Ecologically Based Culture of Foods: Its Systems and Technologies

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Over the past fifteen years I have had the good fortune to travel widely throughout the world investigating ways in which peoples feed themselves and care for their environments. During this period I have become aware of the real magnitude of environmental and ecological destruction and its attendant impact on human societies. It is difficult for us to grasp the full meaning of the change. Desertification and the loss of utilizable habitat for agriculture is occurring at an alarming rate. In the United States, for example, a land area larger than the original thirteen colonies is in the process of becoming a desert. Worldwide the land so affected is larger than the total land area of Brazil. In human terms this means that every minute 20 hectares of land are turned to desert and every minute 24 people die from hunger, 18 of them children.

In many parts of the world contemporary agriculture is exaggerating the problem, and in some cases it is the primary cause of environmental degradation. Agriculture's heavy dependence upon chemical inputs and imported energy has led to a breakdown of the ecological infrastructure which previously sustained the soils, the water and the natural systems, which in turn tended to stabilize agriculture. In summary, the indiscriminate industrialization of agriculture has eroded its potential to be sustainable. It is against this background that my associates and I have been searching for underlying principles for a sustainable agriculture that might have application in both urban and rural contexts and have worldwide applications. We found within the sciences of ecology and cybernetics the basic precepts for an applied science of food culture and earth stewardship. The precepts that we have found useful in the design of agricultural environments are the following.

1. Nature, from the organelle of the cell to the largest ecosystem, is comprised of whole, autonomous systems. The genius of nature is that the building blocks are comprised of independent wholes and at the same time inderdependent with other biotic elements. There is a consistent organization in the living world which is rarely reflected in unstable humanly-contrived systems. Each level of organization in nature mirrors those above it as well as those below. A sustainable agriculture would be made up whole self-regulating systems linked to others in an interactive and mutually-reinforcing way.

2. Integration is another underlying precept. The culture of foods should link and balance aquaculture, field crops, livestock and agricultural forestry into mutually-reinforcing landscapes. Eliminating any of these can destabilize the whole.

3. The ecological rules of succession can be creatively applied to drive change on the agricultural landscape towards greater stability and productivity over time. A farm should not be static but, like a meadow on its way to becoming a forest, should change to take advantage of what can be an important ecological subsidy.

4. Agriculture should be bioregionally based with systems designed to reflect climate, soil type and indigenous ecologies. To a certain extent most agricultures do this, but when bioregional adaptiveness is seen as an intrinsic organizing principle, a wider range of possibilities become apparent.

5. Biological equity between peoples and regions of the world is another important underlying precept: it is in the hands of agriculturalists and foresters to help repair the ecological scars of land abuse. International cooperation based upon the precept of biological equity might well reverse contemporary environmentally destabilizing trends.

6. A sustainable agriculture should derive most of its energy inputs and flows from renewable sources of energy, the sun, wind and biological sources. All of nature is organized around natural inputs and pulses, and it is these inputs and pulses which assist in creating stable and self-regulating systems. An agriculture which uses only minimal non-renewable inputs of petroleum and chemicals has in my view a greater potential to become sustainable because it works with, rather than against, ecological processes.

7. Where possible information should be substituted for capital-intensive hardware and agricultural toxins. Information can come from many sources, from nature itself, from scientific data and from models of the dynamics of resource systems. Information from nature can come from at least two sources, one is from knowledge of how it works, and two from the introduction of plants and animals into the systems themselves. Perhaps the best example of the latter strategy is the introduction of predatory insects to control pests. In this case the predatory insects are a direct substitute for toxic petrochemicals.

8. An agriculture based upon an ethic of stewardship for the larger natural world is more likely to be sustainable. It is from the non-agricultural, or wild environments, if they can be protected and enhanced, that the agricultural regulating organisms and the new genetic stocks will come. I predict that the next phase of genetic exploration for new domestic varieties will include linking traits of certain wild organisms, especially plants, with our current agricultural varieties. An agriculture based upon stewardship would also concern itself with pollution, protection of groundwater and soil erosion.

