April 1980 No. 11

ARID LANDS NEWSLETTER

Office of Arid Lands Studies • University of Arizona, Tucson

COVER

Shelterbelt established in dunes near Shapotou Sand Control Station, near Chung-wei, southeastern edge of Ala Shan Desert, People's Republic of China.

— photo by J. D. Johnson

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Fig. 3: A field of Russian thistle prior to seed harvest.

Fig. 4: Disposal of dry plants by burning.

POTENTIAL USE OF RUSSIAN THISTLE (*Salsola kali* L.) AND OTHER WEEDS AS AN ENERGY RESOURCE

by

Marjorie and Aden Meinel* and Martin Karpiscak**

Introduction

Biomass is potentially an important solar energy option for the simple reason that nature has solved the sunlight storage problem. Plants may be inefficient solar energy converters, but the vastness of land and the storage potential of plant products make plants important. While much work has gone into the study of plants as energy sources, emphasis has generally been on high efficiency of conversion of sunlight, and thus plants like sugarcane and other domestic species, plants usually requiring large amounts of water and fertilizer for sustained high growth rates, are the plants that have been studied. Moreover, such plants tend to use land desirable for food production and thus compete with a growing world demand for food. To expect to raise "energy" crops in direct competition with land, fertilizer, and water needed for food crops is not reasonable in view of increasing pressures from the world's exploding population.

In Arizona idle irrigated fields quickly grow rank growths of *Salsola kali* L. — common Russian thistle or tumbleweed. Here is a plant that can grow on marginal lands without added water or fertilizer. Owners of farmland retired because of the dropping water table would like to have a new crop to replace ones no longer cultivated. Perhaps weeds of the world could provide an energy crop on land otherwise useless.

Research into the characteristics of Russian thistle disclosed that it has a high water efficiency, the ability to generate dry mass out of available water. Few farmers in midwest America or the Crimea need to be told about the water efficiency of this weed, because in periods of drought it still thrives, even after wheat or maize has died out. It also appears that Russian thistle has C_4 characteristics, which means that its solar conversion efficiency is high. In semiarid regions solar efficiency is less important than water efficiency. It is water, not sunshine that limits growth. For these reasons, Russian thistle is getting close study as a possible future energy crop in Arizona.

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In this brief report we shall discuss Russian thistle in the context of our Arizona studies, drawing attention to the fact that some of what we have found will apply to other weed species in other lands. Thus far, our research has been supported by the Arizona Solar Energy Commission (ASEC), supplemented by a new grant for expanded research received from the Appropriate Technology Division of the U.S. Department of Energy (DOE). Initiated under the University of Arizona's Optical Sciences Center, the work is now managed by the University's Office of Arid Lands Studies (Karpiscak et al, 1979).

Scope of Biomass Energy

While public attention toward energy alternatives to oil has been focused primarily on the development of nuclear, technological solar, and coal, a fourth type of energy alternative is quietly being developed in the agricultural sectors of the U.S.: biomass energy, a concept of deriving energy products from plant material. By various processes, cellulitic plant material can be converted into solid fuels, low-grade diesel oils, or even into high octane fuels suitable for automobile use.

Plants, energetically efficient and environmentally clean, are available on a global renewal basis far in excess of the world's current consumption of petroleum. For example, Steffgen (1974) estimated that if it had been possible to convert all U.S. biomass agricultural wastes (Table 1) to a low-grade diesel fuel oil in 1972, the oil created would have been enough to provide one-half the heat energy needed for generating electricity in 1972. This means that enough fuel oil could have been generated from biomass to displace all the petroleum fuel oil and all the natural gas used in electric power generation in 1972. The problem here is that collection of most agricultural wastes is uneconomical and/or physically impossible. A solution to this problem lies in the establishment of "energy plantations" where photosynthetically efficient plants could be grown strictly for their energy value.

Table 1: Annual production of dry organic solid wastes and their equivalent conversion to a low-grade diesel oil (Anderson, 1972)

	Dry material ($t \times 10^6$)	Derived oil ($t \times 10^6$)
Agricultural plant wastes	360	147
Manure*	180	73
Logging and wood wastes	55	23
Total:	595	243

*Manure is seen here as detoured/reprocessed cellulitic biomass.

Russian Thistle Biomass

First introduced into the U.S. in 1873 mixed in flaxseed obtained from Eurasia, Russian thistle spread quickly over the western part of the country because of its ability to become established on disturbed soil, its high water use efficiency (Table 2), and the fact that it is relatively free of diseases and insect parasites which would normally restrict such development.

Table 2: Water efficiency of various plants (modified from Foster, 1979)

Species	Efficiency g/kg*
Amaranthus graecizans (Pigweed)	3.73**
Chaetochloa italica (Millet)	3.56
Salsola kali (Russian Thistle, Tumbleweed)	3.54
Amaranthus retroflexus (Redroot Pigweed)	3.49
Portulaca oleracea (Purslane)	3.48
Zea mays (Corn)	2.79
Beta vulgaris (Sugar Beet)	2.59
Triticum spp. (Wheat)	2.04
Hordeum spp. (Barley)	1.93
Avena sativa (Oats)	1.76
Chenopodium album (Lamb's-quarters)	1.69
Gossypium hirsutum (Cotton)	1.66
Helianthus annuus (Sunflower)	1.58
Glycine spp. (Soy Bean)	1.45
Medicago spp. (Alfalfa)	1.21
Agropyron smithii (Western Wheatgrass)	0.95

*g/kg = grams dry mass per kilogram of applied water.
**Values are means calculated from Briggs and Shantz (1914), Shantz and Piemeisel (1927) and Dillman (1931).

Prior funding by ASEC and ongoing funding by DOE enabled the University of Arizona to assess the biomass potential for Russian thistle in Arizona by conducting field surveys of wild stands and measuring the productivity in kg/m^2. The energy content and the available agricultural land base merited the possibility of using Russian thistle as a burned fuel source (Meinel and Meinel, 1979). Selected samplings of natural stands indicated a possible yield of 25,000 kg/ha. Natural stands, however in Avra Valley, Arizona, and near Casa Grande, Arizona, had yields that averaged 3,000 and 1,700 kg/ha respectively (Karpiscak et al, 1979).

Plants showed a correlation between productivity and plant size as displayed in Fig. 1. The mean cross-sectional area of the spheroidal plants was taken as indicator of plant size. We noted two distinct plant types during these field surveys, distinguishable by the dominant plant coloration, denoted in Figure 2 as "light" and "dark." The frequency distribution of plant productivity is shown in Figure 2, summed for both variants.

Fig. 1: Productivity vs mean plant surface area for Russian thistle measured from the 1976 growing season in natural stands in the vicinity of Tucson, Arizona.

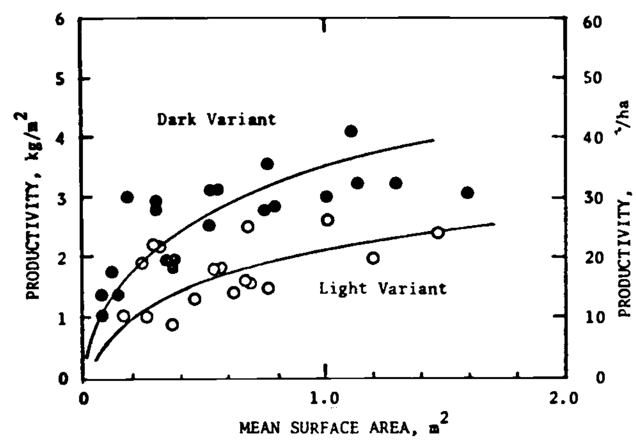
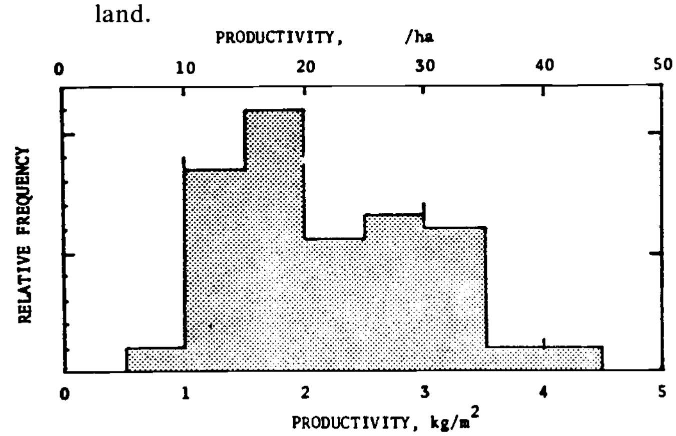


Fig. 2: Statistical frequency of occurrence of Russian thistle as a function of productivity per square meter of land.



The Arizona DOE grant, which began in August 1979, examines the feasibility of agricultural production of Russian thistle as a source of burnable biomass by:

. . . demonstrating a method of planting, growing, and harvesting

. . . demonstrating a means of compacting the biomass to cubes or logs

. . . determining the energy efficiency of the compacted mass

. . . investigating a method of harvesting seed

One problem with evaluating natural stands is the estimate of the actual amount of rainfall used by the plants because of runoff accumulation of an unknown amount. Natural rainfall in field locations surveyed runs from 200 to 500 mm/yr. We can calculate, however, what the productivity would be, based on unaccumulated rainfall, as would be the case applicable to rainfall on deliberately farmed land, where runoff is minimized. In Table 3 we list the productivity in t/ha. The observed productivity from our field survey (25 t/ha) would correspond to a rainfall of about 560 mm/growing season, and since the rainfall during the "growing" season is about 280 mm/season, there is indication that there is runoff accumulation of about a factor of two. Deliberate cultivation of a crop is planned in 1980 at which time accurate field controls will be established, but current indications are that Russian thistle has about the water efficiency expected of a C_4 plant.

Table 3: Expected yields for Russian thistle as estimated from water efficiency and area rainfall

rainfall (mm)	yield (t/ha)
200	8.92
400	17.84
600	26.76

Samples of natural stand Russian thistle, gathered for measurement of the energy content, were weighed in the dry state similar to that which would apply to field-dried harvested Russian thistle. The heat content measured in a bomb calorimeter yielded values ranging from 15.07×10^6 to 15.91×10^6 J/kg. We have based our estimates of energy yield from farming using a mean value of 15.91×10^6 J/kg. The energy content of 20 t/ha is 8.8×10^4 kWh_t/ha, which has a value at 0.01 $/$kWh_t$ of 883$/ha, a reasonably attractive value.

A field of Russian thistle prior to seed harvest is shown in Figure 3, and disposal of the dry plants by burning is displayed in Figure 4. Figure 5 shows the biomass compacted into "cubes," not only for direct burning but as a form for storage of the biomass, as well, for feed stock for further processing into gaseous or liquid fuels.

