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1 Introduction

As was mentioned in Chapter 1: Introduction, the evolution of irrigation has led to a wide variety of irrigation systems now being at our disposal, each with its own unique application.

In this chapter, the currently available systems will be discussed, together with the advantages and disadvantages of each individual system, to help the designer in his choice of an irrigation system.

2 Classification of systems

The following diagram illustrates the classification of irrigation systems.
3 Flood irrigation

In flood irrigation, water floods over the soil surface and thus wets the soil.

3.1 Border irrigation

With border irrigation, the water is diverted into a preconstructed bed and allowed to flow freely over the soil surface. The bed consists of an almost horizontal flow area and two earth borders to define the width of the bed. The longitudinal slope of the bed is influenced by various factors, which are fully discussed in Chapter 15: Flood irrigation.

Advantages

- Low energy costs, because the water flows by gravity over the field.
- The crop is not wetted, thus leaf and fruit diseases are reduced.
- Brackish soils can be leached with relative ease.
- Low capital input costs if the land is relatively level.

Disadvantages

- Considerable water losses may occur if the supply system is not properly designed and maintained.
- The system is very sensitive and small deviations from the design specifications can reduce application uniformity significantly.
- Not all crops can be grown in bordered beds and the type of crop to be planted may thus eliminate this irrigation method.
- The viability of such a system is mainly influenced by the extent of earthworks required for bed preparation.
- This type of system is relatively inflexible and difficult to alter once it has been installed.
- The system is relatively labour intensive.
- Very high management inputs are required.
- Unsuitable for soils with very high infiltration rates.

3.2 Furrow irrigation

As the name indicates, water is diverted to preconstructed furrows, in which the water flows and thus wets the soil. The slope of the furrows are specified in the design instructions, and the factors that influence the slope are fully discussed in Chapter 15: Flood Irrigation.
Advantages

- This type of system is relatively inexpensive.
- The crop itself is not wetted, only the roots.
- Low energy costs, since the water flows by gravity in the furrows.
- A relatively simple system, with few to no mechanical parts that can wear out.
- Less sensitive to ground slope than border irrigation.
- The soil surface is only partially wetted.

Disadvantages

- This type of system is very sensitive to deviations from design specifications and water applications may differ drastically with small deviations from the design specifications.
- Only row crops can be irrigated.
- This type of system is relatively labour-intensive.
- As with border irrigation, proper design and maintenance of the supply system is critical for a high irrigation efficiency.
- Soils with high infiltration rates cannot be irrigated by this method.

3.3 Basin irrigation

With basin irrigation a certain quantity of water is diverted into a preconstructed basin and allowed to infiltrate the soil. The basins vary in size according to the type of application required. Basins in which rice is planted, are up to one hectare in size, while the basins in which fruit trees are planted, approximately 1 m².

Advantages

- The crop being cultivated is not wetted, only the soil.
- More variation in application is possible than with furrow or border irrigation.
- Basin irrigation is possible on soils with very high or low infiltration rates.

Disadvantages

- Relatively high flow rates are required for this type of system.
- The construction of the basins can be relatively expensive, particularly for basins with concrete sides.
- Reasonably labour-intensive.
- With larger basins, the cost of this type of system will be particularly dependant on the extent of the earth-works required to level the bottom of the basin.
3.4 Short-furrow irrigation

Short-furrow irrigation is a combination of basin and furrow irrigation and consists of short furrows with little or no longitudinal slope into which a certain amount of water is diverted in a relatively short time and allowed to infiltrate the soil.

Advantages

- The crop being cultivated is not wetted, only the soil.
- A larger variation in application is possible than with border or furrow irrigation.
- This type of system is less sensitive to slope and flow variations.

Disadvantages

- Mechanised cultivation over short furrows is difficult.
- Water losses occur in the supply furrow.
- Relatively labour-intensive.

4 Mobile systems

Mobile systems include all systems that move over the soil surface while water is applied.

4.1 Centre pivot

A centre pivot consists of a metal frame and pipes supported by wheels with an A-frame at approximately 50 m intervals and it rotates around a fixed pivot. Emitters are mounted on the pipes and they wet the soil while the construction rotates around the pivot.

