Netherlands Journal of Agricultural Science

VOLUME 10 NO. 2 MAY 1962

Sprinkling or irrigation?

G. H. MORHAUS

6 Van Tienhovenlaan, Velp, The Netherlands

Summary

In the event of equal yield and equal general expenses per surface area it will, depending on the proportion of the cost of water in sprinkling and irrigation, be possible that sprinkling will give a greater profit than irrigating, because a greater number of surface units can be sprinkled with the same quantity of water, whereby the total losses will be lower than by irrigation.
In the event of higher yield and proportionally higher general expenses per surface unit resulting from sprinkling, the possibility of obtaining more profit by sprinkling will be favourably influenced.
The data regarding irrigation will generally be known in practice; in the case of sprinkling it will, with the aid of specialist's advice, be possible to calculate the cost of the water (fY) rather accurately. Other factors in the case, however, such as probably increased acreage irrigated by the more efficient sprinkling system, the influence of an increased production on the selling price and the "general expenses" have to be found by approximation.
A specialist's advice must be obtained in order to estimate these factors as realistically as possible, whereby wrong investment can be avoided.

It is often extremely difficult to decide whether the adoption of the sprinkling method will give any financial advantage in regard to a system of irrigation already existing or to a system to be laid out newly.
Great consideration has to be paid to this point, especially in those countries where water is a scarce commodity. In the following we have tried to indicate a method of calculation which, based on data already known or figures which can be more or less accurately determined, make it possible to decide whether the sprinkling method should be adopted or not.
The criteria are:

1. The proportion of the number of acres to be sprinkled and the number of acres, irrigated by the same amount of irrigation water;
2. The proportion of profit per surface unit by sprinkling and by irrigation.

Criterium 1

The loss of irrigation water from the tapping point sometimes amounts to 50 % or more, which is made up as follows:

a_1. Seepage losses in primary mains;
a_2. Seepage in secondary and tertiary mains;
b. Evaporation losses in mains;
c. Percolation losses to the groundwater in the field;
d. Water which flows away unused, so-called "waste water".

Received for publication 19th July, 1961.

If the sprinkling installation gets its water on arrival at the field the losses under a_1 and b would be the same as in the case of irrigation. These may be rather considerable but are not further gone into here. The difference between sprinkling and irrigation now lies in the losses under a_2, c and d. However, it must be taken into account that by sprinkling more or less considerable losses caused by interception and evaporation occur.
In sprinkling a_2 and d hardly occur and if so, only very slightly, while the losses c much easier can be kept in check by regulation of sprinkling intensity and duration. In irrigation the percolation losses are dependent on the system used, viz. basin - sheet or furrow irrigation, but also on the greater or lesser degree of care practised in carrying out the irrigation. Further, the permeability of the ground is of great influence on the percolation losses in irrigation, which are only of slight influence in sprinkling. Cases have been met with in practice from which it appeared that the total losses were $1^1/_2$ to 4 times greater in the case of irrigation than in that of sprinkling.
We have tried hereunder to give a means of calculation which, naturally with some reserve, enables to ascertain whether sprinkling would be advantageous as compared with irrigation. In this regard the following must be taken into account:

A. Based on a certain quantity of irrigation water the area to be sprinkled may easily be larger than the area irrigated. This can be expressed in the proportional figure c.

$$c = \frac{\text{number of surface units irrigated}}{\text{number of surface units sprinkled}}$$

B. The exploitation costs per surface unit are made up, in sprinkling, by the following items:

1. Depreciations on installation;
2. Interest on capital invested;
3. Maintenance;
4. Fuel and oil;
5. Servicing.

The exploitation costs per surface unit in the case of irrigation by an existing system are:

1. Possible depreciation of artificial works;
2. Possible interest on capital invested;
3. Maintenance of mains and artificial constructions;
4. Servicing expenses of the irrigation.

If, however, a new installation has to be constructed, the following items would have to be added to those already mentioned:

5. Interest and depreciation on dams and mains (possible structures too) which have to be provided specially;
6. Interest and depreciation in regard to investments for the necessary ground-levelling.

The expenses falling under 5 will often be allowed for in an annual water retribution. The expenses falling under 6 could be included in an amortisation period of 30 years. In this regard it might be useful to point out that it is sometimes possible when considering sprinkling, to pump the water directly from the river, whereby such losses as those falling under a and b would be completely avoided and the costs of damming and mains would be done away with. Naturally, the expenses attached to sprinkling (especially pumping) would then be higher than in the case of the sprinkling installation being laid down on the field.