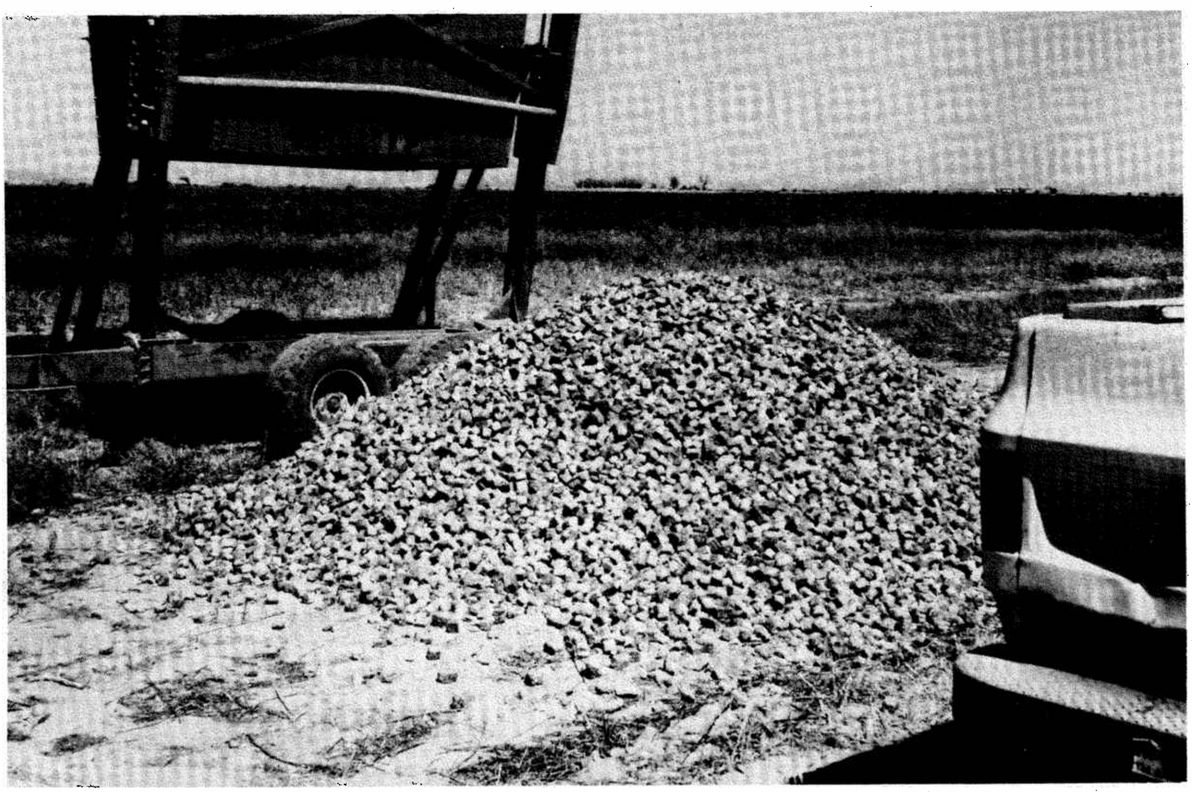


Fig. 5: Biomass compacted into "cubes."

When we became concerned that the cost of retrofitting existing gas- or liquid-fired systems might be economically unfavorable and that the effluents produced by burning the solid material might be ecologically unacceptable, we considered the alternative of conversion of the solid mass directly into a liquid hydrocarbon. The conversion method we chose to test was that of Dr. James Kuester, Arizona State University, Tempe, which has as its end product high octane gasoline suitable for automobile use. According to Kuester (1979), the dual systems offer the advantage of a high quality pyrolysis gas free of combustion products. Product yields of 200-400 l/t liquid fuel for feedstock are to be expected, depending on the type of feedstock used. Kuester (1979) further anticipates that this material could likely be tailored to match paraffinic fuels such as kerosene and diesel.

Energy Potential

As an example of the potential impact of conversion of biomass to a liquid fuel, the State of Arizona consumed 5.8×10^9 l of gasoline in 1974. If we take the high end hydrocarbon figure of 400 l/t of dry biomass material, one ha of Russian thistle (25 t/ha) would produce 10,000 l of gasoline derivative. At this production rate, 580,000 ha would be required to fulfill this energy requirement. If it is possible to double crop Russian thistle (90-day growth requirement), the above land figure could be cut almost in half, and Arizona's gasoline requirements could be met through the use of 290,000 ha of land. At present there exist approximately 120,000 ha of available cropland (Arizona Statistical Review, 1978), i.e., cropland not currently in production for lack of irrigation water — nearly half the amount of land required in principle to meet Arizona's need for gasoline.

Department of Energy predictions for U.S. energy consumption in the year 2000 call for 95-114 quads of energy [1 quad = 10^{15}kJ], depending upon the price of oil in 2000. At the observed rate of 3.2×10^8kJ/ha for Russian thistle biomass, 300-360 x 10^6ha of land would be required to fulfill that energy need. Clearly this figure is impossible to fulfill without adding land from semiarid lands not now being farmed. The ability of Russian thistle to produce well on marginal rainfall does allow for using some additional land, but how much depends on the total environmental picture.

What, then, could the role of a solid feedstock biomass take in the total U.S. energy picture? We believe it will be primarily useful in localized community industries where a solid fuel like coal or biomass can be used. Energy consumers would contract out to local farmers for delivery of the solid to the customer. Stockpiles of the material could be maintained to sustain users during the off-growth season, thus providing storage capability so difficult to obtain with other solar options.

Arid Land Agricultural Gain

The possibilities for expanded production of Russian thistle biomass in Arizona are enormous. Current agricultural practices in Arizona use only two percent of state lands, the primary limitation for further production being water availability. We do not, however, advocate the cultivation of virgin desert land; rather, retired agricultural lands should be used for Russian thistle production. The argument for this position is that:

. . . there may be sufficient agricultural land available to meet local fuel needs in some appropriate growing areas

. . . minimum environmental impact — established desert ecological communities will not be affected

. . . agriculture will be restored to local communities where it has been the prime source of revenue but has been significantly reduced by water limitations

Environmental Impacts

The primary environmental concern for any form of energy production is air quality: What is the effect on the atmosphere of burning or reacting this fuel? and land usage: What state will the land be in after this form of fuel production has ceased? While there exist many more subtle yet equally important environmental concerns (e.g., the effects of certain fuel production on the wildlife community structure), we shall limit our discussion here to land and air quality effects.

While Russian thistle biomass production will involve extensive land usage, we point out again that the land we propose to use is retired agricultural land; no new desert land will be cleared for production. Russian thistle production on such lands will have the positive effect of stabilizing the land to soil erosion by wind and water simply by the presence of a plant groundcover.

While we must admit to not having properly addressed the air quality effects of burning a biomass fuel, there are a few generalizations and comparisons we can make between biomass fuel and coal fuel. Although there are tremendous amounts of coal reserves in the U.S., coal production has been restrained because of the increased carbon dioxide, sulfur, and carcinogenic hydrocarbons released in the effluent. Furthermore, coal liquification, the so-called syngas, has as a by-product high concentrations of benzo (a)pyrene, one of the most carcinogenic of aromatic hydrocarbons known.

Solid-fuel biomass effluent is free of the carcinogenic hydrocarbons and sulfur that plague coal fuels; however, it is relatively high in carbon monoxide and carbon dioxide. Thus any large-scale burning (beyond local use) of solid fuel biomass will most likely be ecologically unacceptable. On the other hand, the liquid biomass-fuel is lead-free and sulfur-free, but has a CO_2 discharge rate similar to conventional gasoline. The air would thus be free of lead, sulfur, and carcinogenic hydrocarbons and experience a lower rate of CO_2 accumulation. The use of biomass would prevent the addition of CO_2 into the atmosphere that accompanies the burning of fossil fuels.

Conclusion

Biomass-derived fuels will involve large amounts of land, water, agricultural input, and processing equipment, but it is clear that the energy and the economic and environmental gains outweight the cost. The liquid fuel system has the advantage of contributing to the country's energy on the national level and being environmentally clean, but it also involves highly technical processing and transporting equipment, which in turn involve substantial capital investment. The solid fuel system has the advantage of stabilizing the energy needs of a local community or industry, and requires only simple processing equipment, but it is believed to be environmentally damaging on a large scale.

In either liquid or solid case, the major energy benefit is in terms of a renewable stable source of energy free of international political control. Both systems offer an opportunity to stimulate the agricultural economies of arid land communities that have suffered loss of revenue due to water limitations.

In no way should this presentation of the potential use of Russian thistle and other weeds as an energy resource imply that biomass-based fuels will replace coal, nuclear, or other solar options. Rather, Russian thistle biomass should be viewed as a supplementary energy source for the next century.

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! TUMBLEWEED SOUP !

Many of the wild greens that grow in the desert don't really taste too good — they're either too bitter (such as wild lettuce) or too pungent (such as wild mustard). Happily, there is one wild green — tumbleweed — which has neither of these defects, nor does it collapse into a limp unappealing mass when cooked, as most leaf greens tend to do.

Tumbleweed is unsurpassed as a green vegetable: it's mild enough to be eaten raw in salads, and has enough body to be interesting when cooked.

Tumbleweed must be picked when it's young and tender. If it's tough or woody, forget it. The best time to find succulent young tumbleweeds is in the spring, especially if there's been a lot of winter rain. If the season is particularly dry, you might have to wait until the summer rains.

A baby tumbleweed looks like a tiny pine tree. Its leaves look like round stems, giving the plant a leafless appearance. The plants like to grow in uncultivated fields or along roadsides.

Here are some recipes:

BASIC COOKED TUMBLEWEED

Pick as many tumbleweeds as you can eat, rinse them and put them, dripping wet, into a pan. Cover and cook until they're tender. If they seem too dry, add a little more water. Or add a lot of water and have a broth. Add herbs, butter, cheese, stock, other vegetables, milk, or whatever you have in the house. Eat.

TUMBLEWEED SOUP

1 qt. stock, preferably chicken. 1 pt. fresh chopped tumbleweed. Simmer, covered, until tender. Mix 2 tablespoons flour into ¼ cup cold water, smashing all lumps and add to the soup, along with 1 tablespoon butter (unless the stock was fat). Add herbs to taste, such as chives or basil. Simmer a little longer. Some people finish this off by mashing a hard-boiled egg and sprinkling it over the top. Serve hot.

CREAM OF TUMBLEWEED SOUP

Cook 1 pt. tumbleweed in 1 pt. water till done. Add a pint of milk and any herbs desired and heat it up again. Or use 1½ cup milk and ½ cup cream. Thicken it by adding 2 tablespoons of flour that have been blended smoothly into ¼ cup cold water, and simmer a little longer. Add cheese if you have any around, preferably a kind that will melt nicely; otherwise it should be grated. Eat it hot.

TUMBLEWEED SALAD

Chop up as many tumbleweeds as you can eat with any other vegetables that are handy. Dress with your favorite salad dressing, and eat.

You can add tumbleweed to any soup, stew, or vegetable casserole. Use cooked tumbleweed in an omelette. Use it anywhere spinach is called for (they're related), such as ravioli.

Try it once and I'm sure you'll agree that tumbleweed is one of the finest greens to be found anywhere. And you sure can't beat the price!

JS

Reprinted by permission from *Dry Country News,* No. 1, p. 11, Spring 1979 (Box 23, Radium Springs, New Mexico 88054). Its Editor, Gordon Solberg, and *Arid Lands Newsletter's* Editor agree that the prospect of a good hot bowl of tumbleweed soup enjoyed before a good hot tumbleweed fire is an experience to be cherished.

THE MATHEMATICS OF SOLAR ENERGY

by
P.T. Landsberg*

P. T. Landsberg

Consider the paradox that while solar energy falling on desert areas alone could supply world energy demand with little pollution if converted at as little as one percent efficiency, it is calculated that even by the beginning of the next century — less than a generation away — it will make only a relatively small contribution to world energy consumption. Consider that deserts could yield power equivalent to 141 60-watt continuously-burning light bulbs per capita, whereas world energy demand averages out at only 33 such bulbs. Consider that this remarkable factor of four, at hand, will be eroded only by increasing living standards and what appears to be an irreversible increase in world population.

Fossil fuel reserves, laid down largely by photosynthesis millenia ago, should bring us to a realization that solar energy, due to nuclear fusion in the sun, is really the ultimate source of energy, falling on planet Earth in great abundance. The rapid increase in its use from this point in time onward, despite much of our impatience with the lagging recognition of its inevitability as the final, unfailing source of renewable energy, is nevertheless foreshadowed by activities now under way.

Let us look briefly on the annual world energy demand which the World Energy Conference measures in 10^{18} Joules, or Exa Joules, as they are called (Bloodworth et al, 1978). This is a large number, greater even than 6×10^{17} which is roughly the number of seconds which have elapsed since the Big Bang. So we divide by the world's population to obtain an annual world energy demand per capita, remembering that annual energy is energy per annum, and that is power, and a good unit of power is a 60-watt light bulb (Table 1). To get a feeling for what is involved here, take the example of a man moving around, giving off heat, taking in food, all roughly equivalent to a power dissipation of 100 watts, or, say, two light bulbs. World energy consumption per annum per capita is actually 16.7 times larger at 33 light bulbs. This factor allows for transport, buildings, roads, etc., requirements dwarfed, however, by the estimated photosynthesis yield per capita and the solar energy per capita incident on planet Earth. This is true even for estimates for the year 2000, when population and energy demand will have increased considerably.