Advantages

- Very low labour requirements.
- Relatively low energy requirements compared to, for e.g., the big gun.
- Chemigation and fertigation is possible through the system.

Disadvantages

- Due to the circular wetting pattern, outfall pieces of land are not wetted. (This problem is reduced where corner systems are used).
- This type of system is relatively expensive.
4.2 Linear system

The structure of this type of system resembles that of a centre pivot. The main difference between the two systems is that the linear system moves linearly across the field and not in a circle like the centre pivot.

Advantages

- Outfall pieces of land is avoided with rectangular fields.
- Low labour requirements.

Disadvantages

- Water supply to this type of system is problematic.
- It is a very expensive system.
- Only relatively large fields can be irrigated economically.

4.3 Travelling gun

This system consists of a big gun mounted on a trolley or sleigh and it is pulled across the field with a cable and winch during the irrigation process. The winch is usually driven by the system pressure.

Advantages

- Low labour requirements.
Disadvantages

- High energy requirements.
- Sensitive to wind.
- High application rate.
- High maintenance requirements.

![Travelling gun (Jensen, 1983)](image)

**Figure 10.2 Travelling gun (Jensen, 1983)**

## 5 Static systems

Static systems includes all systems that remain stationary while water is applied.

### 5.1 Sprinkler systems

With sprinkler irrigation systems water is supplied above ground by means of sprinklers or sprayers.

#### 5.1.1 Permanent systems

With this system laterals and emitters are permanently installed and no pipes or emitters need to be moved. The different irrigation blocks are controlled by valves.

- Working pressure 20 to 40 m
- Delivery 0.6 to 2 m³/h / emitter
- Wetted diameter 10 to 20 m / emitter
Advantages

- Low labour requirements.
- Not as sensitive to wind as portable systems since the whole area is irrigated simultaneously.
- Plants are not mechanically damaged by the moving of pipes and sprinklers.

Disadvantages

- Wet patches often develop around the sprinklers due to the distribution pattern of the stroke type sprinklers.
- This type of system is very expensive.
- Cultivation of the land is impeded by permanently installed irrigation equipment.

5.1.2 Portable systems

With portable systems irrigation equipment is moved from one position to the next after irrigation of a section of the field is completed.

5.1.2.1 Quick-coupling system

A quick-coupling system consists of above-ground quick-coupling pipes of light steel, aluminium, polyethylene or uPVC, with sprinklers mounted on them. The pipes with the sprinklers are placed in position and the pump is then switched on. After a certain period of time,
the pump is switched off and the pipes with the sprinklers are moved to the next position.

**Advantages**

- Less labour-intensive than flood irrigation.
- Supply system losses are usually lower than for flood irrigation.
- This type of system is more adaptable in terms of application per cycle than flood irrigation.

**Disadvantages**

- Crops sensitive to mechanical damage like tobacco should preferably not be irrigated with this system.
- Because the leaves are wetted, crops are more at risk of contracting leaf diseases.
- Irrigation time per day is decreased according to the time required to move the pipes.
- Irrigation water of poor quality can burn the leaves of the crop.
- Labour is still needed to move the pipes.
- Energy requirements are higher than for flood irrigation.
- The application uniformity of the system is affected by wind.

![Figure 10.4 Typical layout of a quick-coupling system](image)

5.1.2.2 Dragline system
With a dragline system the sprinklers are coupled to the laterals by means of high-quality hoses. The advantage is that laterals (if portable) only have to be moved after 5 to 7 standing positions and not after each standing position as with quick-coupling systems.

**Advantages**

- Requires less labour than the quick-coupling system.
- The pump does not have to be switched off when the pipes are being moved.
- With permanent laterals, the pipes do not have to be moved, only the sprinklers and hoses.
- Of all the sprinkler irrigation systems, this is the cheapest system.

**Disadvantages**

- Special measures have to be taken to keep the spacing of the sprinklers constant.
- Energy requirements are higher than for flood irrigation.
- Wind has a negative influence on the application uniformity of the system.
- Draglines are relatively expensive.

