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FUNDAMENTALS OF RRIGATION

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In most parts of New Zealand the oisture in the soil is deficient durng some part of the growing season, hat is, the soil moisture is less than necessary for the maximum growth f crops and pastures, and therefore roduction suffers. An obvious way, hen, to increase production, is to pply water to the soil artificially y irrigation, at times when soil moisure is tending to become deficient. ut this can only be done at a price; so hat, in places where soil moisture is nly occasionally and irregularly decient, the costs of irrigation will ften exceed the value of the inreased return from the irrigation; hat is, irrigation will be uneconomcal. On the other hand, in places here soil moisture is deficient fairly requently and for fairly long periods, hen irrigation can be made to pay, f, in deciding on and planning an rrigation system, careful consideraion is given to all the factors that ffect efficiency and costs, and if ound management practices are folowed.

ource of Water for Irrigation.

In the main areas of New Zealand here irigation is practiced, viz., midanterbury and Central Otago, water s brought to the farm in canals and races under community schemes. The farmer who wishes to irrigate buys the water from the authority controlling the scheme, or pays rates for the privilege of using the water.

Rivers or streams flowing near or through the farm are another common source of water for irrigation throughout the country. Small streams often carry less water than they appear to, and the discharge or flow should be measured to make sure it is adequate for the job. There is also danger of their drying up in a very dry summer when the water is most needed. Before arranging to take the water from a river or stream for irrigation, the authority controlling the stream must be consulted, and the rights to the water of persons lower down the stream must be respected. For particulars of plant for pumping water from streams for surface irrigation, Bulletin No. 254 "Pumping for Surface Irrigation" may be consulted.

Underground water is another common source of supply of irrigation water. This can be tapped by sinking wells, which can be either pipes sunk into the ground or open wells of large diameter lined with timber, steel or precast concrete. Wells in alluvial sands and gravels usually provide the best supplies. Artesian wells or springs rising naturally to the surface sometimes provide a good supply. Where the water does not rise of its own accord, a properly-planned pumping installation will be needed.

For information on the possibilities of obtaining an adequate supply of water, a geologist or a well-sinking contractor experienced in the district should be consulted. No reliance should be placed on so-called "water-diviners" or "dowsers".

Another possible source of water is surface run-off of rain, which can be trapped in a depression dammed by an earth dam, or in an excavated basin, in the same manner as is often done for stock water; but it must be realised that very large amounts of water will need to be stored for irrigation. For example, to irrigate 10 acres with a depth of 18 inches of water during the season, would require as much water as could be stored in a pond two acres in area and eight feet deep.

Highly saline water is harmful to growth. This could occur in brackish creeks and in rivers or wells in arid areas. In cases of doubt, a sample of the water should be analysed.

Soils Suitable for Irrigation.

Almost any soil can be irrigated successfully and even poor infertile stony soils have given good results, provided correct management and fertilizing practices are followed. Shallow top soils on clay-pan sub-soils should be irrigated with care to avoid water-logging, as also should areas with a naturally high water table. Light sandy soils are difficult to irrigate by surface methods and may be inclined to erode.

Measurement of Irrigation Water

The depth of water applied during irrigation is measured, like rainfall, in inches. Thus we may speak of a single irigation application of two inches, or a seasonal irrigation of 2
inches.

Volumes of water applied durin
irrigation are measured in units vi
acre - inches. One acre-inch is th
volume of water that would cove
one acre of ground to a depth o
one inch. A simple calculation show
that one acre-inch is equal to abou
22,600 gallons.

To obtain in acre-inches the vo
ume of water applied during irriga
tion, a simple calculation is require
e.g. if 10 acres is irrigated with
two inch application, obviously th
volume applied is 10 acres x 2 inche
= 20 acre-inches.

On the other hand, if a volume o
say 60 acre-inches is applied to 4
acres of land, the average depth o
irrigation water applied is 60 acre
inches ÷ 40 acres = $1\frac{1}{2}$ inches.