Not to be overlooked is the fact that consumption at 33 light bulbs per capita has been brought to this low value by the large number of people (2.5×10^9) living a very simple life in rural areas of the world with an energy consumption of only five 60-watt bulbs per capita, from averages like 165 light bulbs per capita for a developed country like the U.S. The calculation for the years 2000 and 2020 assumes a gradual increase in energy consumption per capita, or put another way, in the standard of living. Table 1 shows, further, that the average efficiency of photosynthesis is very low: $410/396000 \sim 0.1\%$, indicating considerable improvements in this area are possible by the development of better harvesting methods and more high energy-yielding crops.

TABLE 1

IMPORTANT ENERGY FLOWS (EARTH AVERAGES)

	60-Watt Bulbs Per Capita	Joules Per Annum
1975 [World Population 4×10^9]		
Food Consumption	2	1.5×10^{19}(*)
Energy Consumption	33	2.5×10^{20}
Photosynthesis Yield	410	3.1×10^{21}
Solar Energy Incident on Earth	396,000	3.0×10^{24}
2000 A.D. [World Population 6×10^9]		
Energy Consumption	51	5.8×10^{20}(**)
2020 A.D. [World Population 7×10^9]		
Energy Consumption	76	1.0×10^{21}(**)

(*) *See* Boardman and Larkin (1975)
(**) *See* Bloodworth et al (1978)

* *Professor of Applied Mathematics, University of Southampton, Southampton, UK. Based on a talk before the British Association for the Advancement of Science, Edinburgh, September 1979.*

Table 2 gives us a "quick-and-dirty" look at Earth's desert areas, mindful that there are different degrees of aridity and different ways of defining deserts (Paylore and Greenwell, 1979). This tabulation gives us a possible power yield per capita from deserts of a very low conservative one percent, a poor efficiency. But even though the yield of 141 can readily be checked, one still has the problem of designing the devices, fixing them on the ground, distributing the energy collected as electricity, etc. As world population increases, also, the yield per capita from this exciting use of desert power diminishes, even though in our projection as shown for the year 2020 it is still adequate.

TABLE 2

POWER FROM THE DESERTS?

A. AREAS ON THE EARTH (10^7 km^2)

Antarctica (in the south) 1.4	Arctica (in the north) 0.95 — 1.23 depending on whether or not adjoining seas are included.	
Total Land Area Including Antarctica	(29% of total)	15
Total Sea Area	(71% of total)	36
Total Surface Area		51
Desert Areas (17% of land, 5% of total surface)		2.5

B. POSSIBLE POWER YIELD FROM DESERTS P.C.

Year	Population	Mean Insolation W m^{-2} (∈/10)	Efficiency	Yield (60W Bulbs p.c.)	Requirements from Table 1 (60W Bulbs p.c.)
1975	4 x 10^9	135	1%	141	33
2000	6 x 10^9(*)	135	1%	94	51
2020	7 x 10^9(*)	135	1%	81	76

(*) See U.N. World Population Conference (1974)

The ultimate use of solar energy requires an understanding of quantitative properties of the solar spectrum, of thermodynamic efficiencies, materials, and economics — mathematics is clearly needed, say we, immodestly. But it will be quite simple, especially when we consider that the economic viability of a solar panel for water heating depends crucially on the extent to which fuel price inflation exceeds general inflation. If it is 20 percent as against 10 percent, for instance, its viability can be established. The obstacles to maximum use of this abundance of energy are storage and cost, to which many experiments are being directed in various parts of the world. At present, this rather random attention, despite the total scattered attention, is not expected to contribute more than five percent of the world's energy budget by 2020,

> **although our parrot-like reiteration of this figure may become a self-fulfilling prophecy without greater effort to give it the lie.**

The World Energy Conference shows projection by fuel (Fig. 1), with renewable energy sources taking only 13-15 percent of the total throughout the 40-year period, including wind, hydroelectric, and solar energy. The authors (Bloodworth et al, 1977) do ask, nevertheless: "Have we underestimated the potential demand for solar energy and the rate of market penetration?"

Fig. 1: Anticipated world energy demand as a function of time and fuel type.

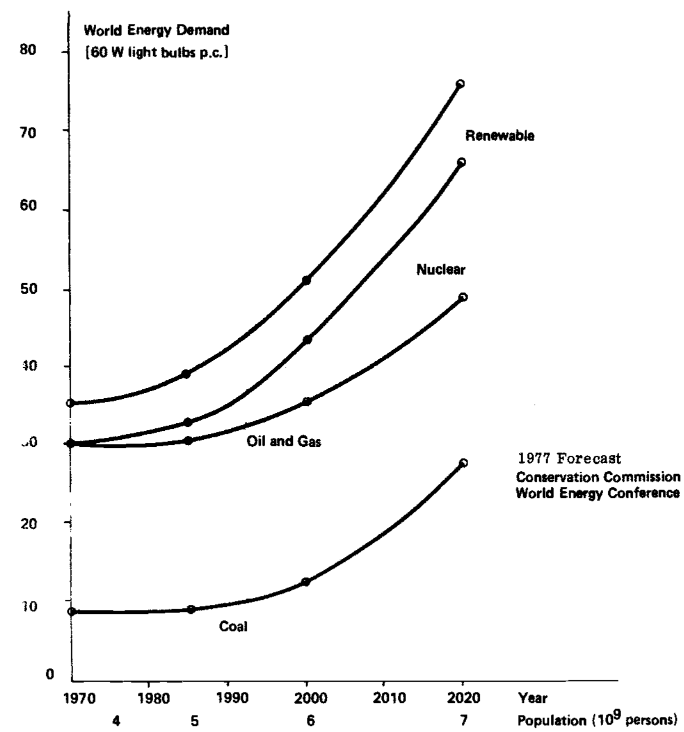
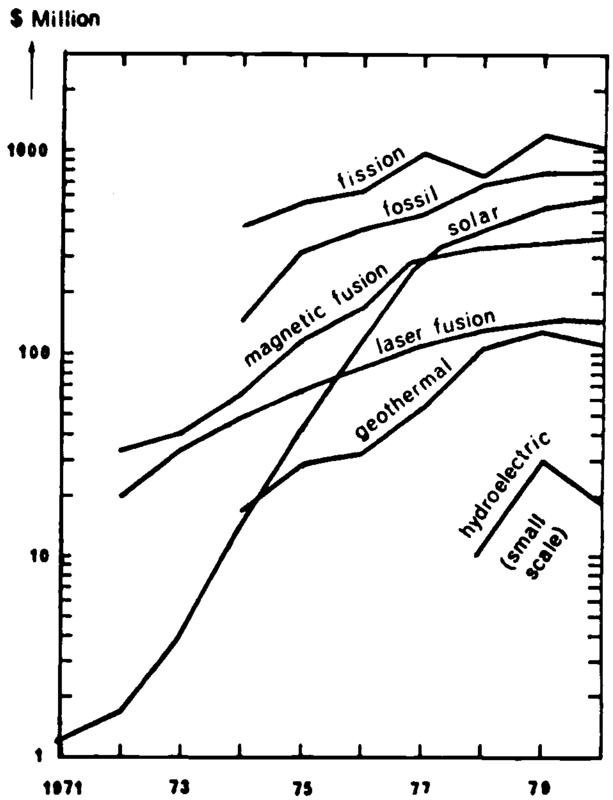


Fig. 1: Anticipated world energy demand as a function of time and fuel type.

An example of the use of simple mathematics concerns solar cells. In a light meter for photography, the incident light causes a reading in the meter, i.e., a current flow. In a solar cell, radiation is also converted to electricity with the idea of getting the largest possible electrical energy out of the system. If one models the cell very simply, the nature of the incident radiation will be shown to lead mathematically to the best value of at least one crucial solar cell parameter —its so-called energy gap.

It is undeniable that the giant of solar energy is gradually stirring. Solar panels for swimming pools are economic, even in the United Kingdom, as well as solar panels for hot water, now accepted energy-saving devices in wide use in Israel, Australia, India, and, belatedly, even in some parts of the U.S. Solar cells are already economical in remote locations, for special uses and on satellites. They will have to become cheaper by a factor of the order of 20, however, if they are to be economical for domestic consumers. To achieve the required lowering of costs, many countries have expensive research, development, and demonstration projects under way (Fig. 2, Rice (1977) and Personal communication, 1979).*

Fig. 2: Federal energy budgets in the U.S. in millions of $/fiscal year.



* See account in this issue of *Arid Lands Newsletter* of the Papago solar project in southwestern Arizona.

There are more ambitious options. Central power stations could receive solar heat to drive a heat engine and hence a large alternator to produce electricity. There are plans for various megawatt schemes, and, most ambitious of all, there are schemes to beam microwave energy to Earth, having produced the energy required via billions of solar cells on geosynchronous satellites with areas of the order of 50 square kilometers. Each such satellite is equivalent to two or three conventional 2000-megawatt power stations, and they might be in orbit early in the next millenium.

Solar energy potential, that stirring giant mentioned above, is destined to come to our aid in the latter part of this second half of this century. But it will help us only if we will help ourselves. Many of us have seen domestic devices take off and become big business: television, transistor radios, pocket calculators. When domestic solar energy takes off, there will be a difference of some magnitude. Instead of the individual pleasures and conveniences that these devices bring us, solar energy on this scale will be accompanied by the social benefits of fossil fuel savings and minimal pollution.

How long will it be before solar energy takes off in the domestic market? Recall that Galvani was the first to produce a current in 1786. He did so by an electric machine to study the contraction of the muscles in frogs' legs to probe animal electricity. Only in 1879 did Crompton establish a generating station to light St. Enoch's Station in Glasgow. The incandescent lamp which we use so nonchalantly as an energy unit came in 1880, and the first central power station was built in 1888 by Ferranti in Debtford to serve London. This truly was a one-hundred-year struggle, and another one hundred years have now elapsed.

But we do things more quickly now. The pace accelerates. Thus fission on a laboratory scale was discovered in 1938, and by 1965, 27 years later, atomic reactors were with us. If we think of solar cells which first arrived in 1956, then surely the 1980s will see them coming into more widespread use. The commercial prizes to be gained are vast, especially so if we are to see satellite solar power stations being built at the rate of two a year for thirty years (Collins, 1979). We shall then have a world with adequate power supply.

But this outlook will present us with new problems, of which thermal pollution due to excessive heat production on planet Earth is only one. All these topics, then, present exciting challenges to the mathematical scientist as we start the countdown to the twenty-first century, challenges to which he must respond if fusion power is not to overtake satellite power.

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WHAT NOW FOR THE BEDOUIN?

". . . The decline of the nomad and his adaptation to settled agriculture can be seen as part of a long historical process stretching back to the 14th Century. . . . The willingness of the bedouin to adopt a settled existence often varies with the strength of their tribal organization. Bedouin have evolved a lifestyle well adapted to their harsh environment. By dispensing with conventional property rights the nomads are able to take their livestock to rainfed areas where grazing is best. Bedouin livestock are an important national resource. Iraq's nomads, for example, own more than six million sheep and goats. Settling the nomad will deplete these stocks and leave the arid lands unused.

". . . Nomads are frequently accused of causing desertification through overgrazing, but they are by no means the only culprits. Settled farming can be equally harmful where ploughing in arid lands can mix poorer soil with the thin nutrient-rich layer on top. One alternative to sedentarization is to help the bedouin manage their rangeland better. Before it began to disintegrate in the face of modern pressures, the 'hema,' the bedouin's own system of range management, was an effective way of preserving scanty pasture, but this very system of range conservation has been a prime target of sedentarization policies. This neglect has led to serious denudation of plant cover, with subsequent soil erosion. The UN through a spokesman argues that the bedouin's grazing rights should be restored. With good agricultural land at a premium and services in many towns stretched by expanding in-migration, emptying the desert may not be a very wise policy. Better range management could help the bedouin make a positive contribution to development."

