Division of Agricultural Sciences
UNIVERSITY OF CALIFORNIA

IRRIGATION ON STEEP LAND

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CALIFORNIA AGRICULTURAL
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STEEP LAND irrigation of citrus, Riverside County.

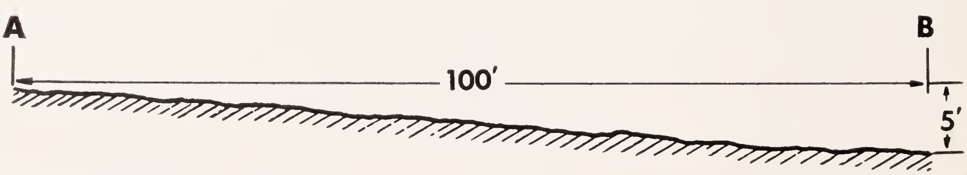
IRRIGATION ON STEEP LAND can be a problem on slopes of 2 per cent or more—that is, where the land drops at least 2 feet within a distance of 100 feet (see below). In such cases proper irrigation methods will save water, conserve soil, and produce better crops. Success will depend not only upon the method of irrigation, but also upon the rate at which water is applied, the cover on the soil, and texture of the soil.

The main irrigation methods discussed in this circular are:

FURROWS . . . . pages 6 to 17
STRIP CHECKS OR BORDERS . . . . . page 18
RETURN WATER SYSTEMS . . . . page 19
CONTOUR DITCHES . . . . pages 20 to 22
SPRINKLERS . . . . page 23
BASIN IRRIGATION . . . . page 24

California farmers have been ingenious in developing many variations of these methods to meet the state's great variations in water supply, topography, soil, climate, and crops. This circular brings together these methods to help you adapt one or more to your own situation. To make the proper choice it will be necessary to understand a few fundamentals of irrigation. . . .

SOIL EROSION can be serious on land with a slope of 2 per cent or more.



This is a 5 per cent slope: the land is 5 feet lower at point B—100 feet from point A.

A FEW FUNDAMENTALS OF IRRIGATION

Soil is a water reservoir for plants

The purpose of irrigating is to fill the soil to *field capacity* to the depth occupied by the plant roots. Roots usually require from one to several weeks to reduce this irrigated soil to the *wilting point* (see terms in the box on the right below).

Soils vary in water-retention

Coarse or sandy soils will hold much less water at field capacity than fine or clay soils. Loam will hold about twice as much as sand, and clay will hold about twice as much as loam. Generally speaking, if the capacity of sand is One, loam would be Two, and clay Four. Expressed as actual percentages of the weight of the dry soil: sand, about 7 per cent; loam, about 14 percent; and clay, about 28 per cent.

Water must be available to roots

Most plants can obtain all the water they need if the soil moisture is in the range from field capacity to approaching wilting point. For most soils, the wilting point is about one half of the field capacity.

How often should you irrigate?

It has been indicated that it is usually necessary to irrigate twice as often on sands as on loams, and twice as often on loams as on clay soils. This is in order to keep a water supply available to plants at all times. Assume, then, that you have three plants of equal size growing in large pots of sand, loam, and clay. *These plants will all use water at the same rate, regardless of the texture of the soil in which they are growing.* Therefore, the water in the sand will be used up sooner than in the loam; the water in the clay will last longer than that in the loam.

When several days are required to irrigate an area, irrigation should be started in order that it be completed so that the last plants receive water before they wilt.

When to start irrigating

Most crops have a definite pattern of water usage. During spring they start out using relatively small amounts. Summer brings peak need, with a lessening during fall. For example, an orchard might require these amounts of water during these months:

April	1 acre-inch
May	3 acre-inches
June	5 acre-inches
July	6 acre-inches
August	6 acre-inches
September	3 acre-inches
October	1 acre-inch

When to start irrigating also depends on the amount of rainfall during the

FIVE IRRIGATION TERMS

FIELD CAPACITY: The amount of water held by the soil shortly after irrigation, provided there is free downward movement through the soil. In other words, when irrigation water has completed its downward and horizontal movements, the soil is at field capacity.

