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CONTROLLED ENVIRONMENT AGRICULTURE IN SINAI

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INTRODUCTION

Conventional agriculture projects in Sinai can only be considered for development where good quality water exists for irrigation and where land capability holds real promise for productive agriculture.

High technology crop production in greenhouse structures may, however, be undertaken with or without good quality water and agronomically productive soils. Under the following conditions, intensive greenhouse food production can be a practical alternative and/or supplement to conventional field production:

1 - When there is a critical need for a supply of high quality vegetables in locations where capital and production costs higher than conventional agriculture can be justified.

2 - Where a source of fresh or saline water is available for irrigation. Ideally, such water should contain no more than 2,000 ppm of total dissolved salts. However, a source of brackish or saline water can be used if the greenhouse has its own power source for desalinization or can be coupled to an existing power plant which provides the electrical and reject-heat requirements for desalinization.

The increases in yield per unit of land in such high technology systems ranges from 100 to 1000 per cent over conventional open-field production, depending upon the crops grown. (1)

The earliest attempt at environmental control for crop production by man was irrigation, the application of water to plants to enhance the use of available sunlight, thereby increasing productivity. Since that time, many technological developments including pesticides, fungicides, improved irrigation devices and greenhouses have come into use. Some of these, such as, greenhouses, have because of capital costs been restricted to intensive production of high value crops and to research programs where a high degree of control can be exercised over valuable plant materials and experiments.

The recent development of low cost plastic films and light weight structural

materials have made possible new systems of crop production. These systems bring more of the essential environmental factors under greater control and at lower costs. Such control enables the grower to produce higher yields of better quality produce per unit of land area.

In open field irrigated agriculture, temperature, humidity, diseases, pests, ambient air quality, crop ventilation, and even soil moisture are environmental factors which are controllable only to a limited degree; and some are essentially uncontrollable. In contrast, controlled environment agriculture (CEA) means production of traditional crops with the grower having control of ambient humidity, air circulation, growing medium fertility, pests, diseases, irrigation water, and in some cases control over water quality and CO_2 content of the air, as well as a high degree of temperature control.

Technological advances of the past twenty years have established the engineering and biological feasibility of CEA. In special situations, economic feasibility has also been established.

CEA structures are now in operation in many nations, including the Middle East. They include both inflated plastic half-cylinders and rigid polyethelene covered houses. These structures in western European nations, Japan, U.S.A., Philippines, Mexico, Israel, Abu Dhabi, and Iran serve a variety of agricultural purposes. They have been built to meet one or more of the following needs:

1 - To assure a year-round supply of fresh produce, in spite of water qualities, temperature extremes or land suitabilities, which would limit conventional open-field production.

2 - To provide fresh produce for shipment to special markets, national or export.

3 - To supply special demand situations which may not be continuously met by traditional agriculture - for example, petroleum and mineral production sites, remote from agricultural areas, coastal fishing communities in non-agricultural areas and major tourist facilities in remote or non-agricultural areas.

4 - To provide experimental facilities for the following purposes:

a - To improve production costs of both greenhouse and open-field

agriculture.

b - To test new varieties under controlled conditions for maximum yield.

c - To determine optimum fertilizer requirements for yield and quality.

d - To test response of crops and varieties to various water quality regimes under controlled conditions.

e - To determine temperature response of crops and varieties through yield under conditions simulating open-field extremes.

f - To determine physiological constraints to production of crops under conditions of open-field management.

In Sinai, special conditions (constraints and opportunities) exist which have prompted this paper. A thorough examination of these conditions together with land reclamation potentials may well determine the advisability of installing one or more CEA units in Sinai.

Water quality, in terms of total dissolved salts and related natural conditions related to aquifer geology and source of recharge water, is low generally throughout Sinai. Expanded use of some existing wells will very likely lower the quality of water even more to a point of unsuitability for either potable or irrigation uses. As briefly indicated above, CEA systems can be designed to use water of essentially any quality.

