RUNOFF FARMING FOR INCREASED JOJOBA YIELDS

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INTRODUCTION

The Jojoba plant is found in a rainfall zone with a mean annual rainfall of 4 to 18 inches. In the lower rainfall zone it has been observed that the plants are limited to sites where the rainfall is concentrated, such as by sandy arroyos or on alluvial fans at the mouth of canyons. (Gentry, 1958) Gentry has also observed, in a 4.3 inch rainfall zone in the Joshua Tree National Monument, a tremendous difference between two Jojoba plants, one growing near and therefore watered by a road pavement and the other growing away from the road was dry and nearly leafless. Thus it may be concluded that runoff farming techniques applied to the Jojoba plant will increase the growth of the plant. According to Gentry (1958) the low intensity, deep penetrating winter and spring rains are more important to its survival and production than are the higher intensity, summer convectional rains. As the last two years in the Southwest have indicated in general there is more variability at a given station in winter rain totals than there is in summer rain totals. (Sellars, 1960) The chances are greater for a dry winter than for a dry summer. Through runoff farming techniques it may be possible to capture the summer rains, concentrate the water, slow it down and give it a chance to penetrate to the deep rooted Jojoba plant. As will be indicated, it may be possible to also catch and store excess summer rains to be fed back to the Jojoba plant during winter and spring to maximize production of seed. Additional research is needed to determine the full extent of the improvement and the economics involved, to determine if the improvement in yields will justify the cost. The remainder of this paper will dis-

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cuss the various methods of runoff farming available which may be applied to the Jojoba plant.

Runoff Farming On The Negev Desert

One of the classic examples of runoff farming extends back to 1000 B.C. in the Negev desert. There, in a 100 millimeter rainfall regime without any source of additional water, the desert was extensively cultivated and supported a thriving civilization. An estimated 300,000 hectare of the Negev was utilized at one time for runoff farming. Israeli scientists (Evenari et al, 1970) have reconstructed some of the ancient runoff farms and have shown that they can work. These farms consist of two parts, the cultivated area and the catchment basin. Each cultivated area was situated in a relatively narrow valley bottom on loess soil 2-3 meters deep. It was terraced by low stone walls. The farms' catchment basin (20 to 30 hectare in size) was on surrounding slopes. Some of these slopes were smoothed and cleared of rock to increase the amount of precipitation that they would catch. The water harvest from the catchments averaged from 150 to 200 cubic meters per hectare per year or 15 to 20 percent of the annual rainfall. The ratio of cultivated land to catchment area was 1:20 to 1:30. One hectare of cultivated land collected runoff from 20 to 30 hectares of hillside catchment. Each hectare of cultivated land received an average of 4,500 cubic meters or a depth of water of 45 centimeters. (17.7 inches) This water enabled the ancient farmers to successfully grow wheat, barley, legumes, almonds and grapes as reported in documents of the time. (Kraemer, 1958)

Three important features were present at Negev, which allow cultivation of crops in an area receiving only 45 centimeters of applied water. These are: (1) The relatively deep loess soil which allows deep storage of moisture in the soil profile. (2) The low evaporation rate of the wetted soil which is caused by a crust which forms immediately after the soil is wetted by floods. This crust reduces evaporation from the soil to eight to eleven millimeters per year. (3) A relatively high runoff rate which is also caused by the tendency of the soil to crust upon being wetted. This crusting tendency is enhanced by the presence of sodium. The combination of natural sodium and raindrop energy causes the crusting which is the controlling factor in infiltration rate.

The Israeli's have determined that the smaller the catchment the larger is the percentage of runoff. Thus for a 100 millimeter rainfall a 350 hectare catchment produced 2.5 millimeters of runoff, a 10 hectare catchment produced 13 millimeters and a "microcatchment" of one tenth hectare produced 50 millimeters. These findings indicate substantial losses in overland flow on the larger catchments.

Following these observations the Israelis have planted trees, each in its own small catchment. The catchments are constructed by forming an earth border in a rectangular pattern on slight slopes. The borders collect and concentrate the runoff around the planted areas. The cost of construction of the microcatchments is estimated to be between five and ten dollars per hectare. Maintenance would be quite minimal, the greatest expense would be weed control. Weed control is vital since the weeds would transpire moisture into the atmosphere which could otherwise be used beneficially on the cultivated plant.