WILTING POINT: The point when the soil has not enough moisture available to prevent plants from wilting.

ACRE-INCH: The amount of water necessary to cover one acre of ground with one inch of water. The equivalent of a one-inch rainfall.

HEAD: The amount of irrigation water delivered, and variously measured as cubic feet, gallons, or miner's inches.

PER CENT SLOPE: The term given the fall (or rise) of lands in feet, compared to horizontal distance. (See page 4.)

previous winter. In the case of permanent crops, such as orchards, a light winter's rainfall makes an earlier irrigation necessary, to bring the soil which plant roots occupy to field capacity. For annual crops, the soil which the roots will occupy should be at field capacity before planting.

Soil is either wet or dry

Rain on a dry field wets down a definite distance. The soil underneath remains dry. So it is with irrigation water—it wets to field capacity, but adjacent ground remains unchanged.

Wet the entire root area

An irrigation should wet all of the soil which the plant roots occupy. Rain is ideal because it falls evenly and wets the entire area. Irrigation can approach this perfection if these warnings are heeded: Furrows, if spaced too far apart, will not wet all the soil between them. Insufficient water in basins will not seep deeply enough. Sprinklers must be left at each setting long enough to allow proper penetration.

Don't overirrigate

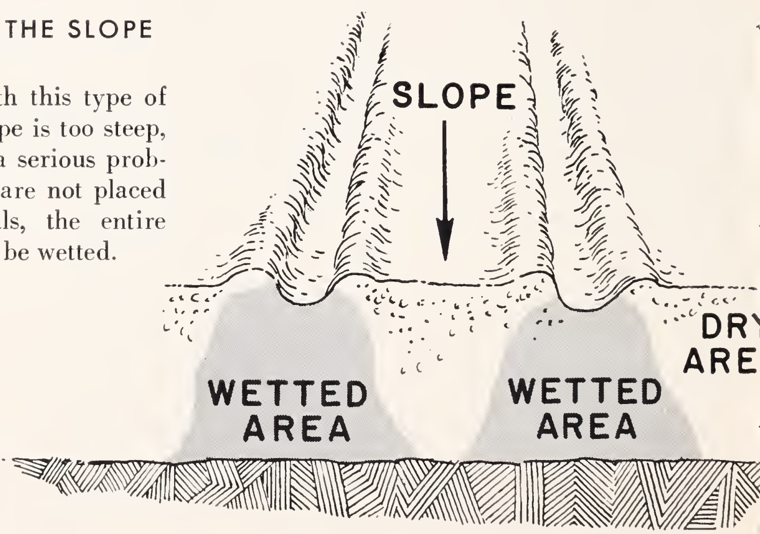
As most of the soils discussed in this circular are of limited depth—underlain by bedrock, hardpan, or claypan—overirrigation is likely to waterlog the soil just above these impervious strata. This water may also seep to the base of the slope in such volume that it could drown out trees. Watch particu-

FURROW IRRIGATION

Below are two illustrations of furrows—one running from top to bottom, the other across the slope.

FURROW DOWN THE SLOPE

Two hazards go with this type of irrigation. If the slope is too steep, soil erosion can be a serious problem. If the furrows are not placed at frequent intervals, the entire mass of soil may not be wetted.



larly citrus crops and avocados: slight overirrigation can cause gummosis in citrus and root rot in avocados.

Variations in soils

Some soils will not give up the usual one half of the water they contain at field capacity. They must be irrigated more frequently. In the Sierra Nevada foothills there are red soils that provide good examples of these exceptions.