In additional to water quality and quantity problems in Sinai, facilities for agricultural investigations are practically non existent. A separate analysis and a project proposal have been prepared, detailing the present situation and proposing a program of development, investigation, and means of putting into use the results of investigation for the improvement of agricultural productivity.

It has also been proposed that tourism in Sinai be promoted and facilities be developed to accommodate visitors in specific regions. If tourism is to become a significant economic sector in Sinai, high quality vegetables and fruits must be available. These perishables lose much in quality when imported from west of the Suez, due to transit time and delays en route.

It is suggested that three CEA facilities be developed in Sinai within the five year period, 1981-86. These would be strategically located to meet increasing fresh vegetable needs and provide critically needed crop investigation facilities.

Each of these units will be discussed in some detail including recommended siting, rationale for each site and type of unit, design characteristics adapted to site and need.

Unit 1 - El Arish

Water quality in and around El Arish appears to be deteriorating continually and rapidly (2). It has been confirmed that the municipal potable supply is very near the level of total dissolved salts (2000 ppm), which makes it unfit for human consumption. Continued reliance on present wells without reduced pumpage from irrigation wells in the same aquifer (and restrictions on development of new wells) will lead to a critical municipal water problem, possibly within one year.

Reduced pumpage and restricted new well development in the aquifer will limit the local production of agriculture at a time when expansion of population and food needs are occurring. Furthermore, planned land reclamation near El Arish, with concurrent new well development may be dependent upon other portions of the present aquifer (3). If this is later confirmed, then a further severe restriction is placed on planned expansion of local food production.

At least three alternatives to alleviate this complex of problems exist:

1 - A fresh water pipeline has been proposed to move water from El Qantara to El Arish for municipal purposes. This would reduce pumpage from the aquifer, thereby extending availability of irrigation water.

2 - Installation of a desalinization plant to meet municipal water needs. This would also extend the life of the present aquifer.

3 - Discovery of a new aquifer(s) with water quality satisfactory for both municipal and agricultural purposes.

Each of these near-term alternatives has distinct capital and operating costs. In addition, Number 3, discovery of new sources, may never occur.

However, an exploratory well drilling program has been proposed (4) for this and other regions of Sinai to provide better information for water planners. It is unlikely that fresh water will ever be considered "abundant" in Sinai.

Food requirements in and near El Arish are presently being met by a combination of local production and imports from the Suez region and the Delta. Although reliable estimates for both sources are not available, it is known that losses in both quality and quantity are sustained in transport of food, especially fresh produce from the west. As population grows and especially as tourism developes, a reliable year-round supply of high quality fresh produce will be essential to sustain economic development.

A five-feddan CEA facility is proposed for El Arish, which would be designed to meet the following conditions:

1 - To produce a continuous year-round supply of fresh vegetables of high quality.

2 - To utilize a spectrum of water qualities from fresh potable to 2000 ppm TDS.

3 - To conduct investigations which would maximize productivity and provide information on varietal adaptability, fertilizer requirements and production techniques of value also to open field agriculture in the area.

Unit 2 - Abu Rudeis

A two-feddan CEA facility is proposed for southwest Sinai possibly in Abu Rudeis. This is the probable site of industrial development, together with Abu Zenima, where processing plants for ferro-manganese, kaolin, and glass sand will likely be located and where fertilizer production from natural gas might also be initiated.

The potable water supplies in this coastal desert region are already limited and, with growth of industry, can be expected to become critical. Whether the old desalting plant at Abu Zenima is rehabilitated or a new one is built, a CEA unit of approximately two feddans should be constructed in association with a desalting plant.

The facility would be built to provide a constant year-round supply of fresh vegatables to assist in meeting the needs of the petroleum develop-

ments and expanding industrial population needs. No experimental activities are proposed for this unit. It would rely for new information and techniques on the larger El Arish facility, where experimentation would be a continuing function.

Unit 3 - St. Catherine's

A one-feddan unit (CEA) is proposed for the major tourist attraction in south central Sinai, St. Catherine's.