![Figure 10.5 Typical layout of a dragline system](image)

**5.1.2.3 Hop-along system**

Like the permanent system, this type of system has permanent laterals, but the sprinklers have to
be moved.

**Advantages**

- Not as expensive as a permanent system.
- Otherwise it has the same advantages as a permanent system.

**Disadvantages**

- More labour-intensive than a permanent system.
- Otherwise it has the same disadvantages as a permanent system.

*Figure 10.6 Typical layout of a hop-along system*
5.1.2.4 Big gun

This type of system entails a very large sprinkler, operating at a very high pressure in order to wet a relatively large area.

Advantages

- Less labour-intensive than the quick-coupling system.
- The wetted area is larger than with other sprinkler systems.
- Capital cost lower than, for e.g., for permanent systems.

Disadvantages

- Owing to the high pressure and flow rate, the energy requirements are higher and consequently also the pumping costs.
- The system is very sensitive to wind.
- The large drops can damage small plants and compact the soil.
- The application efficiency is lower than for normal sprinkler irrigation.

5.1.2.5 Boom irrigation

The boom system consists of a rotating boom on which a series of sprayers or sprinklers are mounted. The boom is mounted on a trolley, which can either be self-propelled or towed by a tractor.

Advantages

- Low labour requirements.
- Relatively inexpensive.
- Large areas are wetted for each setup of the boom.
- With correct design, good application uniformity can be obtained.

Disadvantages

- High-pressure models are extremely sensitive to wind.
- The system always has to move on routes that are wetted by the irrigation.
- Special roads have to be built to move the system.
- High winds may damage the structure.
- High-pressure models have high energy requirements.
5.1.2.6 Side-roll system

This type of system consists of quick-coupling pipes to which wheels have been mounted to facilitate the moving of the pipes.

**Advantages**

- Easier to move the pipes than with quick-coupling systems.
- Labour requirements are lower than those of a quick-coupling system.

**Disadvantages**

- Crops growing higher than 1.5 m cannot be irrigated.
- Rank-growing crops lie down on the wheels and thus impede movement.
- The system has to be anchored against wind to keep it in place.
- Moving is extremely difficult on fields with steep gradients.
- Moving is also impeded by row crops.
5.2 Micro irrigation systems

With micro irrigation small quantities of water is applied on a regular basis in a limited area within the vicinity of the plant's root. Owing to the large number of laterals needed for micro irrigation, it is a relatively expensive system.

5.2.1 Drip systems

Drip irrigation consists of black polyethylene pipes equipped with drippers at fixed intervals. A dripper dispenses small quantities of water (2 to 8 l/h) through a small opening. The pipes are laid parallel to each other across the field. Drippers, spaced at fixed distances on the pipes, distribute the water across the field. The water dripping onto the soil is distributed horizontally by means of capillary force and vertically by means of gravity and capillary force.

Advantages

- The system can be fully computerised.
- Hardly any evaporation of water takes place.
- Irrigation can take place 24 hours a day (no moving).
- Not influenced by wind in any way.
- Low energy requirements.
- Decreases weed growth between the plants since only the root zone of the crop is wetted.
- Runoff does not occur because of the regular, small applications.
- Low labour requirements.
Disadvantages

- A very expensive system.
- Drippers become clogged very easily and effective filtration is therefore essential.
- Cultivation is impeded by the pipes in the field.
- Drip laterals impede cultivation particularly with seasonal crops.
- Highly pervious soils cannot be irrigated with this system due to insufficient lateral movement of soil moisture.
- Some organic matter tend to coat the inner walls of the pipes and thus clog the drippers.
- Rainfall is not effectively utilised due to the continuous high moisture content of the soil.
- Root diseases are more prevalent because of the root zone being almost permanently wet.