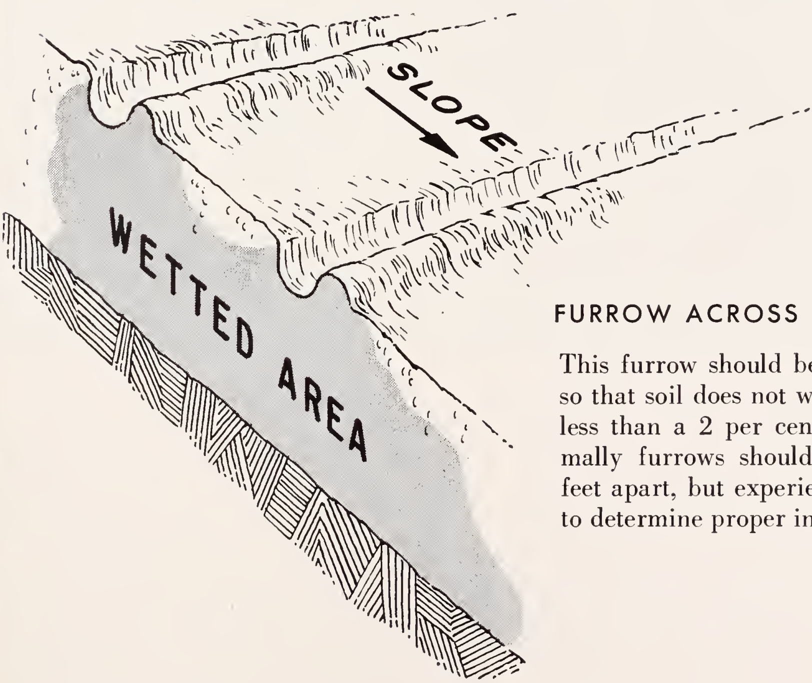
Variations in crops

Some crops, *when young*, require a higher percentage of soil moisture. This is because the young plants have underdeveloped root systems. These should be given lighter, more frequent irrigations.

A length of 3/8-inch rod, sharpened at the end, will help you to find out to what depth water (either rain or irrigation) has penetrated. Press the rod into the wet ground. It will stop at the dry level. Be careful when you use the rod in rocky soil that you do not confuse rocks with dry soil.

EASY-TO-MAKE

SOIL TESTER



FURROW ACROSS THE SLOPE

This furrow should be flat enough so that soil does not wash—usually less than a 2 per cent slope. Normally furrows should be about 6 feet apart, but experience can help to determine proper intervals.

SUCCESS COMES WITH CHANGE IN IRRIGATION TECHNIQUE

This olive orchard in Butte County was originally irrigated almost straight down the slope—left to right in the photograph—on a grade of 5 to 6 per cent. Growth and production were unsatisfactory. It was suggested that the furrows be run across the slope, as shown. Growth was vigorous, and crops increased considerably.

The soil is about 18 inches deep. It is stony, and underlain by bedrock. With the old method of irrigation, a relatively small part of the soil was wetted. Now the water seeps down and wets the root areas. *Caution:* Do not overirrigate. It is particularly harmful for citrus and avocado crops.

A SKILLFUL DOWN-THE-SLOPE IRRIGATION ON 4 PER CENT GRADE

Here is a fine young grove of oranges in Riverside County that utilizes furrow irrigation on a slope that normally would be considered dangerously steep for this technique. However, there has been no evidence of erosion. The photograph was taken following the first irrigation after the furrows were made.

Just prior to making the furrows, a heavy covercrop was worked into the soil. Remnants can be seen in the foreground. A very small amount of water was turned into each furrow to "set" the soil, to prevent washing with large heads during subsequent irrigations. This irrigation has sprouted the next covercrop, and the soil will soon be full of small roots which will make it still more resistant to erosion. Note that the furrows pictured are at frequent enough intervals to assure wetting all the soil to field capacity.