9. Finally, a sustainable agriculture would be co-evolutionary with the larger context of human culture. It would be woven into the fabric of almost all other human activity. It would develop along a continuum with urban, suburban, rural and semi-wild forms. Culture and agriculture would increasingly shape each other.

Over the past decade we have been experimenting with these precepts under a wide variety of conditions in the urban and rural contexts in northern industrial countries and in small tropical nations. I should like to illustrate a few examples and provide a brief explanation of the systems themselves.

My first example represents an attempt to improve the culture of fishes in semi-closed environments. We were trying to increase the energy efficiency of small-scale aquaculture, which is notoriously inefficient. A translucent silo or cylinder was developed that would hold water and absorb large amounts of solar energy. The solar silos were seeded with aquatic organisms from a large number of wild ponds. Gaseous exchange in the high light environment was so rapid and self purification so efficient

Fig. 1

Solar silos

that we were able to grow low food chain fish like Tilapia at densities of up to one fish per nine liters. Our input-to-productivity levels were unprecedented /Fig. 1/. We found an additional benefit from this solar-aquatic technology. When exposed to sunlight, they functioned as solar collectors or low temperature "furnaces". Outdoors they did not freeze even during the coldest winters in our part of southern New England. When they were placed indoors in buildings with glazed southern sides, they provided year-round solar heating. In our bioshelter on Cape Cod thirteen solar silos allowed us to be totally independent of fossil or wood fuel heating and to ripen bananas in February. Our own house gets a good percentage of its winter heating and summer cooling from solar silos as well as providing us with fresh fish. We also grow vegetable seedlings on rafts floating on the surface. The aquaculture water provides both nutrients as well as moisture for the plants.

In 1971 we began our first experiment combining architectural, solar and ecological concepts to create the growing environments for diverse foods in poison-free habitats. These structures we called bioshelters and they were intended to be the solar age equivalent of the traditional barn. By this I mean a way of coping with the pulsing seasons and the biological inactivity winter. Our goal was to create year-round, autonomous structures for the diverse culture of foods. The structure in Figs. 2 and 3 is a fifth generation bioshelter and is known as the Cape Cod Ark. Its whole southern facade, as well as the east and west faces, are light-receiving surfaces. Inside it is comprised of a fish culture zone, an agricultural area, and a tree propagating facility. It contains ecological "islands" that host a wide variety of beneficial organisms from predatory wasps to small lizards. The degree of internal integration is quite extraordinary. One example is the way the fish culture is linked to vegetable production. All the crops are fertilized by fish wastes, but in one instance the vegetables actually purify the fish water. The ponds are linked