![Figure 10.9: Dripper](image)

5.2.2 Micro spray systems

Micro sprayers are very small emitters that distribute water on the soil underneath the crop. The sprayers are coupled with short resilient or rigid pipes, or directly onto the polyethylene laterals. Water is emitted through a small opening (0.75 to 2.2 mm in diameter) and spread by a fixed or rotating distributor. Micro sprinklers are characterised by the following properties:

- Working pressure smaller than 200 kPa
- Delivery 20 to 100 ℓ/ℎ
- Wetted diameter of 1.5 to 10 m

Micro sprayers are usually used for strip wetting, i.e. instead of wetting the total soil surface, only the strips in which the crop has been planted in the field are irrigated. The exception to the rule is in greenhouses, where an overhead system is used to wet the whole area.
Advantages

- The same as for drip irrigation, but clogging is less prevalent.
- Twenty-four hour per day irrigation is possible.
- Wetted area is larger than that of drip and it is therefore suitable for a larger variety of soils.

Disadvantages

- As for drip systems, filtration is also required, but not to the same extent.
- Although this type of system may very well be influenced by wind, it is to a lesser extent than with sprinkler or mobile systems.
- Rainfall is utilised less effectively because of the relatively wet conditions in the root zone.
- It is more sensitive to wind than drip systems.

6 Choosing an irrigation system

Selection of an irrigation system for a specific application is not an easy task because the various systems have wide fields of application. Various factors that play a part in the selection are discussed below.

6.1 Water

The amount of available water, the quality of the water and the cost thereof may influence the choice of an irrigation system. If the amount of available water is a limiting factor on the area to be irrigated, it might be more profitable to select a micro irrigation system, with a high water use efficiency. Where irrigation contain harmful chemical substances that could burn the leaves of the plant or influence the quality of the product, overhead irrigation systems that wets the foliage should be avoided.
6.2 Soil

For micro irrigation of soils with a very high sand fraction, micro sprayers would be preferable to drippers. However, if the soil has a very high clay fraction and a low infiltration rate, a dragline system might be more suitable than a large centre pivot and an overhead system is to be installed.

6.3 Topography

Topography plays an important role where systems such as linear and flood irrigation systems are concerned and may dictate the choice of a system.

6.4 Climate

In very hot climatic conditions, water applied by sprinkler irrigation that wets the leaves of plants may burn the leaves. Under such conditions it would be better to use a micro system or a flood irrigation system.

6.5 Energy costs

Energy requirements and therefore operating costs of some systems such as the big gun, travelling gun and the high-pressure travelling boom are considerably higher than for low-pressure systems such as, for e.g., drip irrigation, and should therefore be take into consideration with system selection.

6.6 Crop

The crop to be irrigated will highly influence the choice of an irrigation system. It would be ineffective to irrigate wheat with a drip system which is only suitable for row crops. It would also be difficult to portable pipes of a quick coupling system in an orchid.

6.7 Labour

A shortage of labour may force the farmer to use self propelled or permanent systems rather than movable systems.

6.8 Capital cost

Micro irrigation systems are generally more expensive than for instance portable systems. The farmer may for economic reasons rather select the cheaper portable system, even though it might not be the ideal system for the application.

6.9 Personal considerations

Although each system has its own field of application, the final choice rests with the user of the system, the farmer. Each farmer has his own personal preferences that are influenced by various factors, for instance whether the system is adaptable to his current farming practice, the level of training of his labourers, whether or not the system can be adapted for other uses and the reliability of the supplier.
## 7 Comparison between systems

Arising from what was mentioned above and discussed in the preceding chapters, Table 10.1 provides guidance to the designer in the selection of irrigation systems with regard to some criteria.

The following symbols are used in the table to indicate the degree of limitation or obstacles that might occur:

- **o** - No limitation
- **x** - Little limitation
- **xx** - Moderate limitation
- **★** - Severe
- **●** - Requires further thorough investigation by an expert.