Runoff Farming in Other Semiarid Areas

Runoff farming has been practiced in other areas of the Middle East and Northern Africa (Shannon et al, 1969). In North America there is evidence of agricultural practices which divert infrequent flood flows onto the land for irrigation. The development of groundwater resources such as in the Safford area, here in Arizona, have reduced the dependence of the Agriculture on flood flows to the extent that this Agriculture cannot be classified as runoff farming. In Mexico, in the state of Coahuila, as well as other states, large bottom land areas are flooded using local runoff from adjacent catchment areas. This practice differs from that in the Negev only to the extent that the catchments are not modified to increase runoff.

The University of Coahuila is also conducting experiments in the raising of peaches in micro catchments. (Martinez, 1970) In 1968-1969 over 200 trees were established in microcatchments. The smallest catchment was 172 square meters and had a cropped to catchment ratio of 1:7. Ratios of 1:9 and 1:13 are also being tested. These plantings were observed by the author in the fall of 1971. In general the peach trees appeared to be doing quite well in spite of the fact that the area had encountered one of the lowest rainfall years on record in 1970. In addition to this the surface of the microcatchments were not kept free of weeds which reduced water yield. Weeds in the wetted area around the tree consumed water which would otherwise be available to the tree. Catchment maintenance and weed control are important items in runoff farming.

Runoff Farming Experiments at The University of Arizona

For the last three years the Department of Agricultural Engineering* has been conducting runoff farming experiments at Atterbury Experimental Watershed. A one-half acre cropped area has been established which is watered from precipitation from a natural hillside catchment area. Two crops of sorgum have been raised during the past two summer seasons on this area.

Beginning in 1963 the Water Resources Research Center in cooperation with the Department of Agriculture Chemistry and Soils* has conducted re-

*The name has been changed to the Department of Soils, Water and Engineering.

search into the area of water harvesting developing techniques that would reduce costs in the harvesting and storage of precipitation. Various treatments have been tested ranging in costs from the sodium treated, but otherwise natural, catchment at five to ten dollars per acre to the use of butyl rubber at a cost of over $10,000 per acre. The sodium treated catchment was effective when initially treated but the effects were temporary and could not be duplicated even with additional treatment. This was apparently caused by the sodium induced clay migration in the light desert soils on which the tests were conducted. (Cluff et al, 1971) An acre plot at Atterbury Experimental Watershed was treated by shaping with a grader, smoothing and compacting. The compaction was done following a natural rainstorm in the spring of 1970. In the two years following this treatment over 200,000 gallons of water have been collected for a catchment efficiency of 33 percent. The treatment is still effective and it should last indefinitely providing it is recompacted every three to four years. Under these assumptions the cost of the water on a large catchment would be less than $.10 per 1,000 gallons. The terminal infiltration rate was found to be 1.8 millimeters per hour. This treatment is similar to that used in Western Australia since 1948. The Australians refer to these catchments as "Roaded Catchments". (Carder, 1970) More than 3,000 acres of these catchments have been installed in Western Australia.

Tests at The University of Arizona have indicated that a treatment of sodium chloride mixed into the surface of the soil prior to compaction will increase the efficiency of the compacted earth catchment and will also tend to eliminate weed growth.

This type of treatment has been established on an acre of land at Page Experimental Ranch located north of Tucson in a 16 inch rainfall area.

This catchment was constructed to be multipurpose to the extent that it would be used for growing horticultural crops and producing water. A schematic of this system is shown in Figure 1. The cost of this system is in the area of $100-$200 per acre. The efficiency of the treatment has been approximately 50 percent. The terminal infiltration rate is essentially zero. The total rainfall required to prime the watershed is less than five millimeters. As evidenced in Figure 1 the excess runoff in this scheme would be stored and pumped back on the horticultural crop during periods of drought. These treatments could be combined with a gravel or plastic mulch as shown in Figure 2 in order to prevent evaporation loss in the wetted area.

The efficiency of the catchment can be increased by paving with asphalt (Myers, 1967) or water repellants such as silicones (Myers, 1969). Deisel oil has been tested by Hillel (1967) as another economic way of increasing the efficiency of the smoothed compacted catchment. These treatments are effective in soils that are stable and that do not shrink and swell.