The flow of a stream of wate
often called the "discharge" of th
stream, either in a pipe or open chan
nel, may be expressed in gallons pe
minute for small streams, such a
are used for sprinkler irrigation; bu
for large streams suitable for surfac
irrigation the unit is usually one cus
ec, i.e. one cubic foot per second. Bu
one cubic foot equals $6\frac{1}{4}$ gallons, s
one cusec is equal to 375 gallons pe
minute.

A very important relationship i
that connecting the discharge or flo
of a stream with the number of acre
inches of water delivered by th
stream. An easily remembered rul
is as follows: "One cusec for one hou
equals one acre-inch". This mean
that, if a stream delivers one cuse
or 375 gallons per minute for on
hour on to a piece of land, it wi
apply one acre-inch Thus if a strea
carrying 8 cusecs runs for 2 hours,
will apply 16 acre-inches; and if th
area of land it runs on to is 12 acre
the average depth applied will be 1
÷ 12 = $1\frac{1}{3}$ inches.

These relationships are embodied i
the following useful formulae.

1 *For large streams where discharge is expressed in cusecs*

$$\text{Depth of Water applied in inches} = \frac{\text{Discharge of stream in cusecs X time of application in hours.}}{\text{Area in acres.}}$$

2 *For small streams and discharges from small pipes and sprinklers whose discharge is expressed in gallons per minute.*

$$\text{Depth of Water applied in inches} = \frac{\text{Discharge of stream in gallons per minute X time of application in hour}}{\text{Area in acres X 375.}}$$

It should be remembered that the depth given above is an average depth of application, and is not necessarily uniform over the whole area. The degree of uniformity will depend on the method by which the water is applied. Losses by run off or evapo
ration may reduce the depth of wate
actually entering the soil.

In order to know how much wate
is being applied to the land it is nec
essary to know the discharge of th

stream or pipe line delivering the irrigation water.

A rough approximation to the discharge of a stream, sufficiently accurate for estimating in preliminary investigations to see if there is sufficient water for irrigation, can be made as follows. Choose a fairly straight uniform reach of the stream and, by measuring the average width and depth of the water flow at any cross-section, calculate the area of cross-section of the stream in square feet. Then by measuring how long a float takes to travel say 50 feet along the stream, calculate the velocity of flow. Multiply the area of cross-section by the velocity, and thus obtain the discharge in cusecs. e.g. the average width of a stream is 3 feet, and the average depth 2 feet, therefore the area of cross section is 3 feet x 2 feet equals 6 square feet. The float takes 25 seconds to travel 50 feet, therefore the velocity of the stream is 2 feet per second. Then the discharge of the stream must be 6 square feet x 2 feet per second, which is equal to 12 cusecs. Of course the above results can only be approximate. More accurate measurements of discharge of the stream must be made when it comes to estimating how long to apply the water to the land to give a desired depth of application. To meassure the discharge accurately, some accurate form of measuring device or water-meter is installed in the stream. The simplest device is a measuring weir, with either a rectangular or V-shaped notch through which the water flows. With a properly installed weir, all that needs to be done to find the discharge accurately is to measure the depth of flow above the crest of the weir. Reference to a weir-table or graph will then give immediately the discharge for that particular depth.

Discharge of water from pipe lines or nozzles is usually estimated by reference to details of pump discharges and pressures supplied by the pump maker, but for small flows direct measurement of discharge in a bucket or drum can be made.

Methods of Irrigation.

There are two main systems of irrigation, surface irrigation and sprinkler irrigation.

In " surface irrigation ", sometimes called " gravity irrigation " or " flood irrigation ", the water is applied to the land to be irrigated by causing it to run by gravity over the surface of the soil. Various methods are used to control the water and thus to apply the correct amount ranging from methods that give excellent control, such as confining the water between low banks or dikes, to those inefficient methods in which water is run on indiscriminately from irregularly placed ditches that are made to overflow.

In " sprinkler irrigation " the water is projected into the air under pressure through one or more sprinkling devices, of which the ordinary lawn sprinkler is probably the best known example. It falls on to the ground to be irrigated in fairly small droplets. " Sprinkler irrigation " is sometimes called " spray irrigation " or overhead irrigation. Both these latter terms are confusing and unnecessary.

Sprinkler or Surface Irrigation.