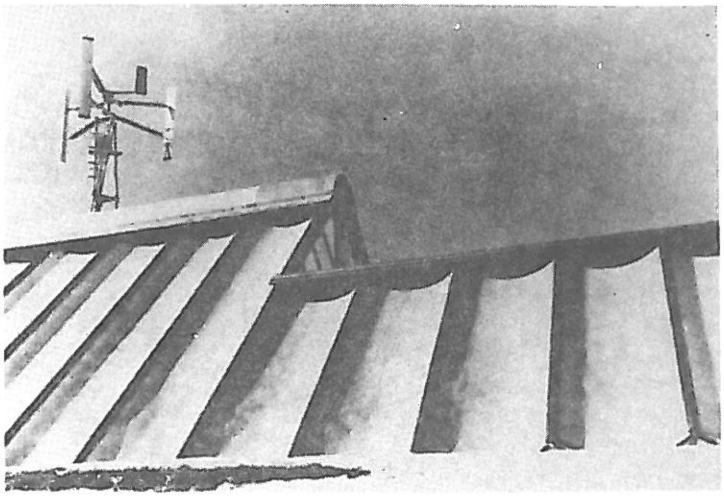

Fig. 2

Cape Cod Ark from the east

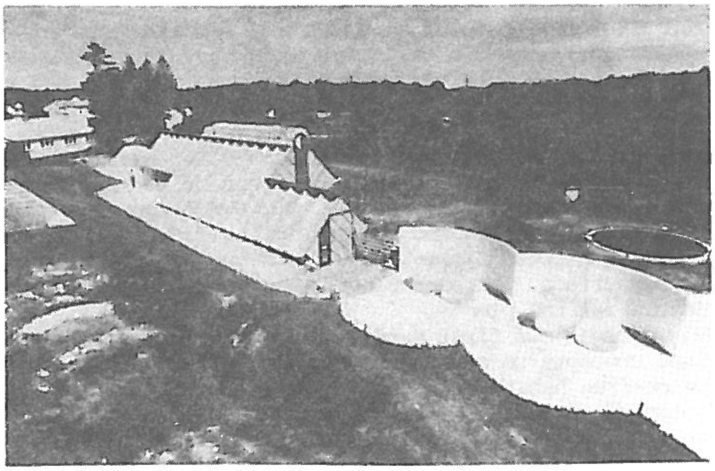

Fig. 3

Southern Facade Cape Cod Ark

together to form a "river" and when the water reaches the downstream point, it is air-lifted to a vegetable growing trough, where the vegetable roots remove the nutrients and particulate matter. They function as superb filters. Already several commercial growers have adopted this technique. The agriculture ranges from herbs to fruits, but the primary crops are vine crops such as cucumbers and tomatoes which employ the vertical space. Disease and pests are controlled through a variety of non-chemical methods.

The sixth generation bioshelter is a minimalist, geodesic structure which uses a new insulation technology and long-lived materials. The last bioshelter, built this year, is heated and fertilized not by an aquaculture system but by a large compost-making area along the north side. The composting system is integral to the design and provides both heat and carbon dioxide to the plants. Sales of produce and bagged compost paid for the structure in its first six months of operation.

In Prince Edward Island, the maritime province of Canada which is situated in the Gulf of St. Lawrence, we had an opportunity to create and operate a large bioshelter which added another dimension to the concept, namely that of human habitat. Our idea was to create an integrated structure that would act as an epicenter for a whole farm landscape providing a wide range of biological materials from fish to trees /Figs. 4, 5 and 6/. Prince Edward Island is an agricultural province, but its winters are long and harsh and its summers short. The structure is designed to absorb and use solar energy in many ways. The vertical collectors trap reflected light from the snow and ice and warm circulating water which is stored in subterranean chambers. The principal heating is in the thirty three solar silos

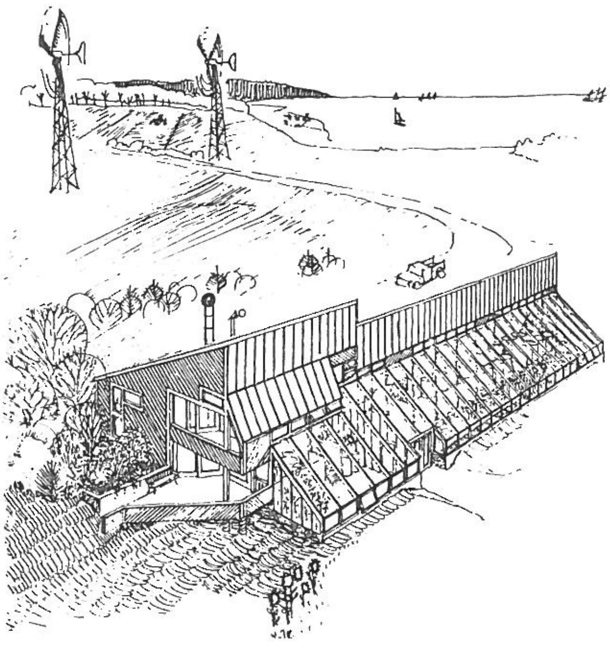

Fig. 4

Prince Edward Island Ark

which do dual duty as a trout hatchery and fish raising facility. The trout born in the facility are placed in the ocean during the summer and raised to market size before winter sets in. The agriculture is similar to that of the other bioshelters.