The climate at St. Catherine's presents a special reason for the facility. The winter season temperature minimums at St. Catherine's completely restrict the production of such vegetables as tomatoes, squash, peppers, eggplant, beans, cucumbers and okra. In fact, winter production of all horticultural and grain crops is practically non-existent because of low temperatures and occasional snowfall.

A controlled environment facility would overcome this climatic barrier to production and provide fresh produce year-round to the community and for the expected increase in tourist population. Although tourism commonly exhibits strong seasonal variations and the St. Catherine's region may develop some seasonal pattern, the availability of high quality fresh produce would assist greatly in strengthening this important tourist attraction.

It is believed that adequate supplies of fresh water are available to permit the construction of a one-feddan unit at St. Catherine's. Water requirement data for this and the other two units are provided in the next section.

DESIGN CHARACTERISTICS

	EL ARISH	ABU RUDEIS	ST. CATHERINE'S
Rigid aluminum structure or galvanized pipe	5-feddan growing area 1/4-feddan storage, processing, packing and office area and mechanical equipment	2-feddan growing area 1/4-feddan storage, processing, mech. equip., office space	1-feddan growing area 1/8-feddan storage, processing, mech. equip., office space
Polyethelene cover	2-year durability	2-year durability	2-year durability
Cooling & humidification system	high volume, low speed circulating air equip.	high volume, low speed circulating air equip.	high volume, low speed circulating air equip.
Irrigation water supply -Quality	Variable up to 2000 ppm TDS	Pure water from desalting plant or own desal. unit	High quality from local or own well
- Quantity*	$3.6M^3$/day/feddan ($6,520M^3$/yr.)	$3.6M^3$/day/feddan $2,680M^3$/yr.)	$3M^3$/day/feddan ($1,095M^3$/yr.)
Cooling & humidification water supply	Saline or brakish	Sea water	Local well water
Power source	Municipal electric system with independent diesel powered generators for emergency requirements.	Coupled to desalinzation plant	Municipal electric supply. Standby diesel generator for emergency.

* Approximately $36M^3$/day/feddan of pure water is produced in the structures as condensate on ceilings and walls from water, which evaporates from the humidification and cooling spray - from low quality water in El Arish, salt water in Abu Rudeis, and local well water at St. Catherine's. More than this amount will be produced in winter and less in summer. Thus, external demand for irrigation water can be reduced to extremely low levels.

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The following costs are preliminary projections, based on design characteristics and extrapolated from average costs of CEA facilities in similar climates. It should be emphasized that such estimates, based on extrapolation, are hazardous.

Capital cost of structure per feddan @ $2.00/ft.^{2}	US$ 90,604
Operating costs per feddan per year (5-feddan unit)	
Labor - Tech. & manual	13,500*
Operation - Power @ $0.02/Kwh	4,000
Maintenance @ $2,000/fd.	2,000
Agr. inputs per feddan	1,000
Plastic film @ $.05/ft.^{2} per feddan	2,265
Total annual operating cost per feddan	US$ 22,765

Amortization of capital investment in power supply (auxilliary) when needed and pumping costs, mainly for cooling, heating and ventilating, accounted for in power operations.

Thus, capital cost of the El Arish facility is estimated to be approximately US$475,670, including storage, packing, etc. space. Operating cost per year, including amortization of pumps, motors, fans, etc., is projected to be US$115,232. Similar figures for Abu Zenima are: capital cost approximately US$204,000; operating cost for one year projected at US$64,000. Figures for a facility at St. Catherine's are: capital cost approximately US$101,000; operating cost for one year at US$50,865.

Production Levels Attainable

Lack of experimental data on productions per feddan make projections quite risky for Sinai. However, controlled environment facilities in similar climates - Abu Dhabi, Iran and Mexico - clearly indicate that an average yield per feddan per year of 100 tons fresh produce is realistic.

Yield of certain crops, such as, tomatoes and cucumbers, can be expected to exceed this figure greatly; while production of lettuce, okra and cabbage may never attain such a yield per feddan per year.