Criterium 2

This is the criterium that leads to a decision as to whether to go in for sprinkling whether to adopt or to continue irrigation. In other words than it has been done before, we may say that the nett profit to be obtained on the sprinkled surface shall at least be equal to and, in general, more than the nett profit made, or to be made, on the irrigated area.
How can this be calculated? First of all we must start with the following assumptions:

1. that the production per surface unit is the same in the case of sprinkling and irrigation;
2. that the selling price of the product in both cases is the same;
3. that the general costs such as for tillage, harvesting, transport, sowing and water retribution are the same in both cases.

Note: In sprinkling there will be a favourable deviation in the cases of points 1 and 2 and in an unfavourable sense in point 3.

In order to simplify the calculation it has been supposed that the two influences balance each other in this theoretical case. The previously determined criteria now can be expressed in the equation:

(Number of sprinkled surface units × nett profit per sprinkled unit) — (number of irrigated surface units × nett profit per irrigated unit) must be equal to or greater than 0.

This can be expressed in the following symbols:

Nett profit per sprinkled surface unit $= X_1$
Nett profit per irrigated surface unit $= X_2$
Selling price — general costs $= A$ (in both cases)
Costs of irrigation per surface unit $= Y$
Costs of sprinkling per surface unit $= f \times Y$

$$\frac{\text{Number of surface units irrigated}}{\text{Number of surface units sprinkled}} = c$$

The equation is then

$$X_1 - c\,X_2 \geqq 0 \qquad (1)$$

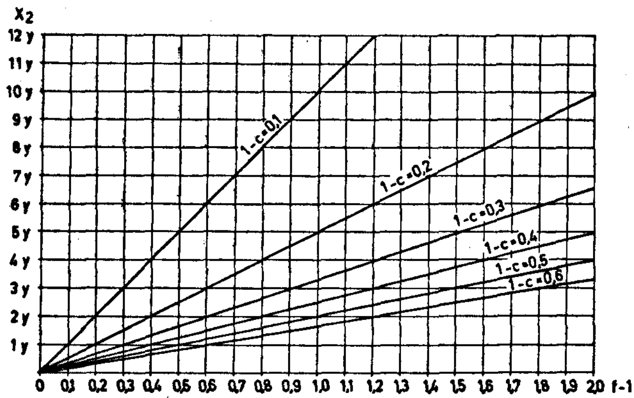
$$X_1 = A - fY \quad (2) \qquad X_2 = A - Y \qquad (3)$$

$$(A - fY) - c\,(A - Y) \geqq 0 \qquad (4)$$

If now different values for f and c are substituted in the formula, then A can thus be expressed in Y (and also X_2, for this is A — Y). By further working out we get

$$X_2 \geqq Y\,\frac{f-1}{1-c} \qquad (5)$$

This is graphically illustrated in GRAPH 1 in which the factor (f — 1) is placed on the X axis and the nett profit per irrigated surface unit (X_2) expressed in the costs of irrigating the same surface unit, on the Y axis.
The lines show at what values of (1 — c) at various values of (f — 1) a nett profit per irrigated surface would make sprinkling a profitable proposition.



GRAPH 1.
Nett profit per unit of surface irrigated

In the *Rhodesian Agricultural Journal* Vol. 58 No. 2 one can find a cost calculation by G. D. GOLDTHORP for the growing of lucerne under the various types of irrigation and sprinkling:

1. Leading water by gravity purely from the natural flow of a river or spring without provision for significant storage at source (diversion dams with little storage regarded as nil storage);
2. Gravity irrigation as in 1 above, but with significant storage at source (e.g. large earth dams or weirs);
3. Flood irrigation with water pumped to the head of the land from the natural flow of a river, natural pool or spring without provision for significant storage at source;
4. Flood irrigation as in 3 above, but with significant storage at source (small reservoirs, small night storage dams and small diversion dams are not significant storage);
5. Overhead irrigation pumping water from the natural flow of a river, natural pool or spring without provision for significant storage at source;
6. Overhead irrigation as in 5 above, but with significant storage at source.

It is striking that in this article the fact that a greater area can be served with the same quantity of water by means of sprinkling has not been taken into account.
The figures given can, however, serve to make an opinion as to whether sprinkling can be advantageous, provided the area sprinkled is larger than that irrigated by the same quantity of water.

Table 7 of the article furnishes the "costs of water" for the various types:

Type	1	2	3	4	5	6
Water costs/acre/year (£)	4.19.0	10.19.0	21.0.0	27.0.0	30.14.0	36.14.0

In *table* 9 we find the "general costs" for a production of 4 and 6 tons of lucerne per acre respectively:

	Yield per acre	
	4 tons	6 tons
Total direct costs per acre excluding water (£)	14.3.5	15.16.5

Table 10 shows the selling price and the nett profit of the various types with a production of 4 and 6 tons respectively:

	Yield per acre	
	4 tons	6 tons
Value of lucerne hay produced based on £ 14 per ton	£ 56. 0.0	£ 84.0.0
Relative profit margin from the various types of irrigation:		
Type 1 Gravity no storage	36.17.7	63.4.7
„ 2 „ with „	30.17.7	57.4.7
„ 3 Flood pumping no storage	20.16.7	47.3.7
„ 4 „ „ with „	14.16.7	41.3.7
„ 5 Spray „ no „	11. 2.7	37.9.7
„ 6 „ „ with „	5. 2.7	31.9.7

From these data the factors f and X_2 expressed in Y are to be calculated.