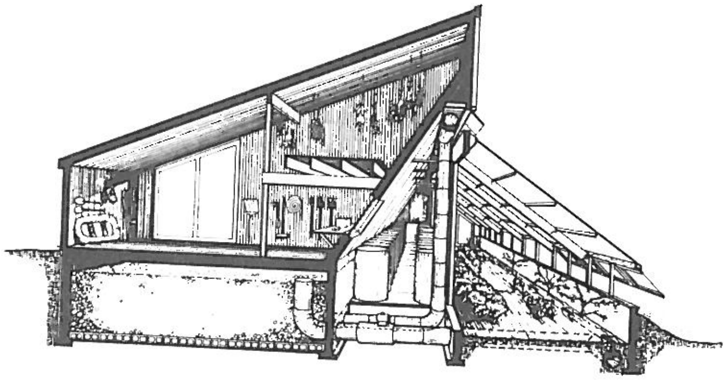

Fig. 5

Interior food growing area: Prince Edward Island Ark

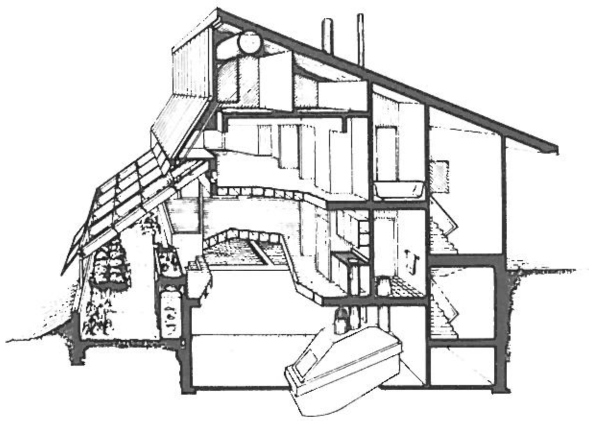

Fig. 6

Residential zone: Prince Edward Island Ark

Both the Prince Edward Island and Cape Cod Arks have been equipped with over fifty environmental and biological sensors which are computer linked and in some cases computer controlled. This information has been used to model the energetics and the biological pathways within the structures. This critical feedback has allowed us to improve our designs continuously.

Most recently we have begun to expand these concepts to encompass whole villages and to examine human settlements in general. We were asked by a community situated high in the mountains of Colorado in the western United States to help them design a village that was self reliant in food, waste treatment and energy. The drawings illustrate our approach /Figs. 7 and 8/. The hamlet is placed within an enclosed wall. The wall, which is

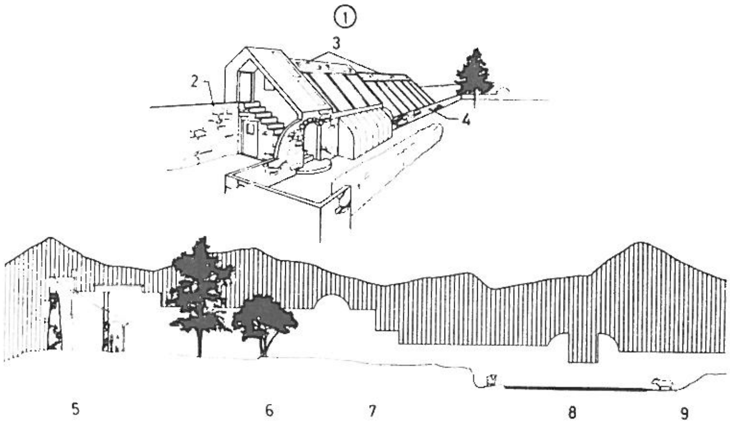

Fig. 7

Lindisfarne hamlet. 1. Greenhouses and residences. 2. Mechanical wall. 3. Span between walls. 4. Secondary wall. 5. Residences. 6. Permaculture. 7. Agriculture. 8. Pond. 9. Grazing lands

the backbone of the architecture, is used for heat storage and for the transport of water, wastes and electricity which in this community could be provided by a small solar-powered station. The region is extremely arid, so a good percentage of the food production is within the hamlet and irrigation is intended to be from purified and sterilized household wastes.

