These negative externalities increase the probability of catastrophic food crises due to crop failures from natural disasters and/or diseases as well as man-made disruptions, including geopolitical tensions and agroterrorism.

Scientific strategies exist to increase traditional crop yields and reduce environmental footprints. Innovation in traditional crops, particularly in areas such as genetic modification and advanced breeding programs, has produced gains in crop yield per unit area and improved resistance to pests and pathogens. While such improvements in traditional crops form a critical component of addressing 21st century food requirements, the current reality suggests an urgent need for agricultural diversification with novel crops and protein sources to meet the world's food demands without increasing global environmental degradation. Not surprisingly, this diversification is consistent with the United Nations' Food and Agriculture Organisation conclusion that increasing biodiversity in the food and agriculture sector is a key element in global food security and sustainable development.

Key requirements of a sustainable, novel crop include: (i) providing balanced, high-quality nutrition; (ii) increasing crop productivity and yields so more crop/protein can be obtained per unit area; (iii) more effectively utilizing marginal or traditionally non-arable lands; (iv) reducing the environmental costs associated with crop production (e.g., soil erosion, nutrient runoff, land usage); and (v) ensuring improved resistance to disasters and disease.

There are diversification approaches using novel terrestrial crops that show promise for meeting these requirements. These include *de novo* domestication of perennial crops to enable superior crop productivity and increased environmental sustainability. A promising complement to diversifying terrestrial crops involves the farming of aquatic plants, such as water lentils, which represent some of the most productive and ubiquitous plants on the planet. Indeed, the potential of water lentils to produce vitamin-rich, high-protein foods has been recognized and studied in academic and government circles for decades. More recently, commercial-scale farming of water lentils has become a focus of private sector start-up companies.

Scientifically credible approaches and challenges: Can aquatic plants, such as water lentils, contribute to solving the challenges of 21st century food security by producing nutritious, protein-rich foods, while mitigating collateral environmental degradation associated with traditional crops?

Farming of water lentils represents a true paradigm shift in crop and protein production since it involves the growth of an aquatic plant that primarily reproduces clonally (i.e., a "mother" plant buds off "daughter" plants). This mechanism of reproduction results in near-logarithmic growth rates and a doubling of crop mass in as little as 24 to 48 hours, thereby allowing the daily harvest of a significant proportion of the floating crop (i.e., about 25%). These explosive growth rates, coupled with the nutritional profile of the plant, are at the core of water lentils' potential as a transformative and sustainable crop.

Water lentils are currently the focus of several private sector enterprises, including a commercial-scale duckweed farm in Florida (Figure 1, more than 50 acres) which provides real-world validation of the opportunities and risks associated with commercial production. Attributes of water lentils that make it an attractive novel crop, as it pertains to human nutrition, environmental sustainability, food security, and reduced environmental impacts, include:

- Nutritious and rich in protein, vitamins, minerals, and omega-3 oils;
- Highly digestible protein, containing a high percentage of essential and branched-chain amino acids (Protein digestibility-corrected amino acid score ≥ 0.90) with the capacity to exceed 40% of the plant mass;
- High areal protein productivities that are an order of magnitude (i.e., 10-fold) or greater than traditional plant protein crops (e.g., soy);
- Expanded availability for food production on marginal and/or non-arable lands, obviating competition with prime farmlands and/or biodiverse habitats;
- Amenable to "lined" growth systems that retain nutrients and prevent runoff pollution;
- Enables "sustainable intensification" (i.e., the production of more food per unit area while decreasing negative environmental impacts);
- Resilient to shock, as crop can recover from natural or man-made disasters on a time scale of weeks (i.e., restarting and repopulating ponds in several weeks);
- Intrinsic resistance to pests, greatly minimizing the use of pesticides and herbicides.

Real-world experience with water lentil farming confirms the rapid recoverability of these crops from natural disasters (e.g., water lentil crops recovered within two weeks to full protein productivity from the approximate 90% crop-loss caused by Hurricane Irma in Florida). In addition, water lentil crops nearly eliminated run-off and pesticide use.

As with other more traditional crops, we expect challenges associated with expanding and optimizing production of novel crops, such as water lentils, that will require continued research, development, innovation, and investment. Perhaps as challenging as the technical risks are the difficulties presented by the lack of clarity and synchrony in the global regulatory environment as it relates to novel foods, as well as a subsidy environment that favors traditional crops and large

producers. In addition, customer perception and public acceptance of novel foods presents a barrier to their widespread market penetration.

Evidence-based options and real-world opportunities: Recognition of the remarkable value of water lentils as a food source, in addition to a wide range of additional environmental and economic advantages, strongly suggests the need to:

- Encourage stakeholders to harmonize the regulatory requirements for novel foods, such as aquatic plant-based products (e.g., water lentils), to ensure an accurate public understanding of their benefits while ensuring a productive commercial environment.
- Implement programs to inform the public about the nutritional benefits of novel foods/proteins that is consistent with similar efforts concerning other food products (e.g., Dairy Promotion Program, “Got Milk?”).
- Promote government policies that decentralize crops by altering the subsidy landscape, thereby promoting crop diversification and supporting infrastructure.
- Encourage government agencies to favor healthier options and more environmentally sustainable producers in food procurement programs (e.g., military, schools).
- Expand industry and government engagement with environmental advocacy groups to promote a standardized system for ranking foods and ingredients based on sustainability to inform customer choices.
- Broaden existing nutritional education programs to include healthy novel ingredients and foods.

In conclusion, environmentally sustainable food production throughout the 21st century will require a revolution in agricultural practices and innovation in the novel food sector to balance the production of highly nutritious and protein-rich diets while minimizing the collateral environmental degradation associated with traditional agricultural practices; aquatic plants such as water lentils can play a significant role in addressing this challenge.

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Figure 1. Commercial “Water Lentils” (duckweed) farm located in Central Florida (Parabel, Inc, USA).