		Production per acre	
		4 tons	6 tons
f 5/1 = 6,2 f 6/1 = 7,4	type 1	$X_2 = 7{,}4$ Y	$X_2 = 12{,}7$ Y
f 5/2 = 2,8 f 6/2 = 3,4	type 2	$X_2 = 2{,}8$ Y	$X_2 = 5{,}2$ Y
f 5/3 = 1,5 f 6/3 = 1,7	type 3	$X_2 =$ Y	$X_2 = 2{,}2$ Y
f 5/4 = 1,1 f 6/4 = 1,4	type 4	$X_2 = 0{,}5$ Y	$X_2 = 1{,}2$ Y

By substitution of the values found in formula 5

$$X_2 = Y \frac{1-c}{f-1}$$

we find:

	Production per acre	
	4 tons	6 tons
Comparison type 5/type 1 (1—c) =	0,70	0,41
„ „ 6/ „ 1 „ =	0,87	0,50
„ „ 5/ „ 2 „ =	0,64	0,35
„ „ 6/ „ 2 „ =	0,86	0,46
„ „ 5/ „ 3 „ =	0,50	0,23
„ „ 6/ „ 3 „ =	0,70	0,32
„ „ 5/ „ 4 „ =	0,20	0,08
„ „ 6/ „ 4 „ =	0,80	0,33

In the case of a production of 4 tons in which margins of profit are greatly influenced by the costs of sprinkling and irrigation, it can be expected that sprinkling will probably be a paying possibility if the area sprinkled with the same amount of water is much greater than the area irrigated.
For example sprinkling is profitable against irrigation in case type 5/type 3 only if the area sprinkled is at least twice the area irrigated with the same quantity of

water. Comparing type 5/type 4 the area sprinkled ought to be at least 1,25 the area irrigated. The other six comparisons are out of consideration.
With a production per acre of 6 tons the possibility of profit by sprinkling is probably existing in all cases. Comparison type 6/type 1 is the most unfavourable; the area sprinkled must be at least twice the area irrigated.

In the examples given above it is presumed that the selling prices per surface area sprinkled and per surface area irrigated are the same. Considering an increased production per surface area due to the sprinkling and assuming the same selling price per unit of product, then the total selling price will be higher.
The same result can be achieved in case the sprinkled product is of higher quality, thus obtaining a higher selling price. For this reason the factor q is introduced:

$$\text{Factor q} = \frac{\text{(Selling price — general expenses) per unit sprinkled}}{\text{(Selling price — general expenses) per unit irrigated}}$$

if assumed, that the general expenses increase proportionally with the selling price.
The following equations result:

$$X_1 - c\,X_2 \geqq 0 \qquad (1)$$

$$X_1 = q\,A - f\,Y \qquad (2')$$

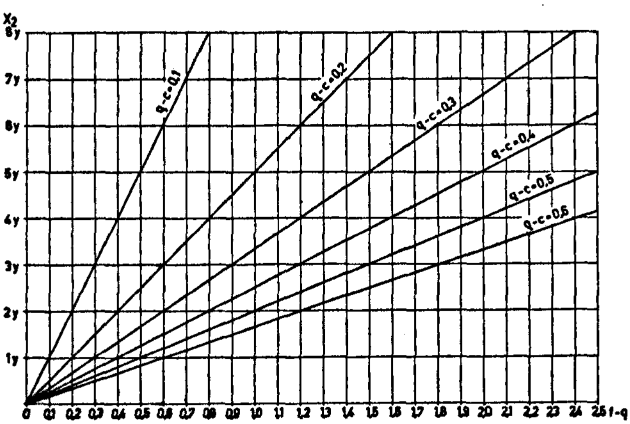
$$X_2 = A - Y \qquad (3)$$

$$\text{thus } (q\,A - f\,Y) - c\,(A - Y) \geqq 0 \qquad (4')$$

$$\text{or } A = Y\,\frac{f - c}{q - c} \qquad (5')$$

$$\text{and } X_2 = Y\,\frac{f - q}{q - c} \qquad (6')$$

The term $(f - q)$ is now set out on the X axis and the profit per surface unit irrigated, expressed in the costs of irrigating the same unit, on the Y axis.
The lines of GRAPH 2 show at what values of $(q - c)$ at various values of $(f - q)$ a nett profit per irrigated surface unit makes sprinkling profitable. We now compare the example in the *Rhodesian Agricultural Journal,* assuming that by irrigating 4 tons/acre are obtained and by sprinkling 6 tons/acre, whereby at the same time it is assumed that $c = 1$, thus no greater area can be served by sprinkling.



