Climate Change Adaptation in Agriculture: Global Review of Floating Beds and Undersea Cultivation

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Abstract: As climate shocks intensify, food production is moving beyond conventional soil-based farming. This review synthesizes the agronomy, resilience mechanisms, economics, and environmental performance of several frontier or revived systems: Bangladesh's floating garden "baira/dhap" undersea biosphere cultivation (Nemo's Garden, Italy), seawater/solar greenhouses (e.g., Sundrop Farms, Australia), halophyte (salt-tolerant) cropping, and "3-D ocean farming" (kelp and bivalves). Based on peer-reviewed literature and institutional reports, we summarize resource use, outputs, indicative costs, and life-cycle Green House Gas (GHG) intensities where (Life Cycle Assessment) LCAs exist. We find strong adaptation benefits for specific stressors flooding (floating beds), freshwater scarcity and heat (seawater greenhouses, halophytes) and coastal nutrient issues (seaweed/bivalves). Evidence gaps include robust LCAs for floating beds and undersea biospheres and standardized cost datasets for marine farms. We conclude with priorities for policy, finance and research.

Keywords: Resilient agriculture; floating gardens; undersea cultivation; seawater/ solar greenhouse; halophytes.

1 Introduction

Agricultural systems are facing compound risks from flooding, heat, aridity, salinization, and degraded soils. In response, innovators are decoupling production from arable land and freshwater (e.g., seawater-powered greenhouses), operating directly in inundated or marine environments (floating beds, seaweed and shellfish aquaculture), or exploiting salt tolerance (halophytes). Several of these are beyond proof-of-concept: Bangladesh's floating gardens are recognized by the (Food and Agriculture Organization (FAO) as a Globally Important Agricultural Heritage System (GIAHS), and the Port Augusta seawater-solar greenhouse has produced

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approximately 15,000 t/y of tomatoes since 2016 [1, 2]. Meanwhile, undersea biospheres (Nemo's Garden) demonstrate a novel controlled-environment agriculture (CEA) microclimate under the ocean surface [3, 4].

2 Methods

We reviewed peer-reviewed articles, FAO/UN reports, and credible trade/technical sources (2010–2025) for five systems: (1) floating beds, (2) undersea biospheres, (3) seawater/solar greenhouses, (4) halophyte crops, and (5) 3-D ocean farming (kelp + bivalves). For each we extracted: (i) resource basis, (ii) agronomic mechanism, (iii) resilience to hazards, (iv) outputs/yields or scale indicators, (v) indicative costs (capex/opex signals), and (vi) LCA-based GHG intensity when available. Where LCAs were absent, we state that explicitly and avoid numeric claims.

3 System Overviews

3.1 Floating bed cultivation (Bangladesh)

Farmers braid invasive water hyacinth (Eichhornia crassipes) and other organics into buoyant mats; decomposed biomass becomes the growing medium for vegetables and seedlings during monsoon flooding. Case material documents vegetables such as amaranth, gourds, okra, eggplant, chilies, and turmeric [5]. Historical and contemporary practice is concentrated in southern Bangladesh's floodplains [6].

Resilience lever. Beds rise and fall with water levels, maintaining aeration during prolonged inundation and converting a problematic weed into substrate and compost.

3.2 Under sea biosphere cultivation (Italy)

Under water agriculture is a smart solution for a growing population and a planet with limited arable land. Nemo's Garden anchors transparent air-filled domes at around 5–11 m depth; sunlight warms humid air, and condensate on the dome provides freshwater for hydroponics, producing herbs/leafy greens in a low-pest microclimate [3, 7].

Resilience lever. Thermal buffering and passive condensation create a stable environment with minimal pesticide need; constraints include storms, biofouling, and permitting [3]. It doesn't require deforestation, offsets habitat destruction, and one day may support sustainable farming without competing for space with traditional agriculture.

3.3 Seawater/solar greenhouses (Australia and beyond)

At Port Augusta, Sundrop Farms couples a solar-thermal field with desalination and hydroponics to produce tomatoes year-round [1, 2]. Public sources indicate a ~AUD 200 million capital outlay for ~20 ha of greenhouse (~AUD 10 million/ha including solar and desal assets) [1].

Resilience lever. Freshwater independence and biosecure CEA in arid coastal zones; economics hinge on energy integration, brine management, and supply contracts.

3.4 Halophyte agriculture

Salt-tolerant species (e.g., Salicornia) are grown on saline soils or irrigated with brackish/seawater; integration with aquaculture effluents is common [8]. Reported biomass and seed outputs vary widely by ecotype and salinity.

Resilience lever. Converts expanding saline lands into production while reducing freshwater demand; market development remains a bottleneck.

3.5 “3-D ocean farming” (kelp + bivalves)

Vertical longline farms suspend kelp with oysters/mussels at different depths, requiring no freshwater, fertilizer, or feed. LCAs exist for large and community-scale farms [9, 10, 11].

Resilience lever. Ecosystem services (nutrient uptake, habitat), low inputs, and diversification of coastal livelihoods.

4 Climate-Risk and Co-Benefit Synthesis

- **Flooding/waterlogging.** Floating beds maintain root aeration and production during monsoon inundation; they also convert invasive biomass into food and compost [6].
- **Heat/aridity & freshwater limits.** Seawater/solar greenhouses decouple irrigation from freshwater and stabilize temperature/humidity for high-value crops [1, 2].
- **Salinization/sea-level rise.** Halophytes use saline water/soils and can pair with aquaculture effluents [8].
- **Marine ecosystem services.** Kelp and bivalves require no freshwater or fertilizer and can provide habitat and nutrient uptake; LCAs highlight gear/material hotspots [9, 11].

5 Policy and Finance Priorities

1. **Floating beds:** Micro-grants and pre-monsoon repair kits; nursery/seed support; integration into disaster-risk reduction plans [5].
2. **Undersea biospheres:** Engineering standards for storm survivability; streamlined coastal permits; techno-economic benchmarks versus land-based CEA [3].
3. **Seawater greenhouses:** Incentives for renewable-powered desalination; brine management/valorization; long-term offtake contracts to de-risk capex [1, 12].
4. **Halophytes:** Breeding/culinary market development; co-location with aquaculture to improve economics [13].
5. **3-D ocean farms:** Low-interest gear finance and marine leases; investment in processing/logistics; material circularity to cut LCA hotspots [14].

6 Limitations

Evidence is uneven. We found no peer-reviewed LCAs for floating beds or undersea biospheres; tomato LCAs are plentiful but site and energy-mix-dependent; seaweed LCAs are growing but still sensitive to gear choices and transport assumptions. Cost data outside Sundrop's public capex and some seaweed engineering studies are scattered and not standardized across currencies, scales and gear types.

7 Conclusion

Resilient cultivation is a portfolio matched to local stressors: floating beds for floodplains; seawater/solar CEA and halophytes for arid, saline coasts; and 3-D ocean farms for nutrient-rich nearshore waters. The near-term research agenda should (1) generate standardized LCAs for floating beds and undersea biospheres, (2) improve kelp/bivalve gear circularity to reduce material hotspots, and (3) align finance and permitting with the public adaptation benefits these systems deliver.

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