Until about forty years ago irrigation was all done by surface methods. At about that time sprinkler irrigation was invented, and during recent years the development of readily portable equipment such as aluminium alloy pipe has led to a rapid rise in popularity of sprinkler irrigation, throughout the world. Nevertheless, sprinkler irrigation still provides only a very small proportion of the world's irrigation.

In spite of claims to the contrary, sprinkler irrigation is not a rival of nor a substitute for surface irrigation. It is rather an extremely useful and valuable method where irrigation would not otherwise be practicable because the soil, crop and ground surface conditions are unsuitable for surface irrigation, or where only relatively small water supplies are available. This view is supported by the world's leading independent authorities on irrigation. For example, in the words of M. R. Lewis, of the U.S. Bureau of Reclamation, a leading authority on irrigation, " Where conditions are favourable for surface methods, in general, surface methods are more economical in labour and money, and may be equally economical in use of water. Where conditions do not favour surface methods sprinkling may be more economical in labour, money and water. In any case, each farm unit must be studied on its individual merits."

There is room for wide development of both surface and sprinkler methods in New Zealand.

Irrigation and Soil-Moisture Relationships.

Crops grow best and therefore produce most when there is enough, but not too much, water in the soil. The purpose of irrigation should therefore be to ensure that there is enough but not too much, water in the range of depth of the soil from which the roots of the plants procure water. So the fundamental question in irrigation is, therefore, how much is "enough water"?

To answer this question let us assume as a starting point that we have in a field under irrigation, soil that at the moment is fully saturated, so that all the pore spaces in the soil are filled with water, throughout the whole depth of the soil through which the roots are found. This condition could occur following very heavy rain or a heavy application of irrigation water. If this condition is prolonged most useful plants will fail to grow and will rapidly die. That is, there is more than "enough water" in the soil; there is far too much. However if a soil has good natural drainage below, the surplus water that fills the pore spaces will soon drain out until the amount of water in the soil will have been reduced to "field moisture capacity". Capillary attraction will then prevent the remaining moisture from draining out. But this remaining moisture that is held by capillary attraction, called "capillary moisture", is capable of being used by the plants as they grow and is indeed, the medium through which the plant roots obtain food from the soil. If no more water is applied the plants will use this capillary moisture by transpiration, while some will be evaporated direct from the upper layers of the soil; and the amount of moisture in the soil will be gradually depleted until the plants cannot take any more from the soil. When this stage is reached, the plants will wilt, and cease to grow. The amount of moisture at which this occurs is known as the "wilting point" of the soil. The "wilting point" is, like "field moisture capacity" a most important level of soil moisture. It measures the upper limit of water that is held too firmly to be used by plants. In fact for the plants to grow satisfactorily the amount of moisture in the soil should lie in the range between wilting point and field moisture capacity. This is the range that soil scientists call "available soil moisture". For most crops growth rate is very much retarded when the available soil moisture has been depleted to anywhere near wilting point. So, to be on the safe side and to ensure maximum growth, it is probably wise to say that there is "enough water" in the soil when the available soil moisture has not been depleted by more than two-thirds of its volume. Within this range of the upper two-thirds of available soil moisture, growth will be at or near its maximum.

What has this to do with irrigation? Practically everything. For under an ideal system of irrigation the soil moisture throughout the rooting zone of the crop would never be allowed to fall so near to wilting point that the available soil moisture had been depleted by more than two-thirds, or to rise, except perhaps for brief periods shortly after irrigation, above the upper limit of available soil moisture, i.e. above field moisture capacity. Under an ideal system, irrigation should begin before the available soil moisture has been depleted by more than two-thirds, and sufficient irrigation water would be applied to bring it up to field moisture capacity again. Then when evaporation and transpiration had again depleted the available moisture by two thirds, another irrigation would then restore it to field moisture capacity again. This is the principle under which irrigation is based in U.S.A., where, from necessity due to water shortage, the world's most scientific irrigation is practised. It provides the key to the amount of irrigation water to be applied at each irrigation and to the desirable interval between irrigations.

Depth of Water to be Applied at Each Irrigation.