Thus, a five-feddan project in El Arish would produce 500 tons of fresh

* Assumed rates for labor do not account for the need for incentives for working in Sinai. Labor rates per feddan are higher for smaller units, because costs of technical and supervisory personnel remain constant.

vegetables per year at a cost of 27 piasters per kilo. Current wholesale price for vegetables ranges from 9 piasters per kilo for zucchini squash to 50 piasters per kilo for bell peppers with tomatoes at 14 piasters per kilo and cucumbers at 12 piasters per kilo in El Arish, when available.

Costs of production are even higher in smaller systems at Abu Rudeis and St. Catherine's, since operating costs, mainly in supervision per feddan, remain fixed, irrespective of scale at these modest levels. It is possible to double production per feddan/unit of time by increasing CO_2 content of the growing environment. This requires special equipment at additional cost. However, in view of costs and returns emerging from this preliminary analysis, it still might not justify the CEA facilities in Sinai.

Feasibility

From an economic standpoint, such projects as proposed may not be feasible. Technically and biologically, they can be accomplished. The usefulness of assuring year-round production of fresh produce is a function of food price fluctuations and special market conditions. These factors would need to be considered in a complete feasibility study before a final decision could be made.

Although it is clear that CEA facilities could meet food needs in special situations, as we know them in Sinai at this time, it is advisable to consider such facilities as only one alternative to meeting such needs.

They should be compared to other alternatives, paying particular attention to their unique capabilities of continuous food production and unusually high annual yield per unit of water or land.

Environmental Impact

The only impact of any significance is discharge of waste salt water. In the cooling system of the Abu Rudeis facility, this would presumably be returned to the Gulf of Suez; and it would have no measurable impact on either environmental temperature or salinity. At El Arish, if saline or very brakish water was used for cooling and humidification, then discharge to the environment would require careful planning and execution to avoid increasing the saline content of groundwaters. Discharge into the Mediterranean Sea would be the best alternative.

ADVANTAGES VS. DISADVANTAGES

1 - Approx. five times the yield per feddan per year over conventional field production.

2 - Higher quality produce.

3 - Full time employment at approx. twice the level of field production.

4 - Can be installed in climates otherwise totally unsuited to conventional agriculture.

5 - Low water consumption per unit of produce - from 1 to 10 per cent of normal open field agriculture.

6 - Year-round production essentially (non-seasonal).

7 - Essentially free of pest and disease risks.

8 - Does not require good agricultural soils - growth medium can be sterile sand.

1 - High capital cost - approx. US$108,000 per feddan.

2 - Fixed operating costs per average unit of produce above costs of field production.

3 - Requires large quantities of saline or low quality water for cooling and humidification.

4 - Requires skilled management and special training for all employees.

5 - All fertilizer (nutritional) needs of each crop must be supplied, since growing medium is usually sterile or nearly so.

A CEA in El Arish then would, over the long term, fill a special market need for an assured supply of fresh (high quality) vegetables. It would consistently produce better quality produce than open field agriculture, because of greater control over temperature, pests, diseases and irrigation. It would also make possible the production during the winter of warm season crops, including tomatoes, eggplant, okra, green beans, melons and squash.

On the basis of produce per unit of water consumed, CEA will consistently out-perform open field agriculture. However, the market price structure in Sinai is so low that CEA as described in this paper may not be economical.

1 - Controlled Environment Horticulture in the Arabian Desert at Abu Dhabi; M. R. Fontes; Hort. Science, Vol. 8 (1), 1973.

2 - Preliminary Evaluation and Recommendations Regarding Groundwater Conditions at El Arish; Optional Working Paper No. 13; Sinai Development Study - Phase I, 1981.

3 - Land Reclamation Using Well Water; Project Summary Code No.5-A&B,Serial No. 170 ; Sinai Development Project - Phase I, 1981.

4 - Drilling Program for Hydrological Investigations; Project Summary Code No. 3-A, B, Serial No. 1; Sinai Development Project - Phase I, 1981.