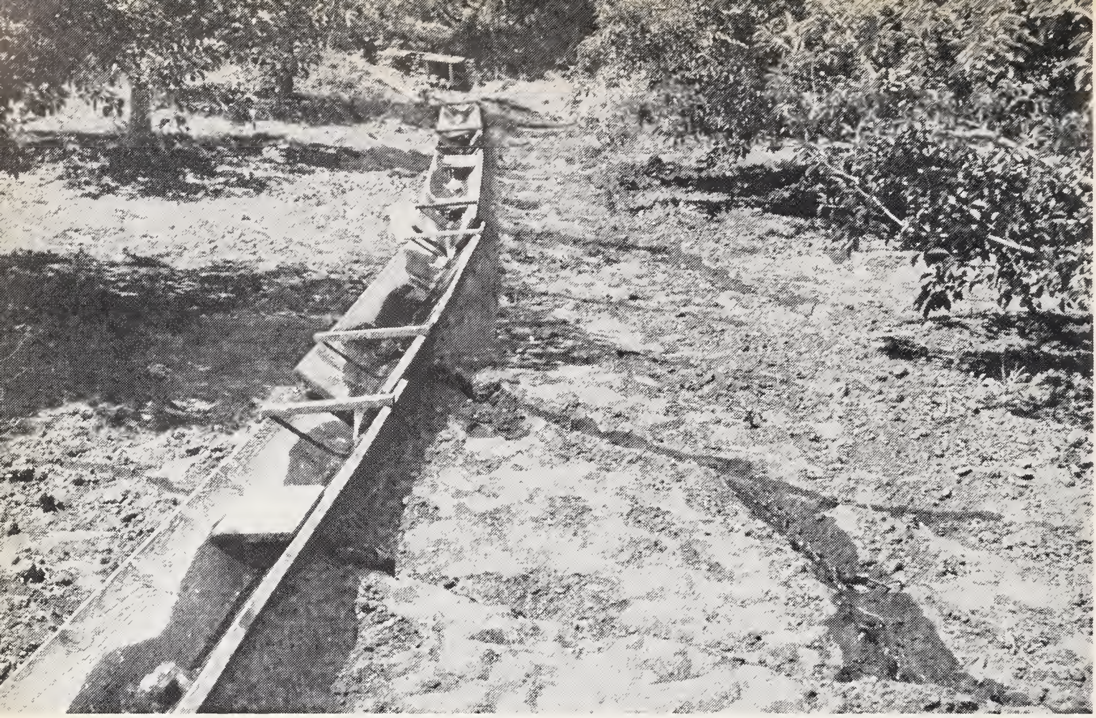
Once again, caution: The most critical point of irrigation under these conditions is the first usage of the furrows. Water must flow very slowly and in small amounts.

"HOMEMADE" DEVICES REGULATE FLOW, AVOID UNDUE WASHING

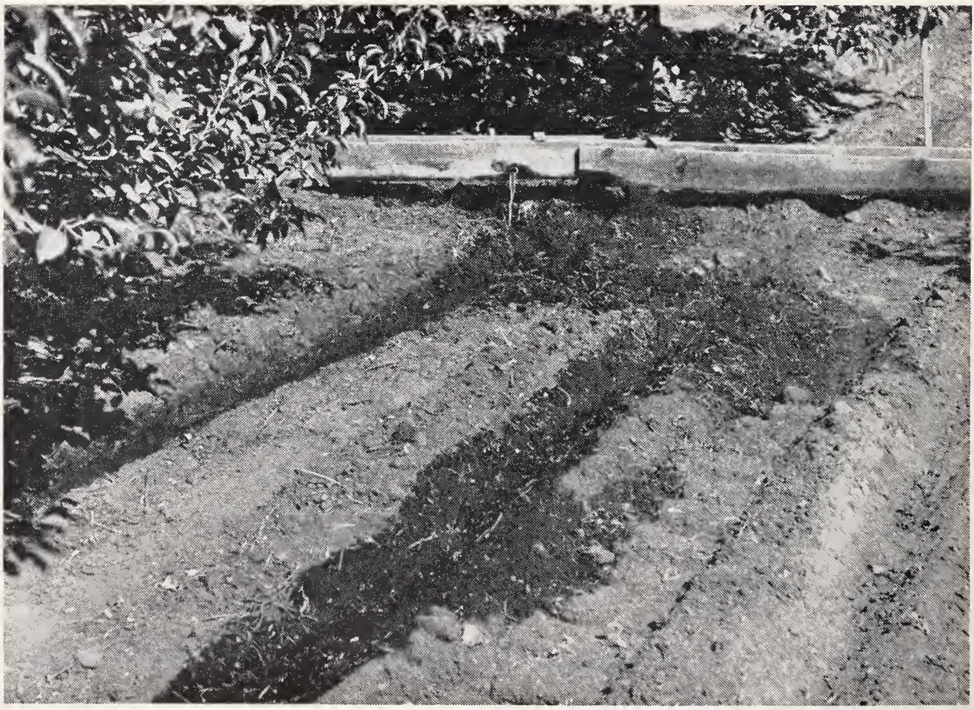
Native ingenuity comes to the rescue in devising methods and using materials at hand to get the job done. A case in point is the use of such items as rocks, burlap, paper, short boards, slats, weeds, and other materials to regulate the amount of water admitted to a furrow.