### Table 10.1 Comparison between systems

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Flood</th>
<th>Sprinkler</th>
<th>Microspray</th>
<th>Drip</th>
<th>Big gun and Boom</th>
<th>Centre pivot and linear move</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Climate</strong></td>
<td></td>
<td></td>
<td></td>
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<td>Temperature &gt; 30°C</td>
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<td>xx</td>
<td>xx</td>
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<tr>
<td>Relative humidity &lt; 40%</td>
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<td>xx</td>
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<tr>
<td>Windspeed &gt; 15 km/h</td>
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<td>★</td>
<td>o</td>
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<td>Rainfall &lt; 300 mm/heap</td>
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<td>o</td>
<td>xx</td>
<td>o</td>
<td>o</td>
</tr>
<tr>
<td><strong>2. Topography</strong></td>
<td></td>
<td></td>
<td></td>
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<td>Earthworks &gt; 250 m³/ha</td>
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<td><strong>3. Salinity</strong></td>
<td></td>
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<tr>
<td>Salinity &gt; 2 000 dpm</td>
<td>x</td>
<td>xx</td>
<td>xx</td>
<td>★</td>
<td>xx</td>
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<td><strong>4. Flow rate</strong></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>&lt; 100 m³/h</td>
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<td>x</td>
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<td><strong>5. Water parity</strong></td>
<td></td>
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<td></td>
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<tr>
<td>Turbidity (silt, fine sand)</td>
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<td>xx</td>
<td>★</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Lime, iron</td>
<td>o</td>
<td>x</td>
<td>xx</td>
<td>★</td>
<td>x</td>
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<tr>
<td>Algae</td>
<td>o</td>
<td>o</td>
<td>xx</td>
<td>★</td>
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</tr>
<tr>
<td><strong>6. Soils</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>&gt; 20% clay</td>
<td>x</td>
<td>x</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>★</td>
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<tr>
<td>10 - 20% clay</td>
<td>x</td>
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<td>&lt; 5% clay</td>
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<td>xx</td>
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### Criteria Flood Sprinkler Microspray Drip Big gun and Boom Centre pivot and linear move

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Flood</th>
<th>Sprinkler</th>
<th>Microspray</th>
<th>Drip</th>
<th>Big gun and Boom</th>
<th>Centre pivot and linear move</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 600 mm deep</td>
<td>★</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>600 - 1200 mm deep</td>
<td>xx</td>
<td>o</td>
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</table>

#### 7. Initial infiltration rate of soil

<table>
<thead>
<tr>
<th>Rate</th>
<th>Flood</th>
<th>Sprinkler</th>
<th>Microspray</th>
<th>Drip</th>
<th>Big gun and Boom</th>
<th>Centre pivot and linear move</th>
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<tr>
<td>&lt; 20 mm/h</td>
<td>x</td>
<td>xx</td>
<td>xx</td>
<td>x</td>
<td>xx</td>
<td>♦</td>
</tr>
<tr>
<td>&gt; 150 mm/h</td>
<td>★</td>
<td>o</td>
<td>o</td>
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<td>o</td>
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</tr>
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</table>

#### 8. Crops

<table>
<thead>
<tr>
<th>Crops</th>
<th>Flood</th>
<th>Sprinkler</th>
<th>Microspray</th>
<th>Drip</th>
<th>Big gun and Boom</th>
<th>Centre pivot and linear move</th>
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<tbody>
<tr>
<td>Nursery</td>
<td>★</td>
<td>x</td>
<td>o</td>
<td>o</td>
<td>xx</td>
<td>x</td>
</tr>
<tr>
<td>Row crops</td>
<td>x</td>
<td>o</td>
<td>xx</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Bed crops</td>
<td>x</td>
<td>o</td>
<td>xx</td>
<td>xx</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Field crops</td>
<td>o</td>
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<td>★</td>
<td>★</td>
<td>o</td>
<td>o</td>
</tr>
<tr>
<td>Orchards, vineyards</td>
<td>x</td>
<td>x</td>
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<td>x</td>
<td>xx</td>
<td>xx</td>
</tr>
<tr>
<td>Fungal diseases</td>
<td>o</td>
<td>xx</td>
<td>xx</td>
<td>o</td>
<td>xx</td>
<td>xx</td>
</tr>
<tr>
<td>Ablution of chemicals</td>
<td>o</td>
<td>xx</td>
<td>x</td>
<td>o</td>
<td>xx</td>
<td>xx</td>
</tr>
</tbody>
</table>