—Robert Lamb in *Earthscan* 2 (3):9-10, June 1979.

editorially speaking:

'OUT THERE'? OR HERE?
Can We Have It Both Ways?

We have been speculating more than usual lately about those ultimate deserts, the deserts of outer space. Perhaps our preoccupation with the question of life on Mars or anywhere else "out there" should be recognized for what it really is: the ultimate in desert technology transfer. We find ourself asking again and again: to what end, and for what purpose? Might it not actually be an expression of our longing to believe that we are not alone in the universe? Our cry for an answer to the fearful question: are we unique? The frightened comfort that if only we try hard enough and spend enough money, there will be a chance to start over again — somewhere?

Whether we are willing to invest in our own despoiled planet the resources we have already invested so compulsively in this technological imperative is moot, in our mind, one of those abstractions whose consideration can be put off until tomorrow. Jeremy Swift's "technological arrogance" which he so impellingly warns us against prevails today, however, not tomorrow, and to a global society nourished on science fiction, it is much more fun to "roll back Mar's deserts" on television than face the uncomfortable nagging seemingly unsolvable problems of desertification on Earth.

But we ask ourself if we have time for another generation of simpler folk to come along, today's young disdainful of our high technology. We see them everyday in our sequestered office, those young graduate students who work with us and for us, who talk over their problems with us, who ask us to reassure them that there is still time for them to come into positions where they can reverse the world and somehow set it right again. They come from the arid world, from Jodhpur to Antofagasta, from Beersheva to Alice Springs, from Medenine to Damascus, hoping to learn here, but wanting, too, to go "home" to help, to introduce a new concept of what is appropriate rather than political, to exorcise the demons that haunt them, those economic and social anxieties that have too often exalted the irrational by the sheer force and cruelty of convulsive events.

These are not your barefoot shaggy wanderers, bent over prematurely from the weight of their backpacks, who follow the sun without support or purpose, but those others, rather, believing desperately that there has to be more to life than mastering the mechanics of the latest buzz fashion (and there *are* fashions in the paper mills of our bureaucracies, believe me), more than programmed routines where people as mere slots are shoved into organization chart slots, rejecting mere technical capacity as a ruling imperative, believing that out of our very failures they can devise other strategies based on an understanding of history, of humanity as it has developed and matured in the world's deserts rather than the expediency of politics or the degradation of wasted intellects and talents.

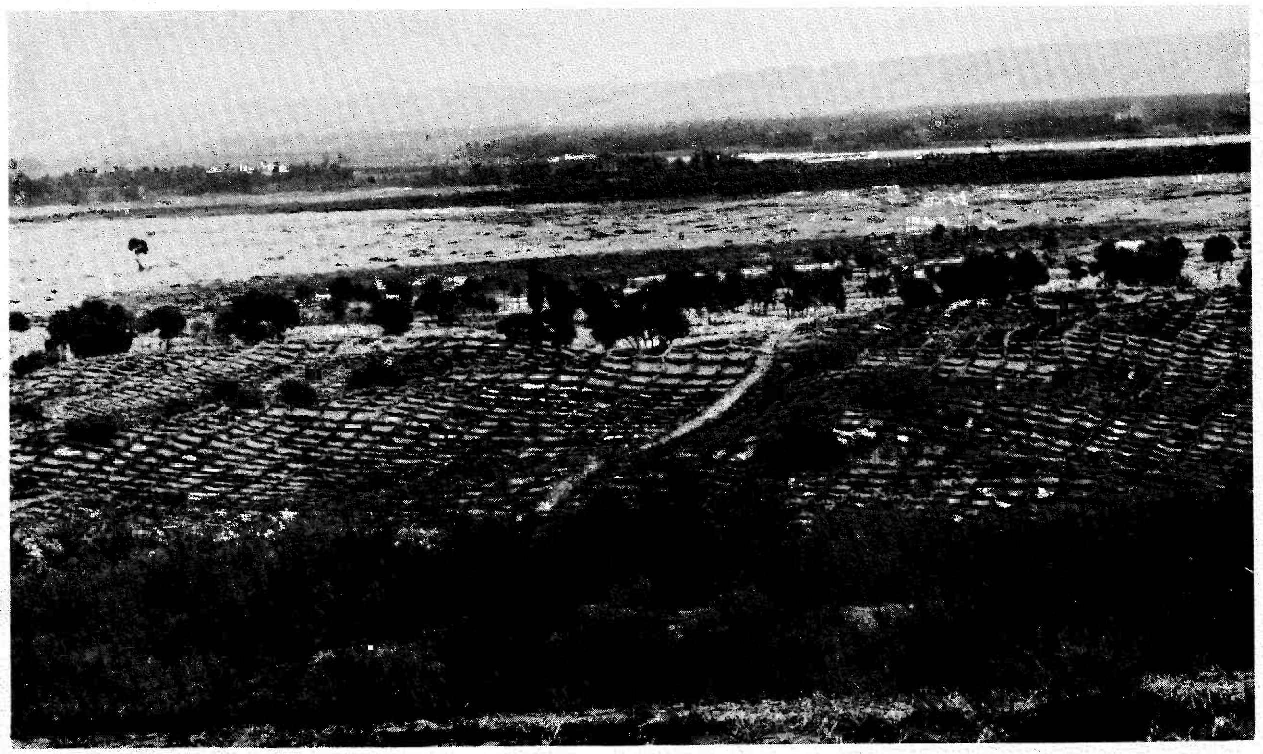
Even that master of space science fiction, Ray Bradbury, over and over again takes pains to delineate, ever so subtly, the bleakness of "out there," the ambivalence engendered by the success of the spaceships that brought them there but at the same time the psychological disorientation in that "brave new world." Those space pioneers think about Earth, remember other times, are distressed when the signals go silent or the return voyage is cancelled, step outside their vessel with all their high technology support systems to confront that ultimate desert, and admit, down in the bottoms of their little black hearts, that this is indeed a poor substitute for Earth, even a despoiled Earth.

So all you space colony buffs, believing that "out there" you can re-create the best of all possible worlds, our own planet, why not think about what might be achieved *here* to make sure that such an adventure, in the end, is best experienced through the science fiction adventure on which there is no restriction but our imaginations, best experienced in that mode because our astronomical views, our satellite revelations of these forbidding deserts of outer space, give us the best reason of all to cherish Earth's deserts the more, where man can indeed still survive if he will but try, in this most beautiful of all environments in our solar system.

So say we, as we settle down comfortably with our Bradbury paperback. Fearful? Yes. Forsaking our youthful adventurousness? Yes. Wanting to go "home" vicariously with those beloved student-friends from the deserts of Iraq, Peru, India, Algeria, Egypt, Iran, Israel? Yes, and yes again.

—Patricia Paylore

Shapotou Sand Control Station, near Chung-wei (37.31N 105.13E) northeast of Lanzhou, at the southeastern edge of the Ala Shan. Water is pumped from the Yellow River (background) to irrigate fields.



Another view of the Shapotou Sand Control Station as seen from the railroad tracks. The checkerboard field, below the slope in the foreground, is straw pushed into the sand by farmers in off-season. About one meter per side, this configuration reduces air motion at the sand surface, thus lowering sand movement and evaporation, a procedure the Chinese have found to be phenomenally successful.

LANZHOU INSTITUTE OF DESERT RESEARCH
People's Republic of China

The Lanzhou [Lanchow] Institute of Desert Research, formally established by 1978, maintains a staff of 120 for its research activities, including studies of the formation, variation, and movement of the desert, as well as its transformation and use.

The history of the Institute's development, from 1958 to 1962, is documented in the several reports issued under the aegis of the Academia Sinica's Sand Control Team,* whose activities covered basic research into the prevention of sand damage to railways, as well as scientific experiments on farmland. In 1963, this Team amalgamated with the Academia's Geography Institute, and later removed from Beijing [Peiping] to Lanzhou (36.01 N 103.45 E) where it went through a number of name changes and enlargements to become the Institute of Desert Research by which name it is now known.

During these more than twenty years, the Academia has tried to sum up systematically the broad experience of the PRC's people in bringing China's great deserts under some kind of control so that encroachment is halted and reversed, and the land made productive. A corps of trained technical personnel has been created to investigate these desert problems and institute the kinds of environmental experiments that will bring these aspirations to fruition.

At the Lanzhou Institute particularly, several laboratories have been created:

. . . to conduct research into the formation and variability of deserts, and particularly eolian sand movement, including the paleography of the Quaternary

. . . to study the desert's ecosystems and environmental changes following exploitation of natural resources (climate, water, soil, vegetation)

. . . to investigate sand fixation through revegetation and subsequent environmental changes

. . . to investigate chemical control of sands

. . . to undertake mapping of desert areas, with particular reference to remote sensing technology

In addition, the Lanzhou Institute maintains a data collection unit to collect, analyze, translate, and disseminate information relating to recent world desert research.

Northeast of Lanzhou, on the edge of the Tengger Desert [Ala Shan], an experiment station is being developed at Shapotou, near Chung-wei, to take some of the abovementioned investigations from the laboratories into the field where they can be tested and then extended into broader areas of need.

The Institute welcomes inquiries. Address Deputy Director Zhu Zhen-da, Lanzhou Institute of Desert Research, Donggand West Road, Lanzhou, Gansu [Kansu], PRC.

All photographs shown here were taken by Dr. Jack D. Johnson, Director, Office of Arid Lands Studies, University of Arizona, Tucson, who was a member of the National Geographic Society's desert study delegation which visited China in the summer of 1979 at the invitation of the Academia Sinica. (*See National Geographic* for March 1980 for an account of the trip.)

**See* detailed abstracts for citations in the accompanying list of references, prepared by *Arid Lands Newsletter*'s Editor.

A SELECTIVE LIST OF REFERENCES RELATING TO CHINESE DESERTS (arranged chronologically)

Norin, E. (1932) Quaternary climatic changes within the Tarim Basin. Geographical Review 22:591-598.

During the ice age, glaciers of the Kunlun extended down to the Tarim Basin and formed large piedmont glaciers outside the valley mouths. In the mountains of Kuruk Tagh no evidence of quaternary glaciation is to be found, this region constituting a refuge for fauna and flora. Travelers have given abundant proofs of a progressive desiccation of certain portions of the Tarim Basin during historical times, in some cases caused by the rivers changing their beds. Apart from these, by far the largest number of ancient desert sites and dead forests are formed along the southern rim of the Tarim Basin whereas there are few along its northern rim. Several southern sites seem to have been deserted because of a dimunition of the volume of rivers that once supplied irrigation water. This reduction of the water supply may have been caused by the disappearance or reduction of residual postglacial glaciers in the headwater regions.

Wissmann, H., von, et al (1956) On the role of nature and man in changing the face of the dry helt of Asia. In W.L. Thomas, Jr., ed., Man's role in changing the face of the earth, p. 278-303. University of Chicago Press.

Summarizes the geographical and anthropological history of the rise, spread and development of cultures, with emphasis on the effect of climate and on the development of herding, agriculture and nomadism. Early migration was facilitated by the steppe vegetation that covered most of the dry belt (during the last Ice Age) allowing more migration than present-day vegetation. Vegetation studies of the dry belt (extending to inner Asia, central Europe and China) indicate that because of lower temperatures, the boundaries of the thermal zones were extended over much greater distances than boundaries of humid zones—including arable steppe and desert steppe. Civilization spread throughout Asia with settlements developing cereal farming, herding of sheep and goats, as well as elementary types of irrigation and oasis economy. Farming and herding spread into 3 distinct regions: 1) the middle belt of Morocco and Spain to northern China, where natural oases and irrigation are still of greatest importance; 2) the southern belt of the tropical steppe of the Sudan; 3) the northern belt from Manchuria and northern Mongolia to Kazakhstan, southern Russia, and Rumania.