The upper photograph shows a pear orchard in El Dorado County, and the use of burlap dams. They can be seen in the ditch at the right. The lowest one is placed to divert the stream to the left and into a furrow. *Note:* If another burlap dam had been placed midway between the two nearest ones, there would have been less erosion. They usually are about ten inches square. Occasionally steep supply ditches are lined with burlap.

The photograph left shows the supply ditch running from upper left to lower right. Small rocks are used to regulate the height of water in the ditch, and the directing of water into the irrigation furrows.



THE USE OF FLUMES TO CONTROL IRRIGATION WATER SUPPLY



The grade of about 20 per cent in pear orchard in El Dorado County (left) is much too steep to allow usage of a supply ditch. Water from a pipe line is run down a portable V flume—and fed to the furrows, as desired, from 1-inch holes in the sides. Control is maintained by small slide gates covering the holes on the outside of the flume. Rocks are placed in the flume below each opening, so that they allow a small pool to form, expediting the flow from the hole. Note, too, the small boards placed to prevent water splashing from the flume as it hits the rocks. The flumes are easy to construct and easy to move.

The main irrigation system for the orchard on page 12, below is a series of concrete pipe lines. The furrows between them are quite long. When the ground has been newly cultivated, as shown, the entire length of the furrow cannot be irrigated without causing some erosion. To avoid such difficulty, this owner has built a portable box flume. It is placed in the orchard about halfway between the pipe lines. Thus smaller heads can be run from both the pipe lines and the flume. (The flume is in 16-foot lengths, with the botton board of each tapered so sections telescope). Note the remnants of the recent covercrop which has been worked into the surface soil.

GATED PIPE FOR WATER DISTRIBUTION

Gated pipe (ordinarily slip-joint pipe with gates to release the water) is a convenient method of distributing water on sloping or uneven land. The photograph on the right below shows a 4-inch gated pipe used between hydrants on a concrete pipe line. This method, which can be used on cropland and in orchards, has advantages because you can easily control the amount of water admitted to each ditch. The photograph on the left shows a long line of 8-inch gated pipe. This method has the same advantages as those of the 4-inch pipe, and in addition makes unnecessary installation of a concrete pipeline. *Caution:* This type of metal pipe can be used only under low pressure. High pressure causes excessive leaking at the joints and may even rupture the pipe.

A "ZIGZAG" PROTECTIVE FURROW SYSTEM

This walnut orchard in Los Angeles County has been prepared for irrigation with a very effective, yet seemingly complicated, furrow system. The furrows "going away" from your vision were prepared first, across the slope, and practically level. Those going from left to right in the photograph were made, using a blocking device, so that the water "zigzags" through the orchard. This method can be used when the slope is as much as 3 or 4 per cent. The slope illustrated, however, is somewhat less.

Because of cultural operations, it is necessary to prepare these furrows at least twice each year—once for protection against winter storms, and again for summer irrigation. After harvest, a covercrop is sown, and the furrows are reworked. The covercrop and the furrows adequately protect the orchard against erosion, which frequently results from heavy run-offs caused by storms. The covercrop is worked into the soil in the spring, and the system is prepared once more for summer irrigation. If weeds grow too vigorously, the orchard may have to be disked and furrowed during the summer.