A treatment which is independent of soil type is the gravel-covered plastic or the asphalt-plastic-chip treatment. These types of treatments, as used in runoff farming, are illustrated in Figure 3. The graveled plastic catchment has been under test at the University of Arizona since 1965. Our research results indicate that a properly constructed graveled plastic catchment in a rainfall regime similar to Tucson should harvest 70 percent of the total precipitation over a 20 year period. The cost of treatment of a graveled plastic catchment depends on the method of installation and the availability of gravel. (Cluff, 1971) For imported gravel a self-propelled chip spreader modified to dispense both gravel and plastic would be recommended. A gravel extracting soil sifter was constructed and tested to install graveled plastic catchments in areas where there is gravel in the soil

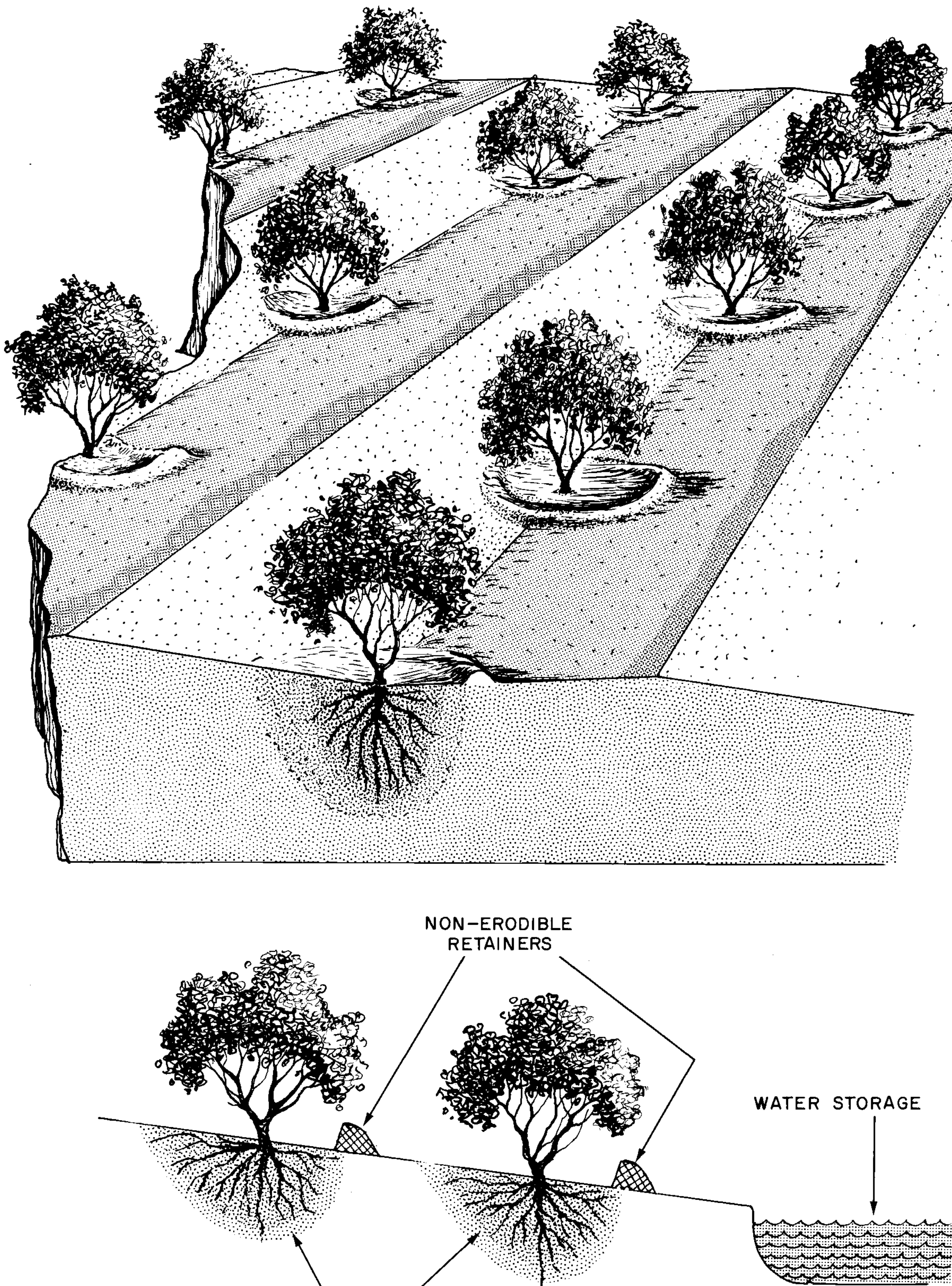
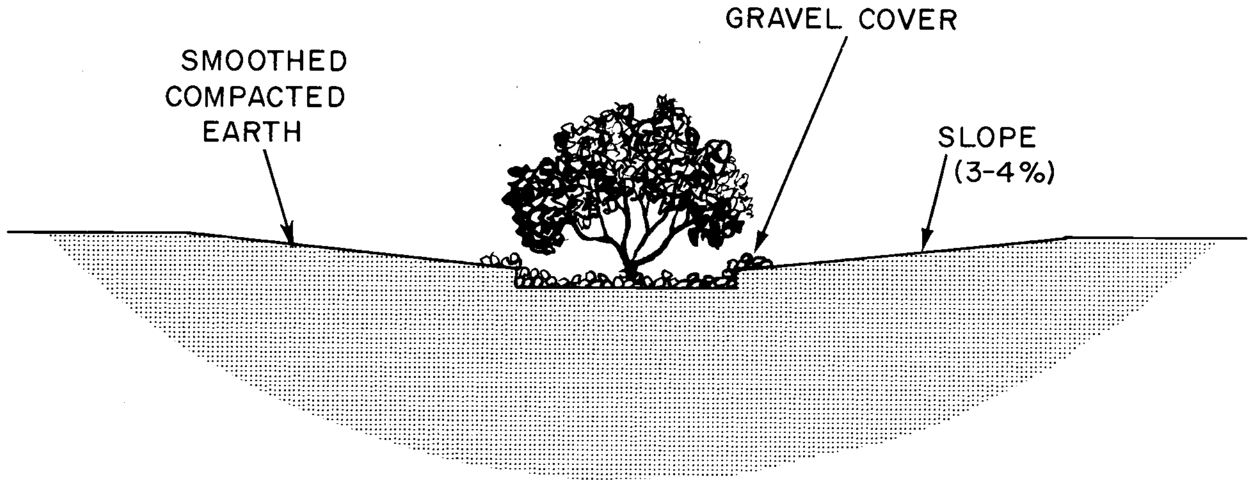
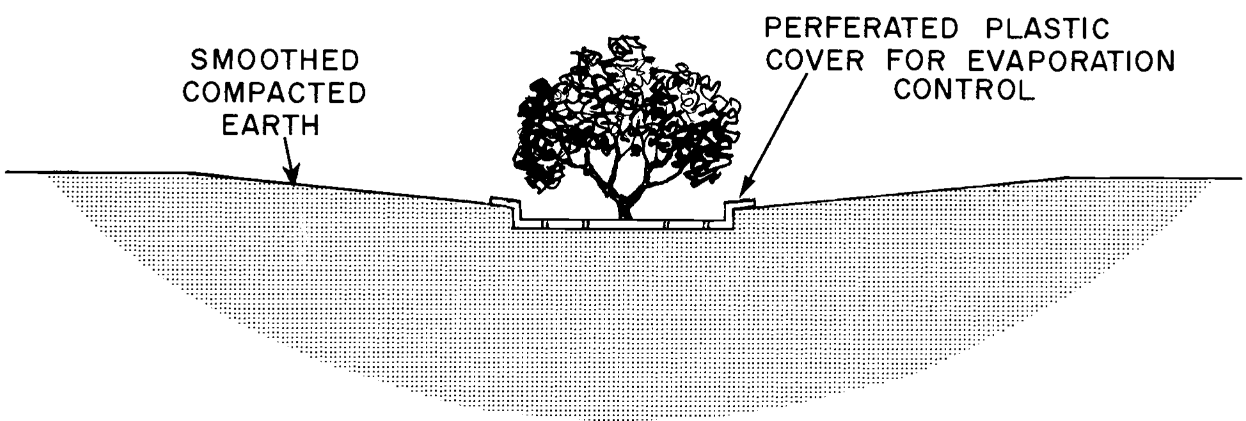


FIGURE 1 -

SCHEMATIC OF SHAPED MULTIPURPOSE CATCHMENTS
FOR GROWING OF CROPS AND HARVESTING OF WATER.