Academia Sinica, Sand Control Team (1958) Sha-mo ti-chu ti tsung-ho tiao-cha yen-chiu pao-kao (A report on the coordinated research on the desert regions), 1-2. Scientific Publications Society, Peiping, 108 p. Translation issued 1963 by U.S. Joint Publications Research Service, Washington, D.C., as JPRS Documents 18,658 and 18,178.

A comprehensive desert survey, organized in 1957, to find methods of sand control and utilization for the amelioration of the extensive areas in China's northwest region that are desertic. Soils, geomorphology, climatology, and vegetation are surveyed in great detail as a preliminary to undertaking reclamation measures. Although the emphasis appears to be on revegetation practices, attention is given to soil conditioning, livestock care, water salvage, and land use classification. The fairly simple and practical methods suggested on the basis of trial sampling should be useful in a worldwide context where sophisticated technological methods are unavailable.

Chu Chen-ta, et al (1961) Sha-mo ti-chu feng-sha ti-mao t'iao-cha-fa (Survey methods on shifting sand topography in desert regions). Scientific Press, Peiping, 61 p. Translation issued 1962 hy U.S. Joint Publications Research Service, Washington, D.C., as JPRS document 16,637. 95 p. Availahle NTIS as AD-299 215.

Contents include surveys on sand sources, formation of wind-sand topography, movement of windblown sands, and investigative methods. 45 references.

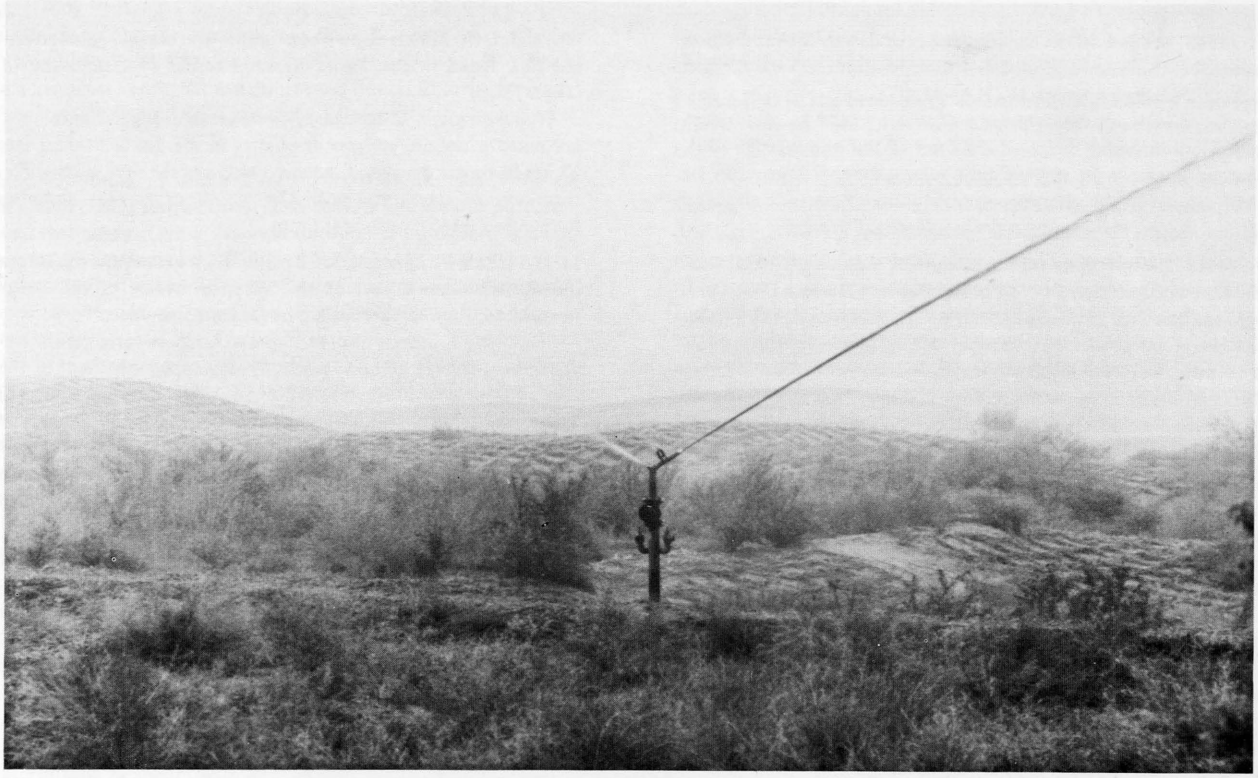
Keng K'uan-hung (1961) Preliminary achievements in study of drift-sand control by clay barriers in Min-Ch'in (translated title). Ti-li (Peiping) 5:200-205. Translation issued by U.S. Joint Publications Research Service, Washington, D.C., as JPRS document 19,037. Available NTIS as AD-408 894.

Tang, H.K. (1961) Relationship between distribution of vegetation and ground water in arid and semiarid areas of Cbina (translated title). Tu Jang 7:34-38. Translated 1968 and available from NTIS as JPRS document 45823, p. 43-53.

Describes a surveyed 40 square km area with an extremely arid climate (annual rainfall less than 10 mm) in the environs of T o-K O-Sun Hsien, Sinkiang province. The area included the Gobi sand dunes and oases with depth to groundwater fluctuating from one meter to several decameters. The relationship between vegetal cover and groundwater is presented. Five main divisions of the area by depth to groundwater and the corresponding plant cover are given, and each discussed in relation to pH and salinity. Results of similar surveys along the middle reaches of the Yellow River in Inner Mongolia are similarly presented and discussed. An annotated profile of vegetation and groundwater level in the environs of Ho-shun-Chuang along the intermediate shoals in Inner Mongolia is shown.

Wang, C.-W. (1961) The forests of China, with a survey of grassland and desert vegetation. Harvard University, Cambridge, Massachusetts, Maria Moore Cahot Foundation for Botanical Research, Publication 5. 313 p.

A general survey is made on the grassland and desert vegetation of the great western interior. The major vegetation types discussed include: the grassland, woodland meadows, muskegs and sand dunes east of Hanhai Gobi in Jehol and the northeastern provinces; steppe of Silingol and Ulanchap, and deserts of Ordos and Alashan south of Hanhai Gobi in Chahar, Suiyuan and Ninghsia provinces; mountain steppe and meadow of Altai; desert basins and oases of Dzungaria and Tarim; and desert alpine vegetation of Sitsang. Chapter VII: grassland and desert, p. 171-210. Includes bibliography (p. 251-274); index of geographic names (p. 277-282); index of Latin plant names (p. 283-313).



Sprinkler at the Shapotou Sand Control Station, using pumped Yellow River water. Although soil development was more advanced and the sand more "fixed" in irrigated areas, due to the mixture of rich river silt with the sandy soil, the stabilization of sand was quite effectively achieved in non-irrigated areas as well. Note characteristic checkerboard field, background.

Academia Sinica, Sand Control Group (1962) Chi-sha yen-chiu (Sand control research), 4. Peiping. 278 p. Translation issued 1963 by U.S. Joint Publications Research Service, Washington, D.C., as JPRS document 20,938. 751 p.

The fourth (and final, question) of the comprehensive reports of this investigative team that gave the world the most detailed description of China's northwest sand deserts known. This last (available) study is addressed to geomorphological features of the entire area, its groundwater supply, distribution of vegetation, soil types, climatology, and wind power. Climatic factors contributing to the 11 percent of China's total land area that are classified as desertic are considered, as is the effect of perturbation caused by man's activities. While the prefatory note points out that even this report is to be considered preliminary, nevertheless the information displayed is detailed, related, scientific, and organized. The physical characteristics of the region and their historical development are now in a fair way to being better known and understood.

Academia Sinica, Sand Control Group (1962) Chi-sha yen-chiu (Sand control research), 3. Peiping. 203 p. Translation issued 1963 by U.S. Joint Publications Research Service, Washington, D.C., as JPRS document 19,993. 508 p.

Reclamation of China's northwest desert regions through sand control was the focus of the investigations reported here. It includes considerable detail on the hydrology, geography, surface materials, and dynamics of the areas covered, particularly the Takla Makan, Tarim Basin, Inner Mongolia, and Sinkiang in general. Attention is given to the geological history as it affects the present geomorphology of the region. Specific recommendations made for the amelioration of conditions responsible for its degeneration are based on vegetation, topographic, and hydrological surveys. Vegetation re-establishment such as windbreaks and reforestation measures seems to be the chief prescription, although there are suggestions for the use of sand to mix with saline soils for crops. Left for future research are ways of increasing water supplies.

Cheng, J.A. (1963) Studies on the characteristics of dew in the sand dunes of desert areas, central Kansu (translated title; in Chinese with English summary). Acta Pedalogica Sinica 11 (1):84-91.

Experimental studies on condensation of water vapor in relation to climatic conditions in sand dunes, conducted in the summer of 1961, indicate that an increase in the amount of condensed water can be accomplished effectively by the proper regulation of particle size and porosity of sand dunes, and also by a dark-colored covering.

Vitale, C.S. (1963) Bibliography on the climate of Sinkiang, China. U.S. Weather Bureau, Washington, D.C. 41 p. Available NTIS as AD-660 813.

Sixty-eight sources with abstracts and author, subject, serial, and subject date indexes were compiled from material dating primarily from 1930-1960. Due to poor meteorological coverage, sources with data for very short or older periods or from narrative books on the whole of China were used to obtain as much material as possible. Much of the material was obtained from the U.S. Weather Bureau library.

Liao, Y.P. (1964) Le controle des deserts en Chine. Acta Geographica (Paris) 51:18-20.

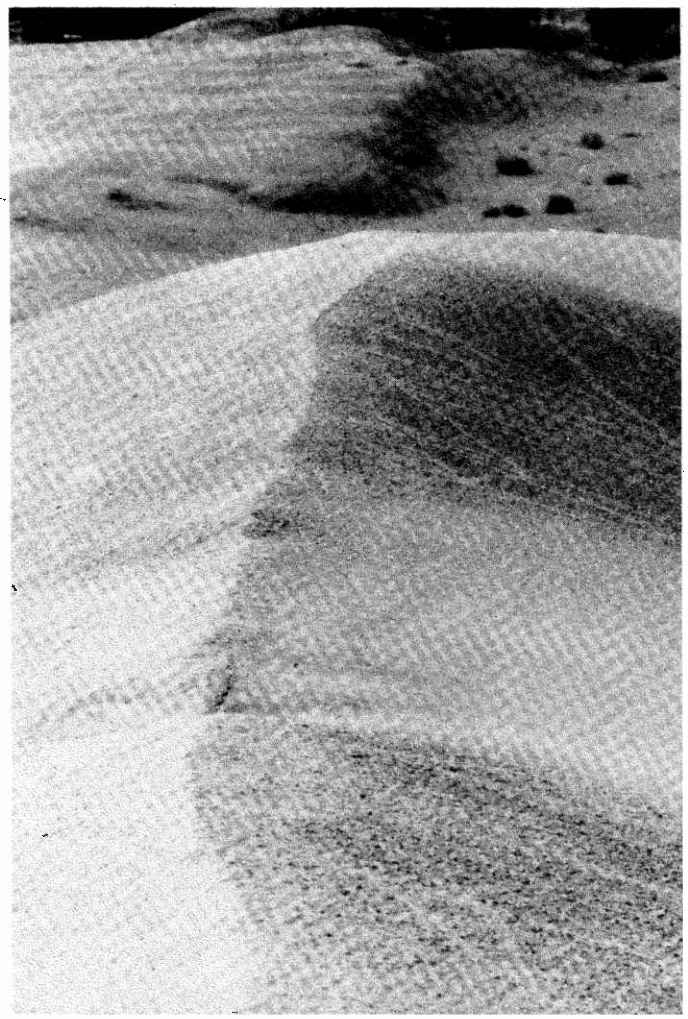
Deserts occupy 11 percent of the surface area of China. This paper briefly describes afforestation programs to build green belts across unprotected areas and bring them into production.