Waste treatment and food production can be integrated, treating systems which can help support human communities. The hamlet's waste treatment is intended to aid the community economically. The purification concept can be further expanded. The Figs. 9 and 10 depict a solar-powered facility which provides burnable gases, generates electricity, purifies sewage, operates as a fish culture facility and produces a soil amendment. The structure is one we developed for such a task. Solar trapping is optimized. The triangles of this geodesic structure are made up of three layers of a long-lived material called Tefzel. The layers of film are kept apart by being inflated with a heavy inert gas called argon. The argon functions as invisible insulation. Combined with heat storage of the solar silos within, the argon provides a close-to-optimal environment year-round. We have yet to build a fully-integrated waste facility and agricultural unit, but all of the pieces have been worked out and we are confident that such a facility would work.

A variation on this theme is what I have called the solar sewage wall, which I have designed for city neighborhoods. It uses higher aquatic plants for the purification of wastes and acts as a physical buffer separating road traffic from the sidewalks /Figs. 11 and 12/.

We are beginning to accumulate considerable experience working with the sun and the wind. In order to work with energy sources of varying and

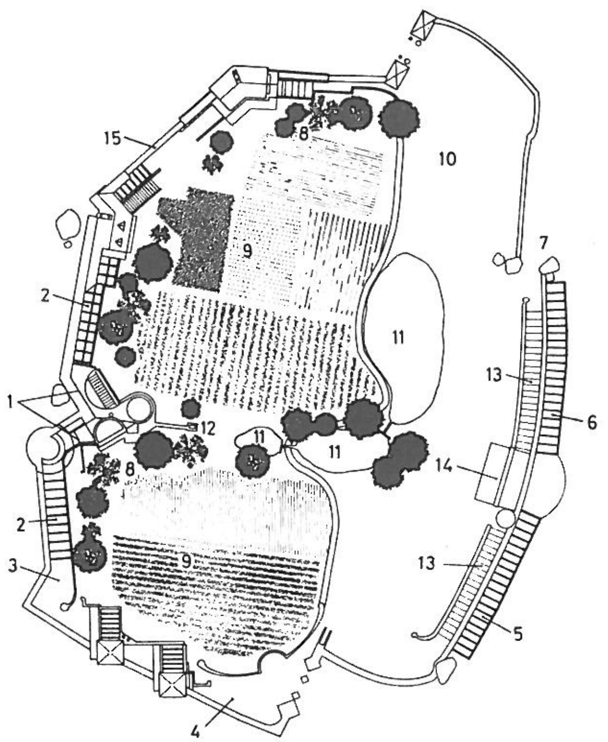

Fig. 8

Lindisfarne hamlet. 1. Secondary wall. 2. Greenhouse. 3. House site. 4. Future building. 5. Ecological waste treatment. 6. Production greenhouse. 7. Service and livestock entry. 8. Permaculture. 9. Agriculture. 10. Grazing. 11. Pond. 12. Well. 13. Stables. 14. Barn. 15. Mechanical wall

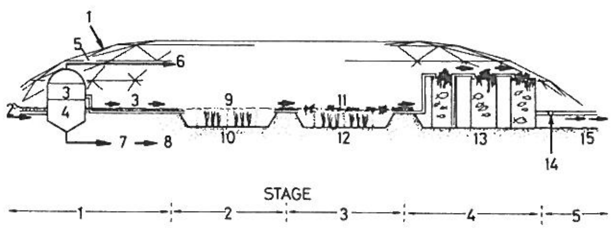

Fig. 9

Sewage treatment facility for Falmouth. 1. Bioshelter: Construction identical to new pillow dome at New Alchemy, built as a barrel vault running east-west. 2. Introduced septage. 3. Supernatant. 4. Sludge. 5. Biogas. 6. To gas powered electric generator. 7. Digested sludge. 8. Compost. 9 Aeration. 10. Pond series 1. 11. Higher plants. 12. Pond series 2. 13. Solar silos; fish hatchery. 15. Ozone sterilizer. 16. To groundwater. /Design: The Company of Stewards, Inc./