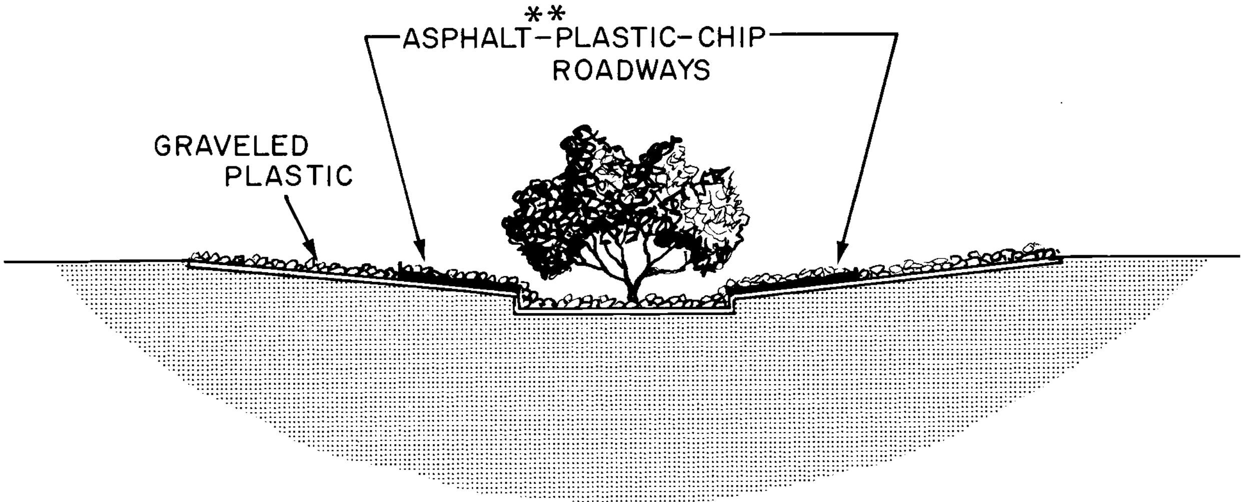
GRAVEL MULCH
COMPACTED* RUNOFF AREA



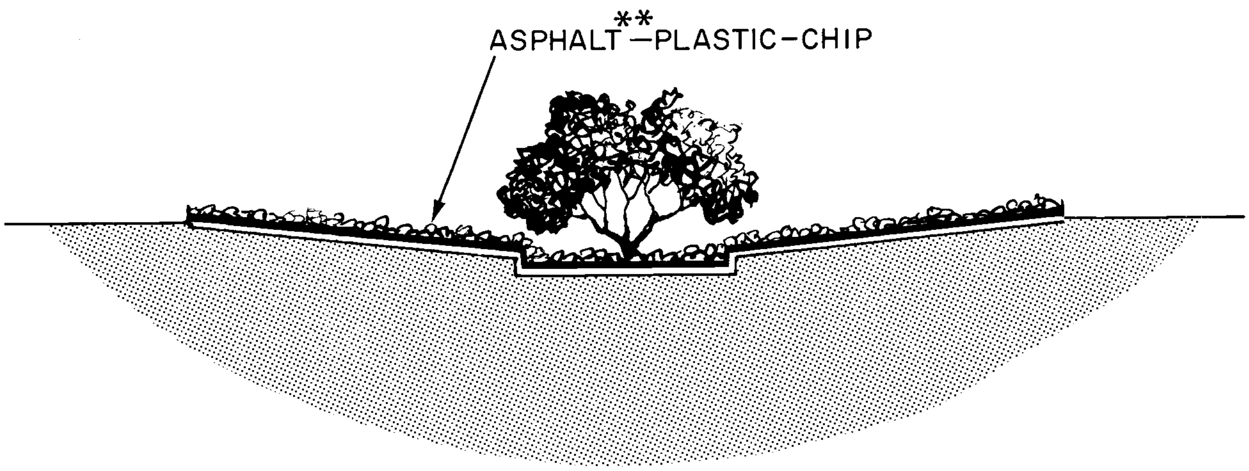
PLASTIC MULCH
COMPACTED* RUNOFF AREA

FIGURE 2 - PROPOSED RUNOFF FARMING TECHNIQUES

*CAN USE SODIUM CHLORIDE IN CONJUNCTION WITH COMPACTION



GRAVELED PLASTIC MULCH
GRAVELED PLASTIC RUNOFF AREA



ASPHALT-PLASTIC-CHIP MULCH
ASPHALT-PLASTIC-CHIP RUNOFF AREA

FIGURE 3 - PROPOSED RUNOFF FARMING TECHNIQUES

**CAN USE EITHER POLYETHYLENE OR POLYPROPYLENE profile. A properly constructed and maintained graveled plastic catchment should last at least 20 years. The cost of water produced from a graveled plastic catchment in a 12 inch rainfall zone using a five percent interest rate would be $.60 per thousand gallons where gravel is imported and $.30 per thousand gallons where there is gravel in the soil profile.

Since the Spring of 1971 an asphalt-plastic-chip treatment is being tested at the Water Resources Research Center. The major disadvantage in using the asphalt is that it requires expensive additional treatment before the water can be used for domestic use. However, this would not be a handicap if the treatment was used in conjunction with runoff farming. The treatment consists of spraying the smoothed soil with asphalt and immediately covering with a layer of plastic. The top of the plastic is then sprayed with asphalt and immediately covered with chips. Both polyethylene and polypropylene plastic have been tested to be used as reinforcement in the asphalt. The polypropylene is more compatible with the asphalt and it is more resistant to mechanical drainage than is the polyethylene. The polyethylene's chief advantages are that it costs approximately one fifth as much as the polypropylene, and is more readily available. The amount of gravel required for this treatment is approximately one third that of the graveled plastic treatment. The water yield efficiency should be greater than 90 percent since most of the gravel chips in this instance are bonded to the plastic with asphalt. The system should be easier to retreat than the graveled plastic system. Firm cost estimates are not available since this system has been under test for only one year. However, if the asphalt-plastic-chip treatment lasts for 20 years the cost per thousand gallons of water should be less than $1.00.

RUNOFF FARMING TECHNIQUES AS APPLIED TO THE JOJOBA PLANT

The runoff farming technique most easily applied to existing Jojoba plants is the microcatchment system. In areas with favorable soil and topography, earth borders could be placed around existing Jojoba plants in such a way as to concentrate the available runoff around the plant. Competing vegetation and grasses could be removed to further enhance the growth of the plant.