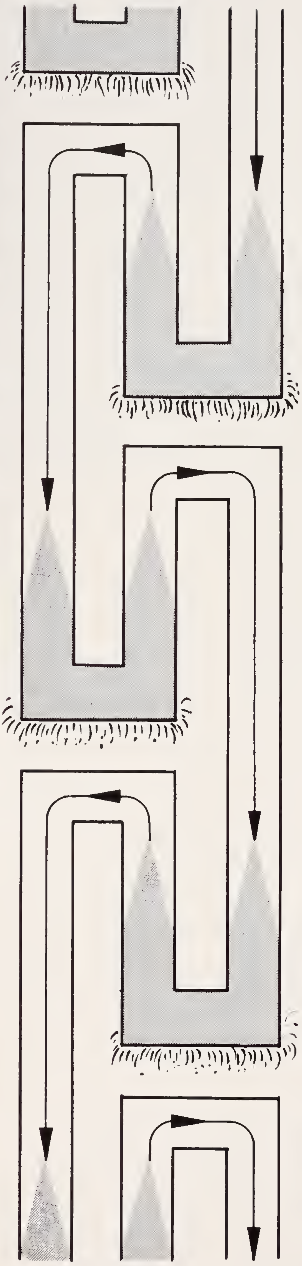
This is one of many effective systems that can be used in stepping water down slopes without danger of washing.

CUTBACK FURROW IRRIGATION

An ingenious method to increase the wetted area in a furrow is the cutback furrow irrigation shown in the diagram. It is useful on sloping land where water does not wet a large enough percentage of the soil to promote adequate crop growth. The reason for this lack of soil wetting is that the water often flows in a small stream in the bottom of the furrow. If the furrow could flow nearly full, the wetted surface would be increased, with consequent greater infiltration.

To use cutback furrow irrigation, you must have 3 (or 6, 9, etc.) parallel furrows between crop rows. In the diagram the water supply comes in the right furrow toward you, is deflected by a dam to the center furrow and runs away from you; then it is deflected to the left furrow, where it runs toward you, etc. The furrow dam and the connection between furrows must be made by hand. The spacing of the dams in the furrows is determined by the slope of the furrow.

A change to this system of furrow irrigation can be very beneficial if trees are not getting adequate water for good growth and production.



STEEP-SLOPE IRRIGATION ON ADOBE SOIL

Here is a grove of orange trees, planted in adobe soil, with a slope of about 6 per cent. On drying, the soil cracks very badly which eliminates the use of any form of contour irrigation, because contour furrows just would not hold the water. If furrows are used at all, it is recommended that they run straight downhill. Small heads, run for a considerable time, give a satisfactory irrigation and avoid erosion.

The upper photograph shows the metal supply pipe line at the left, with the nozzles projecting toward the orchard. The lower photograph illustrates cracking of the adobe soil.

As can be seen, the Bartlett pear tree shown is stunted. The irrigation furrows have cut deeply into the soil, which is about two feet deep on bedrock. Even if they had not, they would still be inadequate to wet the entire soil mass. This side-hill orchard could be irrigated successfully by any of these methods:

1. *Contour furrows* run across the slope on a grade of about 1½ per cent. (At right angles to those shown in the photograph.) Two furrows to the row would be sufficient, because the water would penetrate to the bedrock, seep down the slope, and wet all of the soil.

2. *Contour ditches,* as shown on page 20, could be employed in this orchard at intervals of about 60 feet. The orchard should then be planted to permanent cover. Irrigation water could be spilled over the bank of the ditch every few feet to guarantee complete wetting of the soil.

3. *Sprinklers* and a permanent covercrop would be very effective. (See page 23 for details.)

CLEVER ADAPTATION TO PREVENT WASTING WATER

STRIP CHECKS OR BORDERS

Most irrigated pastures are planted on soils with hardpan or dense clay subsoils. The Ladino clover pasture shown is an excellent example of a relatively new method of land preparation for the maximum usage of irrigation water. Formerly the land was graded so that the strip checks ran all the way to the drainage ditch. The length of time necessary to run the water in the strip checks in order to get good penetration often resulted in great waste. The new method of leveling is shown in the sketch below. The ridges extend only to the basin. The excess water from the checks irrigates the basin, shown in the foreground of the photograph. The small amount of excess water runs into the drainage ditch.