Hoyanagi, M. (1965) Sand-buried ruins and shrinkage of rivers along the old Silk Road in the Tarim Basin. Journal of Geography (Tokyo) 74 (1):55-75.

Archaeological, historical, hydrological and climatic factors that may account for the abandonment of sites in the Takla Makan Desert in the Tarim Basin are discussed. Abandonment of the sites is associated with the shrinkage of rivers and with the retreat of glaciers and their general fluctuation during historical times.

Li, H-f (1965) The genesis and development of stabilized sand dune soils in the central eastern part of the Moyusu Desert of the Ordos Plateau (translated title). Acta Pedologica Sinica 13:66-76.

Fixed sand dunes are widespread and covered with rich natural vegetation. There are few perfectly developed profiles. In the past the surface layer was alternately subjected to wind erosion and sand burying. There is no differentiation between the humus horizon and calcium carbonate layer, but well drained stabilized sand dunes have a profile development with A and AB horizons and sometimes an incipient calcium carbonate horizon. The soils are classified into four depending on the predominance of *Artemisia ordosica, A. frigida, Ephedra sinica* or *Juniperus sabina.*



The edge of a shallow barchan dune near Shapotou.

Whitney, J. (1977) Striking a blow against desertification: Cooperative initiative in Chungwei County, Ninghsia-hui Autonomous Region, China. Economic Geography 53 (4):381-384.

Glorified account of heroic battle against sand dunes, following the line of self-sufficiency, low-technology solutions developed and implemented at the local level.

Wushenchao Commune, Wushen Banner, Inner Mongolia, People's Republic of China (1977) China: Control the deserts and created pastures. An associated case study. United Nations Conference on Desertification, Nairobi, August 29-September 7, 1977. A/CONF. 74/17. 50 p.

Summary report of efforts by this commune to combat encroaching sand dunes and create pastures on the Ordos Plateau of Inner Mongolia, a temperate zone dry grassland. *Artemisia ordosica* and *Salix michrostachyra* have been planted for sand control. Timber and pasture protective forests, a chiefly dry willow and small leaf poplar, have been established, and grazing grasses, particularly sweet clover and alfalfa, planted. Wells and irrigation canals are being developed, and sprinkler irrigation introduced. Detailed descriptions of planting strategies are included. Soil changes are described and plant species listed.

Lanchow, Department of Desert Research/Academia Sinica (1978) Desert transformation in China. Summing-up of masses' experiences in sand control. Scientia Sinica 21 (2):251-278.

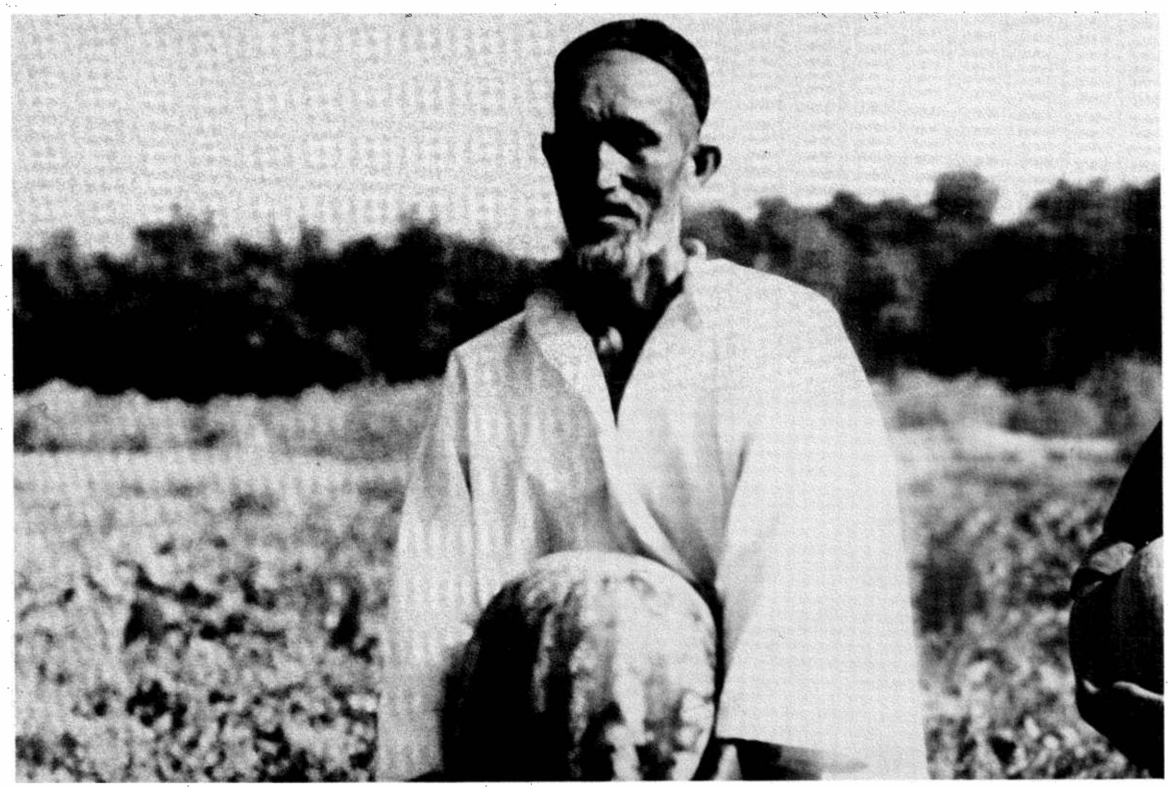
This study describes the 11.4 percent of the total area of the People's Republic of China that constitutes its desert areas of over one million square kilometers, located largely in Sinkiang, Shensi, and Kansu provinces and the Inner Mongolia Autonomous Region. These deserts include several bioclimatic zones which determine the varying degrees of desertification present. This summary of efforts to control this phenomenon includes descriptions of shelterbelts, vegetation establishment to anchor sand and protect natural vegetation, grazing controls, and mechanical barriers. Where water resources permit, reservoirs, irrigation canals, and drainage systems have been introduced. The PRC's long history of attempts to combat desertification is beginning to pay off in increased success at sand stabilization and increased productivity of the land resources so affected.

Li, H-f (1979) The problem of desertification in China's semi-arid region. *In* J.R. Goodin and D.K. Northington, eds., Arid land plant resources, p. 678-683. ICASALS, Texas Tech University, Lubbock. 724 p.

The author, attached to the Academia Sinica's Commission of Integrated Survey of Natural Resources, Division of Land Resources, Peking, discusses in detail the particular area called Maowusu sandy land, a temperate semiarid monsoon region, with a scarcity of rainfall contributing to frequent droughts, in spite of the mean annual precipitation figure of 250-400 mm. Of the total area of nearly 40,000 sq. km., some 13,000 sq. km. are active dunes, causing serious damage to fields, pastures, and roads. In an exploration of ancient cities, it has been demonstrated how great the changes have been over a millenium which is now attributed to overgrazing and exploitation. There is a brief reference to steps being taken contemporaneously to overcome the phenomenon through reclamation and stabilization.

Li, W-h (1979) The vegetation in Tibet of China and its economic significance. *In* J.R. Goodin and D.K. Northington, eds., Arid land plant resources, p. 650-654. ICASALS, Texas Tech University, Lubbock. 724 p.

A preliminary report of the work of the Academia Sinica's Tibet plateau comprehensive investigation team. The distribution of the area's vegetation is determined by a series of environmental factors, among them the relief, monsoons, latitude, and the thermo-effect of increasing temperature by plateau. The so-called alpine desert lies in western and northwestern Tibet: the western, a temperate desert; the other, a cold desert, the highest in Asia, characterized by extremes of climate. Rainfall varies from 50-100 mm. The flora is poor, and because of the cold climate and sparse growth of vegetation, the alpine desert is unsuitable for pasture development.



Melon grown in the Turfan [and eaten, incidentally, by the NGS delegation on the spot].

Despite the *National Geographic's* characterization of the Turfan Depression (42.55N 89.06E) as "one of the world's deepest and hottest," this reclaimed area in the foothills of the Tian Shan Mountains, Sinkiang Uighur Autonomous Region, southeast of Urumchi, is a major producer of grapes and wine. This photo shows grain stubble remaining after harvesting. Irrigation water is brought to this project by underground canals called in China karez (the Persian qanat).

Dalrymple, P.C. et al (1970) Environment of the central Asian highlands. U.S. Army Natick Laboratories, Technical Report 71-19-ES. 58 p. Available NTIS as AD-728 460.

A survey of the physiography, vegetation, and climate of the central Asian highlands that might affect military personnel and equipment above the 2000 m elevation. It treats portions of Afghanistan, China, India, Mongolia, Pakistan, and the Soviet Union in two ways: a general synopsis of the environmental character of the area as a whole, and a series of more detailed treatment by sections, including configuration, water supply, climate, and vegetation. Maps of the general area cover vegetation, climatic stations, mean annual precipitation, temperature ranges, and climatic classification after Koeppen. The maps of the second part cover the physical and cultural features, separately, of the five sections into which the area is divided. While the intent of the report as stated would seem to exclude any consideration of desert areas, the maps are in such detail, though at a very small scale, for those Central Asian deserts like the Takla Makan, Gobi, Tarim Basin, and Dzungaria, that the report serves as a valuable resource for Asiatic arid zone research.

Salter, C.L., ed. (1973) Doing battle with nature: Landscape modification and resource utilization in the People's Republic of China, 1960-1972. University of Oregon, Asian Studies Committee, Occasional Paper 1. 96 p.

This annotated bibliography of 619 items includes such topics as: agricultural technology, land reclamation, industry, industrial wastes, maximizing resources, water resources, afforestation, irrigation, desert, and water conservancy. Subjects of interest are indexed and a short summary of each report is given. Sinkiang, Northwest China, Inner Mongolia are included.

Lanchow Institute of Glaciology, Cryopedology and Desert/Chinese Academy of Sciences (1977) Combatting desertification in China. Summary report on the experiences of the masses in combatting the deserts. An associated case study. United Nations Conference on Desertification, Nairobi, August 29-September 9, 1977. A/CONF. 74/18. 50 p.

Measures of desert control are classified into categories: 1) sand-blocking forest and farmland protective forest network to combat sand scourge, 2) trees, shrubs and grasses combined to stabilize shifting sand, 3) contain-sand-cultivate-grass to protect vegetation, 4) "grass kulun" to block wind and sand and create pastures, 5) engineering measures in addition to sand stabilization with vegetation to protect roads, 6) water and soil resources utilized to create new oases.

Sinkiang Uighur Autonomous Region, Office of Environmental Protection, People's Republic of China (1977) China: Tame the wind, harness the sand and transform the Gobi. An associated case study. United Nations Conference on Desertification, Nairobi, August 29-September 9, 1977. A/CONF. 74/16. 21 p.

Describes desert control measures undertaken in the Turfan Basin of the Gobi to protect farmland from wind and sand. In addition to protecting the natural vegetation of the surrounding areas by grazing and cutting regulations, winter irrigation and manual grass cultivation have been introduced. Resulting increased plant cover reduces surface wind velocity. To further weaken wind-sand onslaughts, white elm, poplar, mulberry, sand date, and apricot trees have been planted as belts on oases fringes, in wind eroded areas, and as protective forest networks within oases. Planting patterns and species arrangements are described, and wind reducing effects discussed.

Even though extensive shelterbelts have been created around Turfan, a single severe windstorm exposed some 20 cm of the root of this plant. The combination of 60-mile-an-hour winds, intense seasonal cold, and the presence of overshadowing dunes makes vegetation vulnerable without the protection of introduced shelterbelts.