#### 9. Operation

<table>
<thead>
<tr>
<th>Operation</th>
<th>Flood</th>
<th>Sprinkler</th>
<th>Microspray</th>
<th>Drip</th>
<th>Big gun and Boom</th>
<th>Centre pivot and linear move</th>
</tr>
</thead>
<tbody>
<tr>
<td>Managerial inputs</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>♦</td>
<td>xx</td>
<td>x</td>
</tr>
<tr>
<td>Labour</td>
<td>xx</td>
<td>xx</td>
<td>o</td>
<td>o</td>
<td>x</td>
<td>o</td>
</tr>
<tr>
<td>Energy requirements</td>
<td>o</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>♦</td>
<td>xx</td>
</tr>
<tr>
<td>Water use</td>
<td>♦</td>
<td>xx</td>
<td>xx</td>
<td>x</td>
<td>xx</td>
<td>xx</td>
</tr>
<tr>
<td>Application of chemicals</td>
<td>♦</td>
<td>xx</td>
<td>x</td>
<td>x</td>
<td>xx</td>
<td>♦</td>
</tr>
</tbody>
</table>
8 Summary

The estimated costs, system efficiency and labour requirements of various irrigation systems is given in Table 10.2.

Table 10.2 Summary of systems

<table>
<thead>
<tr>
<th>Irrigation group</th>
<th>Irrigation system</th>
<th>Estimated capital costs [R/ha] (x 10³) 2003</th>
<th>System efficiency [%]</th>
<th>Life expectancy [years]</th>
<th>Labour requirements [ha/labour]</th>
<th>Annual maintenance costs [% of capital costs]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flood</td>
<td>Furrow</td>
<td>5 - 6</td>
<td>60 - 80</td>
<td>10</td>
<td>15</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Border</td>
<td>7 - 9</td>
<td>60 - 80</td>
<td>15</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Basin</td>
<td>6 - 9</td>
<td>60 - 80</td>
<td>20</td>
<td>12</td>
<td>5</td>
</tr>
<tr>
<td>Static</td>
<td>Permanent</td>
<td>14 - 16</td>
<td>75</td>
<td>15</td>
<td>50</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Dragne</td>
<td>10 - 12</td>
<td>65</td>
<td>10</td>
<td>25</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Quick-coupling</td>
<td>9 - 12</td>
<td>70</td>
<td>12</td>
<td>20</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Hop-along</td>
<td>11 - 13</td>
<td>65</td>
<td>12</td>
<td>25</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Big gun</td>
<td>8 - 9</td>
<td>65</td>
<td>10</td>
<td>20</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Side-roll</td>
<td>11 - 13</td>
<td>65</td>
<td>12</td>
<td>25</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Boom</td>
<td>8 - 10</td>
<td>65</td>
<td>15</td>
<td>25</td>
<td>4</td>
</tr>
<tr>
<td>Micro</td>
<td>Drip</td>
<td>18 - 20</td>
<td>90</td>
<td>5- 15</td>
<td>30</td>
<td>2*</td>
</tr>
<tr>
<td></td>
<td>Subsurface drip</td>
<td>20 - 22</td>
<td>95</td>
<td>10</td>
<td>25</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Micro sprinkler</td>
<td>14 - 17</td>
<td>80</td>
<td>10</td>
<td>30</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Micro sprayer</td>
<td>22 - 25</td>
<td>80</td>
<td>15</td>
<td>30</td>
<td>3</td>
</tr>
<tr>
<td>Mobile</td>
<td>Travelling gun</td>
<td>9 - 11</td>
<td>65</td>
<td>10</td>
<td>25</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Travelling boom</td>
<td>10 - 12</td>
<td>65</td>
<td>12</td>
<td>30</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Centre pivot</td>
<td>18 - 20</td>
<td>80</td>
<td>15</td>
<td>100+</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Linear move</td>
<td>30 - 35</td>
<td>80</td>
<td>15</td>
<td>100+</td>
<td>6</td>
</tr>
</tbody>
</table>

Note: The estimated capital costs include the costs of the pump station, supply system, distribution system and installation of the equipment. Drip and micro system costs were calculated for vineyards.

*In the case of thin walled pipe installed above ground, the maintenance costs is estimated as 30% of the capital cost.
The graph in Figure 10.11 shows the various irrigation systems estimated energy requirements in kWh per mm gross irrigation requirement per hectare. The energy costs (in R) can be calculated by multiplying this value by the electricity tariff. The graph was developed for a pump efficiency of 80% and a motor efficiency of 95%.