The shaped runoff farming technique as indicated in Figure 1 would require the planting of new Jojoba plants. The number of plants that could be supported per acre would be dependent on the amount of rainfall and the type of treatment applied to the shaped catchment. For instance, more plants could be supported if the catchment area were surfaced with an asphalt-plastic-chip treatment than if the catchment were only compacted.

DISCUSSION AND CONCLUSIONS

Runoff farming experience in the Negev indicates that three factors are important in order for this system of farming to be successful:

(1) Inexpensive method of concentrating precipitation.

(2) Good soil moisture holding capacity in the cropped area.

(3) Some method of reducing evaporation loss from the surface of the soil in the cropped area.

In the Negev desert the above requirements can be met rather economically making the runoff farming practical in a 100 millimeter rainfall zone.

In the natural habitat of the Jojoba on the North American Continent some of these factors are not present. However, a compensating feature is that rainfall in excess of 100 millimeters occurs in most of the natural habitat of Jojoba. With this higher rainfall it may be possible to compensate in those areas with sub marginal soil moisture holding capacity by storing excess flood flows in surface reservoirs to serve as supplemental water to be used on the plants during long periods of drought. Evaporation loss from the surface of the soil can be reduced by artificial means.

The cost of water produced by water harvesting methods may be higher than that normally used in irrigated agriculture, but the value of the water when used as a supplemental source may justify the expense. Questions, such as what is the value of one thousand gallons of supplemental water to a Jojoba plant, need to be answered. The Jojoba is an ideal plant to use in runoff farming because it is a native of semiarid deserts and can survive extended droughts. Using runoff farming techniques this plant could be grown on presently pump-irrigated lands in the Southwest which are being forced out of production because of rapidly declining groundwater tables. The Jojoba plantation depicted in Figure 1 would be much more esthetically pleasing than the fields of tumble weeds that are presently growing on abandoned farms. The potential is there but additional research is needed before management decisions concerning increasing Jojoba yields with runoff farming techniques can be made.

Acknowledgement

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