RETURN WATER SYSTEMS

ANOTHER WATER SAVER: USE OF RETURN FLOW

Irrigation water is becoming less abundant and more expensive. Therefore methods to use water more efficiently are in demand. One such practice, known as the "return-flow" system, is coming into widespread use. It consists of collecting runoff irrigation water and pumping it back into the irrigation system.

In the photograph above, runoff water is being collected in a sump and pumped back into the irrigation lines to water the orchard in the background. Below, runoff water from the pasture shown is being pumped back into the irrigation system.

CONTOUR DITCHES

Steep land can be utilized for irrigated pastures if proper methods are used. Contour ditches are simple and successful. The photograph at left shows a ditch with a grade of about ½ per cent. The water is spilled over the lower edge by means of sod dams in the ditch (see arrows). Other methods of diversion are shown on page 22. Excess water collects in the next ditch which is usually about 75 feet below, supplementing irrigation water in the second ditch, and so with others down the grade. Use your judgment to assure complete irrigation; space ditches close enough to wet the entire area.

The pasture shown in the photograph below is a good example of the use of contour ditches. Note how the dry pasture at the crest of the hill contrasts with that irrigated. The light patches in the right center of this picture indicate dry areas—the probable result of the ditches being too far apart to wet the entire area.

SUCCESSFULLY IRRIGATED PASTURES ON HILLSIDES

ORCHARDS, TOO—

Deciduous orchards can also use this irrigation method in conjunction with a permanent covercrop. Under these conditions, however, the ditches must be steeper, because the unpastured vegetation tends to clog them.

Caution: When permanent covercrops are used in orchards, gophers become a problem, as it is not easy to detect their workings. Field mice sometimes build nests at the bases of trees, and girdle them. Consider the rodent problem before adopting a permanent covercrop program.

DIVERTING WATER FROM SUPPLY DITCHES

Water can be diverted from the ditches to the field by many methods. Two are shown in the photos below.

Here, the water is diverted from the field ditch by means of temporary partial dams. Rocks have been placed in the ditch to hold back the water so that part of it will overflow the lower sides. Sometimes straw or weeds are used with the rocks to make a tighter dam. In some cases shovelfuls or blocks of sod are used instead of rocks. Water can be diverted at the same time from several of these dams.

In this case a metal tapoon is used to divert all of the water in the supply ditch onto the field at one outlet. Note the unirrigated area at the left above the supply ditch.

SPRINKLER IRRIGATION

SPRINKLER SYSTEM REPLACES FURROWS IN PEAR ORCHARD

From clean cultivation and irrigation by furrows, this orchardist switched to permanent covercrop and sprinklers. The orchard is on a slope of about 5 per cent, with soil about 22 inches deep on bedrock. Result of the old system was uneven application of irrigation water and soil erosion. The new technique has proved very successful.

Irrigation water is delivered at a high point, so pumping is unnecessary to develop pressure. The water is distributed through an underground 3-inch pipe, equipped with outlets for the portable sprinkler line.

Each irrigation starts at the upper edge of the orchard, with the portable line moved progressively downhill—wetting every other middle. When the lower edge of the orchard has been irrigated, the sprinkler line is moved once again progressively up the hill, and the alternate middles are irrigated. Thus complete wetting is accomplished.

The covercrop is predominantly Ladino clover, ryegrass, and orchardgrass. It is mowed and left in place each year just before the props are put in the orchard. Once again, caution is advised with regard to careful control of rodents who may take up habitation in the covercrop.

Note: Instead of the sprinkler heads shown in this picture, rotating sprinkler heads are now used extensively.

Tanking—shown in the top photograph—is simply the use of a circular basin around the tree, and watered as indicated. A second method using a long narrow basin is shown in the photograph below. A third technique employs the running of a single furrow close to the tree rows, with a circular furrow around each tree.