Figure 10.11: Energy requirements of different irrigation systems for different dynamic heads
9 Guidelines for the design of irrigation systems

9.1 Introduction

These guidelines were drawn up to assist the designer with the various decisions that would have to be made during the design process. The designer can use the guidelines to recognise any unpractical or unfeasible answers that might crop up and to then consider alternative solutions. The guidelines suggested are general guidelines for the whole country and have been tested in practice. The designer is advised to contact his nearest SABI branch for specific guidelines that might apply to the region in which the system will be based.

Furthermore, the designer is advised to seriously motivate any deviations he might make to protect himself against possible future legal proceedings.

9.2 General

In South Africa there is a great need for farmers, crop, soil and fertiliser specialists to have information on crop water requirements, nutritional requirements and the scheduling thereof in terms of recommendations for the designer to optimally design an irrigation system for specific circumstances. A multi-disciplinary approach is required when evaluating water quality for irrigation purposes, so as to identify any anticipated problems with drip systems, the determination of and management of available water sources e.g. boreholes, peak and annual crop water requirements, analysis of soil water holding capacity and infiltration rate. The designer must highlight any problems e.g. the blockage of drip systems with irrigation water, and make recommendations to solve the envisaged problems.

The following norms are proposed:

9.2.1 Pipe friction in main and sub-main pipelines

The filling up of pipelines and examples of mainline design must be according to industry standards, which must be covered in manuals specific for designers. The designer must take into account the possible affect of water quality on pipes as well as the deterioration of pipes with age during the design process. The following values for allowable pipe friction in mainlines are proposed as norms:

The following applies for pipelines with a diameter of 200 mm or smaller:

Rising pipeline: Maximum 1,5% (m/100 m) friction.
Gravity pipeline: Maximum allowable flow velocity of 3,0 m/s.

If the above figures are exceeded, the designer must show that the chosen pipe diameter’s total cost (capital and annual running cost) has been optimised and is the best of the available options. For pipelines of larger diameter, the effect of water hammer is critical and must be investigated and optimised.

9.2.2 Application efficiencies

These values mentioned are important when used to change nett irrigation requirement to system capacity (gross irrigation requirement). The efficiency of a system is made up of two components, namely the losses that take place between the emitter outlet and before the water reaches the root zone as well as the distribution uniformity (DU) of the total system after operating for a number years (Burt, 1994). Although there are numerous figures in the literature, there is a lack of reliable figures for South African conditions. In the interim the following figures are recommended as norms:
Drip systems 90%
Micro sprinkler systems 80%
Permanent sprinkler systems 75%
Moving systems 80%
Movable quick coupling sprinkler systems 70%
Traveling sprinklers and other portable sprinkler systems 65%
Flood irrigation (with piped supply system) 80%
Flood irrigation (with earth channel supply system) 60%

9.2.3 Irrigation hours per week

These values are used to determine the required pump-/stream flow size. The norms recommended by DWAF (1985) are accepted:

- Micro and permanent sprinkler systems \( \leq 144 \) hours
- Centre pivots systems \( \leq 144 \) hours
- Portable sprinkler and other portable systems \( \leq 110 \) hours
- Flood irrigation systems \( \leq 60 \) hours

9.2.4 Minimum pump capacity (safety factor for wear and tear)

These values are added to the calculated system capacity and are used to indicate the duty point (pressure and flow) when selecting a pump. The present norms are accepted:

- Discharge rate 10%
- Pressure head 5%

Where an irrigation pump is also used for the mixing and application of fertilisers, then an additional 20% pump capacity must be provided for.

9.2.5 Permissible suction velocities

A foot valve’s “open” area must be four times that of the open area of the suction hose, thus ensuring that the velocities through the foot valve do not exceed those of the suction hose by more than 25%. The following is proposed:

- Suction hose (absolute maximum) \( \leq 1,5 \) m/s
- Suction strainer \( \leq 0,4 \) m/s

9.2.6 Maximum permissible velocity in filterbank manifold

\( \leq 0,5 \) m/s

9.3 Micro irrigation

The manufacture’s standards for equipment in the industry, for example the minimum back pressure/flow required for the backwash of filters must be adhered to. The choice of equipment, for example a pressure control valve at the inlet of a block, is not part of the norms.