GRAPH 2.
Nett profit per unit of surface irrigated

The selling price in the case of sprinkling is 1,5 $\times$ the selling price in that of irrigation or q = 1,5. The factor f for various cases is:

f 5/1 = 6,2	f 5/3 = 1,5
f 6/1 = 7,4	f 6/3 = 1,7
f 5/2 = 2,8	f 5/4 = 1,1
f 6/2 = 3,4	f 6/4 = 1,4

These factors enable to calculate the minimum profit per irrigated unit of surface expressed in irrigation costs by which sprinkling becomes profitable (Column 1 hereunder). Column 2 gives the actual proportion derived from the data given. In column 3 the result of the comparison of column 1 and 2 is shown.

Column 1		Column 2 Actual proportion by production of 4 tons/acre	Column 3
$\frac{f-q}{q-c}$ Y = X_2			
$\frac{6{,}2-1{,}5}{1{,}5-1{,}0}$ Y = 9,4 Y	in case 5/1	7,4 Y	Sprinkling unprofitable
$\frac{7{,}4-1{,}5}{1{,}5-1{,}0}$ Y = 11,8 Y	„ „ 6/1	7,4 Y	
$\frac{2{,}8-1{,}5}{1{,}5-1{,}0}$ Y = 2,6 Y	„ „ 5/2	2,8 Y	Sprinkling hardly profitable
$\frac{3{,}4-1{,}5}{1{,}5-1{,}0}$ Y = 3,8 Y	„ „ 6/2	2,8 Y	Sprinkling unprofitable
$\frac{1{,}5-1{,}5}{0{,}5}$ Y = 0 Y	„ „ 5/3	Y	Sprinkling profitable
$\frac{1{,}7-1{,}5}{0{,}5}$ Y = 0,4 Y	„ „ 6/3	Y	Sprinkling profitable
$\frac{1{,}1-1{,}5}{0{,}5}$ Y = –0,8 Y	„ „ 5/4	0,5 Y	Sprinkling profitable
$\frac{1{,}4-1{,}5}{0{,}5}$ Y = –0,2 Y	„ „ 6/4	0,5 Y	Sprinkling profitable

When comparing the results given in column 3 with table 10 given bij GOLDTHORP differences occur.

According to GOLDTHORP's table the type 5 (with production of 6 tons/acre) is profitable compared with the irrigation types 1 incl. 4 (with a production of 4 tons/acre). Column 3 indicates that type 5/type 1 is unprofitable, type 5/type 2 hardly profitable and the remaining two are profitable.

Type 6 (according to GOLDTHORP) is unprofitable compared with type 1, hardly profitable with type 2 and profitable with types 3 and 4. Column 3 gives an unprofitable result with type 1 and 2 and also profitable with types 3 and 4. So we find, that the result does not tally, the reason being that the "general expenses" in the case of a production of 6 tons are practically equivalent to those for 4 tons (see GOLDTHORP's table 9). It is, however, assumed in our scheme of calculation that this has also become 1,5 times as high.

If we now amend table 10 in this sense we get as profit for type 5 £ 37.9.7 — (1,5 × £ 14.3.5 — £ 15.16.5) = £ 32.0.10/acre and for type 6 £ 26.0.10/acre. We see that the difference in the ultimate result is only due to the prudent assumption of increased "general expenses".

Check calculation 1

Case 6/3

In the case of a profit (X_2) greater than 0,4 Y per irrigated surface unit, sprinkling becomes profitable.

Y = £ 21.–.–, thus 0,4 Y =	£ 8. 8.–	
General expenses =	£ 14. 3.5	
Cost of water =	£ 21. –.–	
Selling price per 4 tons =	£ 43.11.5	
In the case of sprinkling:		
Selling price per 6 tons (1½ × £ 43.11.5) =		£ 65. 7.2
Cost of water 1,7 × £ 21 =	£ 35.14.–	
General expenses 1,5 × £ 14.3.5 =	£ 21. 5.2	
Total costs		£ 56.19.2
Profit in the case of sprinkling		£ 8. 8.–

Check calculation 2

Case 5/3

In this case there will be no profit (X_2 = 0.Y).

General expenses =	£ 14. 3.5	
Cost of water =	£ 21. –.–	
Total costs = selling price per 4 tons	£ 35. 3.5	
In the case of sprinkling:		
Selling price per 6 tons (1½ × £ 35.3.5) =		£ 52.15.2
Cost of water 1,5 × £ 21 =	£ 31.10.–	
General expenses 1,5 × £ 14.3.5 =	£ 21. 5.2	
Total costs		£ 52.15.2
Profit in the case of sprinkling		£ 0.–