It will be seen that under an ideal system of irrigation, at each irrigation sufficient water would be applied to supply two-thirds of the available soil moisture capacity, throughout the depth of soil in which the roots of the plants are effective in using soil moisture. For example, if analysis of a certain soil shows that its available soil moisture capacity is $1\frac{1}{2}$ inches of water for each foot of depth of the soil, and the effective rooting depth of the crop is 2 feet, then allowing $1\frac{1}{2}$ inches of water for each foot of soil, the total available soil moisture is 3 inches. Assuming that irrigation is done when it should be, i.e. when the evaporation and transpiration has caused available soil moisture to be depleted by two thirds, then two-thirds of 3 inches. i.e. 2 inches of water would be needed to bring the soil up to its field moisture capacity. If appreciably more water than this is applied, it will be wasted in deep drainage, or will cause waterlogging.

The available soil moisture capacity depends on the nature of the soil, and soil with a high clay content or high in decomposed organic matter will hold more available moisture than more open sandy soils. So the depth of water to be applied at each irrigation depends on the nature of the soil and on the rooting habits of the crop.

Interval Between Irrigation.

Obviously the more available soil moisture that a soil can hold, the longer it will be before irrigation has to be done again. Thus soils with high clay content or high in decomposed organic matter require less frequent irrigation than do sandy soils, assuming, of course, that each irrigation is sufficient to fill the available soil moisture capacity. Similarly, plants with a deep rooting system will need less frequent irrigations than shallow rooting plants, because they can draw on a greater depth of available soil moisture.

But the rate of loss of water by evaporation from the surface of the soil, and by transpiration by the plants also has much to do with the interval between irrigations. Thus in hot, dry, windy weather, water will be used more quickly than in cool, humid, calm weather, and irrigation will need to be more frequent under the former conditions. Similarly, some crops are capable of removing water from the soil more rapidly than others, and thus need more frequent irrigation.

Thus whereas depth of water applied at each irrigation is a function of the soil and the rooting characteristics of the plant, " frequency " or interval between irrigations is a function of the foregoing and also of the climate and the water-using characteristics of the plants.

As a consequence of this, whereas a typical irrigation schedule for a shallow rooting crop such as lettuces on a sandy soil might be half an inch of water applied every five or six days in the same climatic conditions, a deep rooted crop like lucerne on a heavy soil might require irrigation of four inches applied every three weeks. In particularly hot dry weather, these intervals between irrigation may have to be shortened.

Practical Factors Affecting Water Application.

Even though he may understand these fundamentals of " irrigation need ", it is not easy for the irrigator to determine in practice how much water to apply and how often. Methods used by scientists are not usually available to the irrigator. Probably at present until scientific advice on irrigation need is available to the irrigator, the best guide as to whether he is putting on enough water at the right time is to take soil samples before and after irrigation at several depths, with a spade or preferably a soil auger, and to judge its moisture content by feel and appearance. Experience in this way, and observation of the state and rate of growth of the crop, will help him to determine whether or not he is observing a sound irrigation schedule. Too heavy an application of water will be wasteful and can be harmful. Too light an application will require the irrigation to be repeated sooner than necessary, and this will be wasteful of labour. Too frequent irrigation can also be harmful and waste water and labour, whereas too infrequent irrigation will reduce yields.

Of course, many practical factors may make departure from the ideal schedule unavoidable. For example, in a public scheme, water may not always be available when it is needed. But in spite of these factors, the ideal of irrigating according to available soil moisture capacity and rate of water used should be adhered to as closely as possible.

Irrigation and Drainage.

The best results are obtained from irrigation if the drainage is naturally good. Where drainage is naturally poor, great care must be taken to avoid excessive applications, particularly on clay pan soils. For best results from irrigation, it may be advisable to instal a drainage system on the irrigated areas. Then excess water will drain away without damaging the irrigated area by water logging, or the land at a lower elevation by seepage.

Conclusion.

This bulletin deals with the essential principles of irrigation that apply to all methods of irrigation. Subsequent bulletins will deal in greater detail with the selection and design of irrigation systems, the application of the water, and management practices under irrigation, for both surface and sprinkler irrigation schemes.

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