As the root systems enlarge each year, increase the irrigated area for each tree. Generally, do not use such partial irrigation more than two or three years. There are some exceptions to this. Widely spaced walnut trees, as shown in both photographs, can be wetted in this fashion for a longer period.

BASIN IRRIGATION

During the first few years after planting, the root systems of trees do not develop to the point where they occupy the entire soil mass in an orchard. It is unnecessary, therefore, to irrigate the middles of the rows during this period.

Caution: Citrus and avocado trees should not be treated so that the irrigation water comes into direct contact with their trunks. Nor should the earth be mounded against the trunks. A donut-shaped circular basin, with the inner margin a few inches from the tree, is recommended.

METHODS USED FOR IRRIGATING YOUNG FRUIT TREES

A NEW IDEA: DRAG-LINE HOSE SPRINKLERS

Shown in these two photographs is a new system of sprinkler irrigation developed during the past several years. It consists of an underground pipeline with occasional outlets. The above-ground part consists of a hose about 150 feet long connected to the outlet and with 2 to 5 sprinklers about 20 feet apart at the opposite end. To irrigate, turn on the water as with a garden sprinkler and from time to time drag the sprinklers to new locations. Various sized nozzles can be used on the sprinklers to regulate the rate of application to the infiltration rate of the soil. This system has proved to be very effective on steep lands to minimize runoff and soil erosion. It is also finding some use for applying water evenly on flat lands.

IN BRIEF . . .

Irrigation of steep slopes is a difficult undertaking. You do not necessarily have a "best" method for a certain situation, but rather several alternatives.

IN ORCHARDS,

land on less than about 6 to 8 per cent slope can be square planted and irrigated effectively by the furrow system. Land less than about 20 per cent slope can be planted on the contour and irrigated by either furrows or sprinklers. On steeper lands sprinklers must be used because furrows will break over the lower side.

ON PASTURES,

strip checks can be used on land up to 6 to 8 per cent slope. On steeper land contour ditches or sprinklers can be used.

HOW THE UNIVERSITY OF CALIFORNIA WORKS WITH AGRICULTURE

As one of the nation's Land-Grant institutions, the University of California plays a multiple role in service to agriculture. This involves teaching, research, and conveying the facts developed by research to those who may put them to good use in the best interest of all the people.

These activities are combined in the University's *Division of Agricultural Sciences.* This statewide framework includes:

The *College of Agriculture* providing instruction in agriculture and related sciences on campuses at Berkeley, Davis, Los Angeles, and Riverside. The *Schools of Forestry* and *Veterinary Medicine* function as separate professional schools within the Division but are closely related to the College of Agriculture.

The *Agricultural Experiment Station* conducting research on the four campuses mentioned above as well as on numerous field stations, experimental areas, and farms throughout the state. Closely allied with the Experiment Station are the *Giannini Foundation of Agricultural Economics* and the *Kearney Foundation of Soil Science.*

The *Agricultural Extension Service* with 53 offices serving 56 counties carrying out the responsibility of "extending" research results to the people. The Service cooperates with the Experiment Station in local research on thousands of farms. It also conducts youth educational activities through the 4-H Club program.

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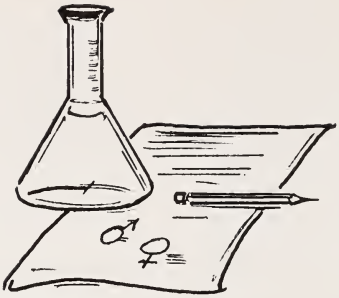
it works here . . .

Many experiments conducted in the laboratories by staff members of the Division of Agricultural Sciences show promise of benefiting crops or animals.



it may work here . . .

Laboratory findings are often given further tests under controlled conditions in greenhouses (new plant varieties, for instance).

but will it work here?

Possibly not. Some (these new plant varieties, for instance) fail miserably when the Experiment Station and Extension Service staff members collaborate in field testing the experiments.

if it does . . . if field tests indicate higher yields, greater resistance to pests or disease, drought or moisture—if the development benefits mankind, the facts will be made available. Thus is science applied to agriculture by the

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