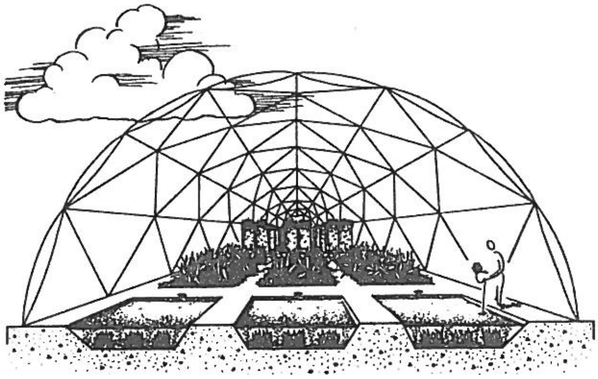

Fig. 10

Interior sewage treatment facility

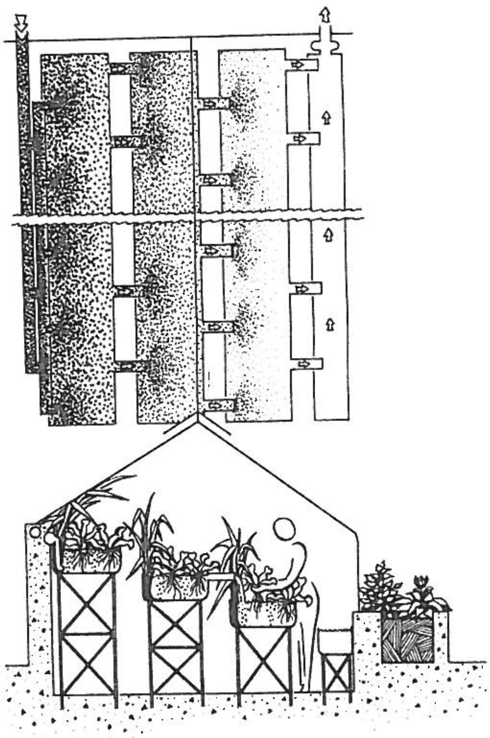

Fig. 11

Solar sewage wall

unpredictable intensities, one must design buffers into the systems and find creative ways of working with pulses. One example is a small windmill-power fish farm. The windmill is designed to pump water through the small aquaculture facility. It is a recycling and recirculating system powered by the wind. The various components are separated physically into a series of

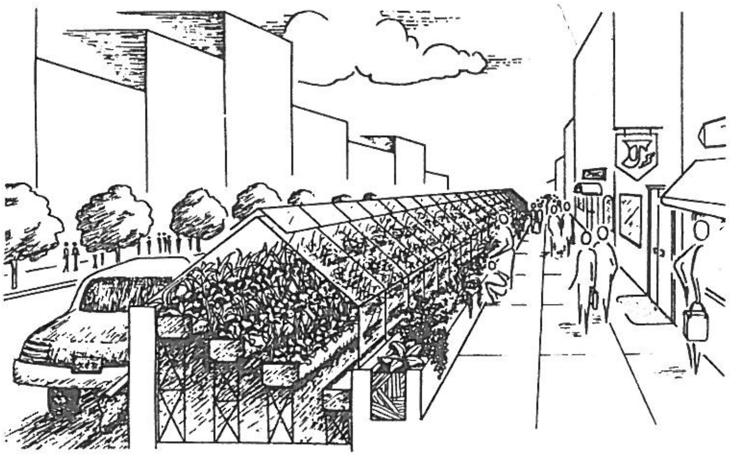

Fig. 12

Interior solar sewage system

cascading ponds. Each pond is a different ecosystem. In one the fish are concentrated, in another wastes are purified and in another natural fish feeds are cultured in populations which can be kept growing exponentially. When the wind is light and the windmill not pumping, the various subcomponents, particularly the feed and purification elements improve as ecological buffers, while the fish chambers stabilize because food inputs are much reduced. It is self-correcting so that the system functions both when it is windless and when the windmill is pumping and recirculating the water.

Up to this point I have placed a strong emphasis on how new technologies might be coupled to create ecosystem-based food culture in northern climates. In the tropics our emphasis has been on finding information that can be inexpensively applied in even the poorest of communities. In many degraded environments soils quickly lose their ability to hold water. Throughout the world shallow ponds and lakes have disappeared as soils have lost their water-retaining structure. Yet, water catchment is an essential ingredient of a sustainable agriculture, as reservoirs can provide water for livestock, and irrigation for crops and orchards.