Northwest of Urumchi (43.43N 87.38E) is State Farm 150, a reclaimed area of approximately 50,000 acres, on the southern edge of the Dzungaria. This photo shows one of the larger dunes in the area, where there is some expectation of future further development. Presently there are some 20,000 settlers, with crops consisting in the main of melons, cotton, and grain.

A DRY AREA TREE PROJECT IN KENYA

In the Rift Valley of west-central Kenya, an interesting experiment is being undertaken by the Catholic Diocese of Nakuru called "The East Pokot Agricultural Project." *Arid Lands Newsletter* receives its progress reports, and shares the following from that for 1978:

> . . . The terrain is rough . . . for the most part bush scrub petering out to scrub desert in the north. Rainfall is sporadic and variable. The Pokot people are semi-nomadic, though the tendency is now toward settling. The Diocese believes that it is in the best interests of this pastoral tribe to make the inevitable change as gradual as possible, keeping what is good of the old and incorporating it with the new.
>
> The Dry Area Tree Project was undertaken with a trial 2-acre plot set up in Kositei to attempt to determine the best planting methods and spacing for different varieties. It is very easy to cut down a tree, but much more difficult to grow and establish a new one, particularly in marginal semiarid and arid areas where the ecosystem is so much more fragile than elsewhere. But if the ever-present threat of desertification is to be stemmed, trees will have to be planted to help prevent excessive runoff, return nutrients to the soil, encourage better groundcover, as well as provide the source of charcoal, firewood, animal feed, and building materials.
>
> Trees planted included species of Acacia, *Eucalyptus, Bahinea, Tamarindicus,* and *Azadirachta,* with all seed first being started in the nursery. Plantings were set out during the summer rainy season, in mixed stands of two rows of each type. Measurements were taken to monitor growth and mortality. *Leucaena leucocephala* (Giant Haiwan), the only species to be set out directly as a transplant, showed the greatest growth rate. Mortality percentages otherwise varied from 24 percent for *Tamarindicus indicus,* up to 74 percent for *Eucalyptus cyteriodora.* [At the time of this writing] it is difficult to ascertain the drought resistance of the different species, but perhaps in the future, spacing should be increased and the micro-catchment enlarged so as to make more effective use of what rainfall there is. It is also important to plant well-developed seedlings so that seed material has a better chance of rooting properly.
>
> By the middle of November, it was noted that a good grass cover had been established on the previously bare soil.

The Report has much other information about the Mission's food-for-work schemes, training of extension workers, establishment of stores, and the demonstration plots for maize, sorghum, legumes, root crops. Perhaps this low-key, quiet, down-to-earth attempt to help the Pokot help themselves on a small scale without benefit of great international organizations or government subsidies overseen by those far removed from the field, is the way to go.

Write Mr. Edmund G.C. Barrow for more details, c/o Kositei Catholic Mission, Nginyang, P.O. Marigat, Nakuru, Kenya.

INTERNATIONAL CONFERENCE ON ARIDIC SOILS

Aridic soils cover one third of the world's land surface, but lack of adequate data on their properties and distribution has frequently resulted in deceptive notions on the nature of soil resources in arid lands. Desert weathering and soil formation are no less complex than in other zones, and merit a detailed scientific examination of all their aspects. The soil is and will remain the chief resource of arid lands that now provide the livelihood for some fifteen percent of the world's population.

Reflecting the growing interest in aridic soils, an international conference for the exchange of information and ideas on their properties, genesis, and management will be held in Jerusalem, Israel, March 29-April 4, 1981, under the joint sponsorship of the International Society of Soil Science, Commissions V and VI, and the Israel Society of Soil Science. Papers and posters are invited on all aspects of aridic soils, including weathering processes, soil distribution in relation to desert landforms, classification and evaluation of soil resources in arid regions, and biological cycles in arid ecosystems.

Contact: Dr. D.H. Yaalon, Department of Geology, The Hebrew University of Jerusalem, Jerusalem 91000, Israel. Tel: 02-584249.

SO WHAT'S NEW?

". . . It is plain that we do not need aid from Congress, nor do we need millions of money wherewith to people the available areas of the arid regions with a population of progressive and prosperous farmers . . . . There is one great principle to be established by law and honestly applied, and that is, that he who irrigates land for the purpose of raising crops upon it must have as clear right and title to the water used in the irrigation as he has to the land which he irrigates. Without this ownership, untrammeled by State meddling through engineers or other agents of State or corporations, there can be no value, stable value, to the lands and other property invested in the business. There should be no State ownership in the waters any more than in the air; but if the State does anything in the matter it should be by vesting in the owners of the land a right to water sufficient to successfully irrigate it, and *the title to the water should be merged in the title to the land, and forever thereafter the two should become inseparable.*"

—Charles W. Irish, USDA, in an address to The International Irrigation Congress, October 4, 1893, Los Angeles

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But that same International Irrigation Congress itself, on October 20, 1893, took the following stand:

". . . We declare it to be the correct principle that water in natural channels and beds is public property; and when, under the law of any State, vested rights have been secured thereto, such rights, like all other private property, may be supervised for beneficial purposes and be condemned for public uses, under the exercise of the power of eminent domain. *We declare that all streams rising in one State and flowing by natural courses through one or more other States must be conserved and equitably divided under Federal authority.*"

And this:

". . . Windmills in Arizona are one of the commonest features of the landscape, and one of the most pleasing. In some sections of the State every homestead requires a windmill to complete its equipment, and to the cattlemen windmills are indispensable. It is often asked to what extent they can be used for irrigation pumping. Is the possible acreage large enough to justify the expenditure? And are the uncertain winds sufficiently reliable to mature the crops? . . . . There are large areas in Arizona where dry-farming unaided is almost, though not quite, successful, provided judicious selection of crops is made. Experiments have shown that in such cases a small amount of supplementary irrigation increases the yield out of proportion to the small amount of water applied [and] the slow constant draught of a windmill pump can make the difference . . . .

"The amount of wind blowing across a section of land —that is, one mile in width — and extending upward 100 feet into the air, and blowing 14 miles per hour, has a theoretic energy of 10,000 horsepower! Is it any wonder that the rancher is opposed to seeing all of the wind-power go to waste?"

—G. E. P. Smith, Windmills for Irrigation Pumping. Arizona Agricultural Experiment Station, Timely Hints for Farmers, no. 95, June 1912.

??? DOES ANYBODY WANT ???

Heartened by the response to the offer carried in this column in the issue of *Arid Lands Newsletter* for December 1978, we are listing here various publications received since then that are duplicates of our collection. They are available without cost, except for shipping, to *Arid Lands Newsletter*'s readers. Foreign requests should indicate whether materials selected are to be shipped surface mail or air mail parcel post.

AGRINDEX, v. 1, no. 3 (1975) FAO, Rome

Annals of Arid Zone (Jodhpur, India):
- v. 2, nos. 1-2, Oct. 1963-Mar. 1964
- v. 3, nos. 1/2, Sept./Dec. 1964
- v. 4, nos. 1-2, Mar.-Sept. 1965
- v. 5, nos. 1-2, Mar.-Sept. 1966
- v. 6, nos. 1-2, Mar.-Sept. 1967
- v. 7, no. 1, Mar. 1968
- v. 8, no. 2, Sept. 1969
- v. 9, nos. 1-4, Mar.-Dec. 1970
- v. 10, nos. 1,2/3,4 1971
- v. 11, nos. 1/2-3/4, 1972
- v. 12, nos. 1/2, Mar./June 1973

American Association for the Advancement of Science, Southwestern and Rocky Mountain Division, Committee on Arid Zone Research, Contributions:
- #2: Bioecology of the arid and semiarid lands of the Southwest. 1958. 69 p.
- #5: Ecology of groundwater in the southwestern U.S. 1961. 74 p.
- #6: Water improvement. 1961. 73 p.

Arid Zone Newsletter (CSIRO, Australia) 1978

Arizona State Fuel and Energy Office, et al (1975): Water requirements for Lower Colorado River Basin energy needs. 344 p.

Bogaards, J.N. (1969) Report on an inquiry into the farms of some Kusasi farmers. Garu Agricultural Station, Gawku, Ghana. 50 p. + fold. drawings.

Carpenter, J.B./Elmer, H.S. (1978) Pests and diseases of the date palm. USDA Agriculture Handbook 527. 42 p.

Current Agricultural Research Information System (1973): Directory of agricultural research institutions and projects in West Africa. FAO/CARIS, Rome. 543 p.

International Botanical Congress, 12th, Leningrad (1975): Abstracts of papers. 2v.

Journal of Arid Environments:
- v. 1, no. 4, Dec. 1978
- v. 2, nos. 2,3,4. June, Sept., Dec. 1979

Martin, J./Halacy, D. (1974 ?) Arizona and tomorrow's solar powerplants. Arizona State Fuel and Energy Office, Phoenix. 29 p.

Miller, G.T., Jr. (1975) Living in the environment: Concepts, problems, and alternatives. Wadsworth Publ. Co., Inc., Belmont, California. v. p.

Schreiber, J.F./ Matlock, W.G. (1978) The phosphate rock industry in North and West Africa. University of Arizona, Tucson. 21 p.

Tottori University, Japan, Sand Dune Research Institute, Bulletin:
- v. 12, March 1973
- v. 13, March 1974
- v. 14, March 1975

UNESCO, Paris MAB [Man and the Biosphere], Technical notes:
- #6: Development of arid and semi-arid lands, obstacles and prospects. 1977 42 p.
- #8: Environmental effects of arid land irrigation in developing countries. 1978. 67 p.

United Nations Environment Programme (1977): Directory of Mediterranean marine research centres. Genève. v. p. loose-leaf.

University of Arizona, Environmental Research Laboratory/Arid Lands Research Center, Abu Dhabi
Annual report, 1972-1973. 48 p.

??? HAVE YOU SEEN ???

Arid Land Plant Resources, vol. 1, no. 1 - n.d. (1980 ?) ICASALS, Texas Tech University, Lubbock, Texas 79409.

Bishay, A./McGinnies, W.G., eds. (1979) Advances in desert and arid land technology and development. Harwood Academic Publishers, Chur/London/New York. 618 p.

Papers presented at the International Conference on the Applications of Science and Technology for Desert Development, sponsored by the National Science Foundation and the American University in Cairo, September 9-15, 1978. Originally oriented toward Egyptian problems, the international audience insured coverage of desert regions generally, including desert development and combatting desertification, water resources and irrigation, desert plants and environment, energy and mineral resources, technology problems and desert communities, and biosaline research. The Desert Development Demonstration and Training Centre (DDDTC) has since been initiated following Conference recommendations.

Brealey, T.B./Newton, P.W. (1978) The Hedland study: Living in remote communities in tropical Australia. CSIRO Divison of Building Research, Graham Rd., Highett, Victoria, Australia 3190. 100 p. ISBN 0-643-02279-1.

One of a series demonstrating how conditions can be created in remote communities that will attract people and that residents will enjoy as much (or more) than they might expect to in developed centers elsewhere in Australia. Hedland, in a coastal location in the arid Pilbara region of northwest Western Australia, includes company housing but also housing intended for residents other than mining company employees to give the community a more "open" aspect. Included in this comprehensive study are sections devoted to resident attitudes to the town environment, population mobility, and in the appendix the questionnaires used in determining these responses to life there. Numerous illustrations and designs.

Clark, K.N./Paylore, P. (1980) Desert housing: Balancing experience and technology for dwelling in hot/arid zones. University of Arizona, Tucson, Office of Arid Lands Studies. 354 p. $15.00.

A selected series of international studies aimed at achieving a balance between the house and the desert, assuming an energy-conscious future. Experimental houses and examples from the world's desert communities are discussed, documented, and illustrated.

Centre National de la Recherche Scientifique, Centre d'Etudes Phytosociologiques et Ecologiques Louis Emberger, Montpellier, France (1978) Contribution à l'analyse écologique des zones arides de Tunisie avec l'aide des données de la Télédétection Spatiale Expérience ARZOTU, Rapport Final 1975-1978. 222 p.