Nowhere is the crisis created by porous soils more acute than on coral islands. A few years ago I was visiting an atoll in the Seychelles which are situated in the middle of the Indian Ocean. The atoll supported a community of about one hundred people whose economy was based upon the preparation of copra from coconuts. Their major source of water was a fresh water lens resulting from a long-term accumulation of rain water under the island. Coral soils are so porous they are unable to hold water near the surface. The community, when I arrived, was threatened by a collapse of their water supply. Overuse had resulted in salt water intrusion into the lens and there was talk of abandoning the atoll.

I remembered an abstract of a research paper I had read eight years before. Two Russian scientists had investigated why, on occasion, bogs and small lakes form on tops of rubble mounds which normally do not hold water. They discovered a natural process called gley formation which occurs when organic matter accumulates in a wet anaerobic environment. Apparently under certain conditions, nature has the ability to produce a biological plastic or sealant which in turn can hold water.

I was curious to find out if the process they discovered could be simulated on the porous soils of a tropical coral island, and if it could be accomplished rapidly. A pond was dug and a mat of shredded coconut husks was placed on the ground and tamped down. Our source of nitrogen and bonding elements was the leaves, stalks and fruits of the wild papaya which was abundant in the island's understory. This material was placed 16 cm thick

Fig. 13

Sketch of Java farm showing some of the interrelationships on top of the husks and tamped as well. Another 16 cm layer of coral sand was placed on top of the organic matter. The subsequent rains caused gley to form and the experiment was a success. The pond has held water for a number of years. Its presence has permitted the island to diversify agriculturally. The experiment is to be repeated on five remote islands in the new Federated States of Micronesia.

One of the greatest challenges facing us in both the tropics and temperate regions is the creation of farms which mimic the structure and natural processes of the forest. I first studied such an approach on a traditional farm on Java in Indonesia /Fig. 13/. This farm which uniquely balanced tree crops, aquaculture, livestock and grains into an integrated whole, had remained productive over centuries. The farm was designed to gain nutrients and fertility continuously.

On several hundred hectares of tropical lowland rain forest, in Costa Rica in Central America, for ten years my associates have been trying to create a farm which mimics the forest in many respects. More than one hundred varieties of economic trees have been collected from comparable environments in South America and other parts of the world, and the tree-crop work has been linked to aquaculture, livestock and vegetable culture.

A comparable approach to agriculture is being followed by the New Alchemy Institute on a small research farm on Cape Cod in New England where the bioshelters are located. It is too early for us to present a coherent economic picture of this work, however, it is already clear that the approach is ecologically viable. Humus-rich and productive soils have been created from what was, in the beginning, mostly sand.

I should like to end by returning to my earlier concern about biological equity between peoples and regions of the world. In my travels I have been struck by the inability of most peoples to get access to biological material - seeds, plants, trees, fish to culture and so on. The problem is

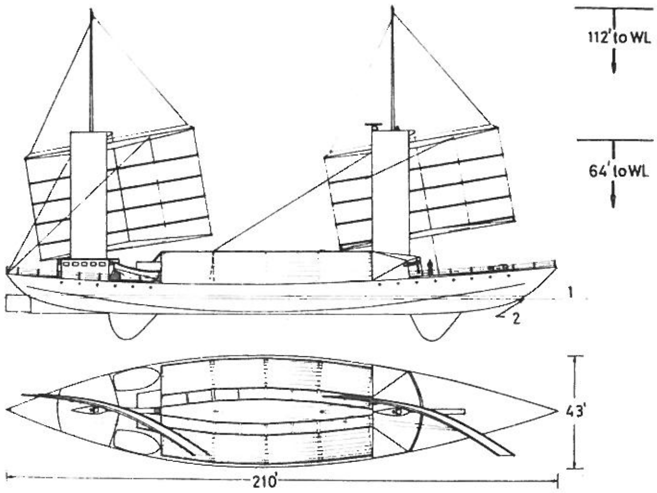

Fig. 14

The Ocean Ark the "Margaret Mead". Total sail area including masts: 10,685 ft^2. 1. Sea level. 2. Flotation shown for 750 tons displacement global and it is acute. To draw attention to the problem and to try and help solve it we have begun to develop a biological hope ship to carry material to ecologically-damaged islands and coastal regions. This ship, powered by the wind and sun and capable of solar desalination on board,

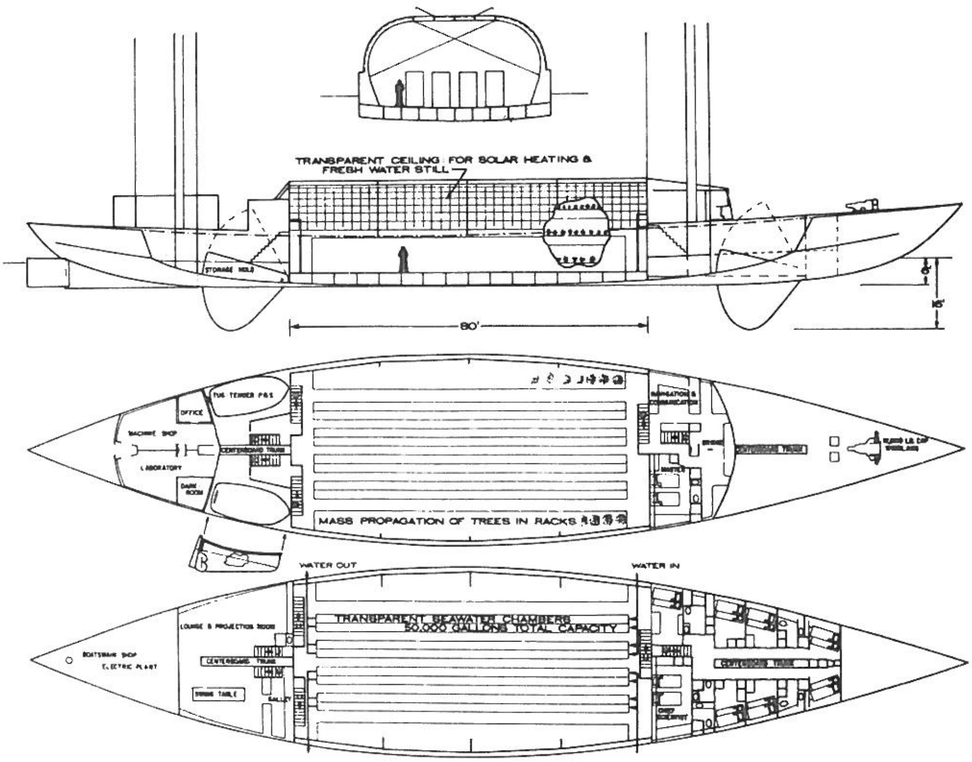

Fig. 15

The Ocean Ark's biological systems

will be able to carry a diverse range of agricultural and aquacultural materials, and to propagate such materials within the vessel. Figs. 14 and 15 depict an early version, a vessel 80 meters in length. We have built a 20 meter prototype to experiment with new rig concepts. We hope that when the ship is built and undertaking useful work, it will come to symbolize the beginning of a solar and ecological age.

Summary

It is my thesis that it is only through the application of ecological concepts that agriculture can be transformed to become biologically and energetically sustainable, and, at the same time, become environmentally restorative. Inherent in this new agro-ecology is the assumption that food culture should develop along a continuum with urban, suburban, rural and semi-wild forms. Each form will make its own contribution to the food needs of a population. Each will have its own subset of technologies, which are primarily renewable-energy-based. Whether in cities or on remote farmsteads, however, all agroecologies share common ecological principles and strategies, and high levels of integration of aquatic, soil, vegetative, structural, energy and nutrient elements.

Ecological principles and strategies are outlined below with specific examples of early designs and prototypes which have been developed by the author and his associates. The examples are drawn from urban and rural environments in both industrially-developed and tropical, agriculturally-based countries. Included are descriptions of bioshelters, solar-ecosystem aquaculture, new methods of water purification, surface catchment of rainwater on porous soils and farms designed in the image of the forest. The paper concludes with reflections on global strategies for the restoration of devastated habitats and argues that only through a new approach to agriculture can ecological recovery of the planet take place.