The Arid Zone of Tunisia (ARZOTU) experiment, based on the use of LANDSAT data, sought to achieve small-scale cartography of ecological zones, land use, and desertification conditions, and to determine the usefulness of multitemporal satellite data for regional ecological modelling. Results appear to allow establishment of a comprehensive view of present potential of spatial remote-sensing techniques in the arid areas along the northern fringe of the Sahara. Recommendations are made for the implementation of a spatial remote sensing experiment, in view of the opportunities for using these techniques in developing countries of the Mediterranean arid zone. Maps, figures, charts, tables. Bibliography of 230 items.

Environmental Conservation, A Quarterly Journal Devoted to Global Survival, vol. 4, 1977. Elsevier Sequoia S.A., P.O. Box 851, 1001 Lausanne 1, Switzerland, for the Foundation for Environmental Conservation. Subscription price SWFr. 120.

This volume contains articles of interest to arid lands investigators on the connection between climate and desertification, Systems analysis of Mediterranean desert ecosystems of northern Egypt, Reclamation of the Sahara, and Animal life and desertification.

Floret, C./Le Floc'h, E./Pontanier, R./Romane, F. (1978) Modèle écologique régional en vue de la planification et de l'aménagement agro-pastoral des régions arides. Application à la région de Zougrata. Tunisie Ministère de l'Agriculture, Document Technique 2. 74 p.

A cooperative study by the French CNRS, UNESCO, FAO, and ORSTOM, on behalf of the Republic of Tunisia. Includes extensive mapping covering the climate, relief, vegetation, rural population, and ecological systems; and the results of the modelling showing the evolution of soil use, regeneration, degradation, and desertification, plus recommendations for management. Many photographs and tables. Bibliography.

Floret, C./Pontanier, R. (1978) Relations climat, sol, végétation dans quelques formations végétales spontanées du sud Tunisien (production végétale et bilan hydriques des sols). Tunisie Ministère de l'Agriculture, Institut des Régions Arides Medenine, Document Technique 1.96 + [25] p.

Includes 64-item bibliography plus sampling of species lists for various stations. Collaborators include UNEP (Project TUN 69/001); CNRS, Montpellier; and ORSTOM. Maps, numerous figures and charts.

George, U. (1977) In the deserts of this earth. Translated from the German (In den wüsten dieser erde) by Richard and Clara Winston. Harcourt Brace Jovanovich, New York/London. 309 p.

Gischler, C. (1979) Water resources in the Arab Middle East and North Africa. Middle East & North African Studies (MENAS), Ltd., Outwell, Gisbech, Cambridgeshire PE14 8TN, England. 144 p. UK£ 11.50, £7.50 paper.

While the author has brought together here a comprehensive review of published sources, the main value of this MENAS Resource Study is its references to a large number of unpublished reports and conference papers of the last decade. He provides an assessment of the scale of renewable and fossil water resources, and reviews the extent and quality of underground aquifers, attempts of governments and institutions to explore and gain access to these resources, and new solutions sought to release water from previously inaccessible sources in the atmosphere.

Goodin, J.R./Northington, D.K., eds. (1979) Arid land plant resources. Proceedings of the International Arid Lands Conference on Plant Resources, Texas Tech University, ICASALS, Lubbock, Texas 79409. 724 p.

In their Preface, the Editors state the theme of the Conference as one centering on new and unused plant resources for food, forage, medicinal and industrial uses. In addition to papers covering these topics, the workshop on plant ecology, management and improvement is included. Contributions from its 92 authors include those from recognized familiar authorities but also expert testimony from many not so well known but with something to say worth listening to. Citations accompany each contribution. Author index.

Hollaender, A. et al, eds. (1979) The biosaline concept, an approach to the utilization of underexploited resources. Plenum Press, N.Y./London. 391 p. (Environmental Science Research, 14) ISBN 0-306-40295-5.

With the threat of worldwide food and fuel shortages, there is pressing need for innovative approaches to increasing global output of these products. Use of regions formerly considered unsuitable for agriculture or energy production, due to their high salt content, is one of the most promising new attacks. This volume explores the food and fuel production potential of various high saline concentration environments, including arid or semiarid land areas, open oceans and bodies of brackish water, and land exposed to irrigation for prolonged periods. Development of salt-tolerant crops is discussed, along with the potential of native plants for food, fiber, and fuel in arid regions.

Institut de Recherches Agronomiques Tropicales et des Cultures Vivrières (1979) IRAT Publications, 1977. Centre de Documentation, Paris. 252 p.

Over 500 citations, with substantial abstracts, covering 14 countries including such arid land areas as Ethiopia, Upper Volta, Mali, Mauritania, Niger, and Senegal. Author, geographic, and in-depth subject indexes, together with addresses of research agencies and missions of IRAT.

Nabhan G. (1979) New crops for desert farming. New Farm [Rodale Press] 1 (3):52-60.

Native plants that drink like a camel hold promise for southwest farmers facing water shortages and high irrigation costs. Jojoba, guayule, buffalogourd, and devil's claw.

Singh, S., ed. (1977) Geomorphological investigations of the Rajasthan Desert. Central Arid Zone Research Institute, Jodhpur, Monograph 7. 44 + 1 p.

Besides aridity, the major environmental problems limiting agricultural productivity and overall development are erosional, depositional, and salinity hazards, shifting of sand dunes and river courses, and scarcity of water. This report details nearly 20 years of scientific investigations covering these aspects, including a section on paleoclimate and desertification. One conclusion is that the Rajasthan is not advancing north/ northeast, although desertic conditions are being aggravated westward through human activities.

Walker, B.H. (1979) Management of semi-arid ecosystems. Elsevier Scientific Publishing Company, Amsterdam/New York. 398 p. (Developments in Agricultural and Managed-Forest Ecology, 7) ISBN 0 444-41759-1. US $78.00.

Easily degraded and difficult to maintain, the world's extensive semiarid regions are under increasing pressure as expanding human populations move in and endeavor to force a living from them. As a result they contain some of the worst examples of resource degradation. This book examines the problems and opportunities involved in man's use of these areas, and provides an up-to-date description of semiarid ecosystems, both abiotic and biological components. It reviews current research and recommended land-use practices.

Weitz, R. (1979) Integrated rural development: The Rehovot approach. Settlement Study Centre, P.O. Box 555, Rehovot, Israel. 92 p. (Publications on Problems of Regional Development, 28) $5.00.

The Rehovot approach to IRD takes into account the political, organizational, social, and economic situations prevailing today in most of the world's poor countries, based on a defined strategy which recognizes within the rural space all relevant sectors of the economy, and uses the interrelationship in such a way as to identify and increase the multiple effect between agriculture, industry, and services. It proposes a set of methods and techniques for planning and implementation, showing how to coordinate policy, investments, and manpower programming between local and area levels, and the objectives and constraints of the national level.

Whyte, R.O. (1979) Initial causation and subsequent periodicity of droughts in China. [Abstract of Paper given at] International Conference on Climate and History, 1st, Norwich, England, July 1979.

Witmer, W./Büttiker, W. (1979) Fauna of Saudi Arabia, vol. 1. Pro Entomologia, Natural History Museum, Augustinergasse 2, CG-4001 Basel, Switzerland. 400 p. 85 SwFr.

Covers mainly insects and other arthropods comprising 42 sections by eminent specialists. Illustrated by numerous drawings, photographs, plates. Additional volumes are projected.

Ben-Gurion University the Negev
INSTITUTE FOR DESERT RESEARCH
Sede Boqer, Israel

The First Annual Scientific Report (December 1978, 223 p.) of the Institute confirms the view gained by the outside world during its dedication Symposium in December 1978 (see *Arid Lands Newsletter* No. 10, p. 8-10). The publication is divided into sections covering a General Progress Report, a Scientific Progress Report, and a comprehensive Scientific Report where the focus is the greatest on those aspects of desert life affecting most of the world's millions of desert dwellers: water, food, habitat, and environmental awareness.

Included are details of several feasibility studies such as a shallow solar pond project, measurement of air flow rates in a dusty environment, storage rings for thermal energy, and an assessment of wind power at Sede Boqer.

A bibliography of 129 citations reveals the scope of scientific activities of the Institute's staff, publications that have appeared in many of the world's most prestigious journals covering a wealth of interests and research investigations relating to world deserts.

The Institute steadfastly maintains its dedication to assisting the State of Israel develop the Negev intelligently and fully, and to providing in the heart of the mid-eastern deserts a research institute for international attention to desert issues, with a broadly-based Scientific Council, workshops and seminars for students from developing desert countries, and facilities for visiting scholars for study and research.

Copies of the Report are available from the Scientific Secretary of the Institute, who put together this impressive account of the Institute's activities to date, Dr. Shabtay Dover, Sede Boqer, Israel (tel. 057-88466).

??? DID YOU KNOW ???

•••that "the world's first solar-powered village" deep in the Papago Indian Reservation, 120 miles west of Tucson, Arizona, might become a model for the other three million of the world's remote villages that now lack electricity? The photovoltaic system generates 17 kwh of electricity per day, energy soaked up from the sun by 24 receptor panels and stored in 53 batteries, provides two 20-watt fluorescent bulbs in each of its dozen or so houses, runs a two-and-one-half horsepower pump for the town's well, and powers 15 pint-sized refrigerators and freezers, a wringer washing machine, and a sewing machine in a community building.

The village of Schuchuli is the beneficiary of this experiment in the Sonoran Desert, funded by the U.S. Department of Energy and installed and monitored by NASA. Present costs are $1.76/kwh, but two-thirds of the cost of the entire project are the non-recurring and experimental costs that subsequent installations elsewhere can avoid. Reports of how the villagers have responded to this event emphasize that it does not bring them everything that a power line, the nearest one presently 17 miles away, might do, nor do the villagers truly understand the technology involved, which may explain their somewhat indifferent response to many aspects of the experiment. Much needs to be done to help developing countries, as well as isolated villages like Schuchuli, understand that the positive advantages of solar electric power need not necessarily conflict with their cultural and historic backgrounds.

For more detailed information, *see* Blevins' article in the November issue of *Smithsonian,* p. 157-167, as well as the technical report by Rosenblum et al, *Photovoltaic power systems for rural areas of developing countries,* sponsored by the Lewis Research Center of NASA, and available from NTIS as document #N79-15411.

•••that the world's first successful at sea, closed-cycle, self-sustaining system generating electric power solely from temperature differences between surface and deep ocean water made its historic breakthrough on August 2, 1979, when power was first generated from a barge moored off the Kona coast of the island of Hawaii? The plant, assembled from off-the-shelf hardware in just 15 months, was financed entirely without Federal funds. It generates 50,000 watts of power, of which 40,000 are needed to operate the system itself, freeing the remaining 10,000 for other uses. In advanced and much larger systems, efficiency will increase with a smaller proportion of the generated electricity required to operate the plant itself. It uses warm surface water to convert ammonia from liquid to gas, then uses this gas under pressure to drive a turbine to generate the electricity. The most desirable areas for its type of operation are in latitudes within 20 degrees of the Equator where maximum variations in water temperature occur. Called Mini-OTEC (for Ocean Thermal Energy Conversion), the trial project is being used to develop and test components and operations for future commercial OTEC power plants of a size that will be of practical interest to electric utilities.

Coastal deserts, take note.

QUOTES

". . . There are only two possible ways in which a world of ten billion people can be averted. Either the current birth rates must come down more quickly. Or the current death rates must go up . . . . But if our choice is for lower birth rates rather than higher death rates — as it must be, for any other choice is inconceivable — then we simply cannot continue the leisurely approach to the population problem that has characterized the past quarter century . . . . Governments, then, must avoid the severe penalties of procrastination, and try to hasten the reduction of fertility forward."

—Robert S. McNamara, President of the World Bank, as quoted in *The Other Side* No. 18, January 1980.