The following norms are recommended:

9.3.1 Minimum gross application rate

The present norm for gross application rate of \( \geq 3 \) mm/h on the wetted area remains unchanged (Lategan, 1995). The minimum recommended wetted area norm is scrapped due to management problems in the past, when irrigation controllers were not freely available.
9.3.2 Filters

Ring/mesh filter openings must be \( \leq \frac{1}{5} \) that of the emitter orifice diameter. The appropriate micro emitter manufacturer’s recommendations must be used for flow path openings of \( \leq 1 \) mm. The following norms are recommended unchanged (ASAE EP405.1, 1997):

Maximum allowable pressure drop over ring/mesh filters:

Recommended pressure drop over a clean ring filter is \( \leq 10 \) kPa. Recommended pressure drop over clean filter bank \( \leq 30 \) kPa. Maximum allowable pressure drop over a filter bank before backwashing \( \leq 70 \) kPa.

9.3.3 Minimum emission uniformity (EU)

The minimum emission uniformity (EU) is used for calculating the available pressure band for the lateral and manifold diameters. The emission uniformity is used to calculate the pressure band, as the maximum design flow variation norm amongst others, does not make provision for the manufacturer’s coefficient of variation (CV) of micro systems. The recommended EU value for flat ground is 90% (slope \( \leq 2\% \)) and 85% for undulating terrain of slopes > 2% (Keller, 1990). Each manufacturer of micro sprinklers is responsible to supply the required information (e.g. CV) to designers to determine the pressure band variation.

9.4 Drip irrigation

The dripper spacing should be determined through multi disciplinary collaboration between experts in the agricultural field. As mentioned earlier, pressure regulated valves and anti-vacuum valves installed at block inlets do not form part of the norms. The use of specific filter equipment for specific drippers depends on the specific manufacturer’s recommendations because research results for sand filters on drip irrigation are not always conclusive. This norm is thus scrapped until such time that relevant research results are available. The following industry specifications for sand filters are recommended:

A minimum of 50% of the maximum filtration rate (50 m\(^3\)/h per m\(^2\) sand surface area) is required to backwash the filters. The maximum backwash rate must not exceed 1.2 times the filtration rate. A minimum of 6 m inlet pressure is required during backwashing. The backwash time of sand filters can be between 90 - 180 seconds. Remembering that as the flush process starts, the raw water is above the sand bed, and at first appears to be clean. Thereafter the dirty water, which was trapped in the sand bed, is then expelled. During the flushing process the water will gradually appear cleaner. Thus it is so important to allow sufficient time during the backwash operation to ensure all impurities are removed from the filter.

Pressure compensated drippers are recommended to operate at a maximum of 75% of the allowable pressure of the dripper so as to protect the dripper diaphragm.

The following norms are recommended:

9.4.1 Filters

When using a sand filter, a 200 \( \mu \text{m} \) control mesh or ring filter must be placed on the downstream side of the sand filter to catch the impurities in case of damage to the sand filter. The drip manufacturers recommendations must be followed when using a ring/mesh filter. The present norms should be adjusted as follows (Van Niekerk, 1983):

The maximum allowable flow rate through a clean sand filter: Flow rate \( \leq 50 \) m\(^3\)/h per m\(^2\) with a maximum pressure drop over the sand filter of \( \leq 10 \) kPa. The maximum allowable pressure drop
over a sand filter with ring/mesh filters: Total pressure drop over a clean filter bank (including sand and ring filter) ≤ 40 kPa. The maximum allowable pressure difference over the filter bank before back-washing should be ≤ 60 kPa. When using a ring/mesh filter, the maximum allowable pressure drop norm as described in Section 9.3.2 must be complied with.

9.4.2 Minimum emission uniformity (EU)
The minimum emission uniformity (EU) is used for calculating the available pressure band for the lateral and manifold diameters. The emission uniformity is used to calculate the pressure band as the maximum design flow variation norm amongst others, does not make provision for the manufacture’s coefficient of variation (CV) of dripper systems. Each manufacturer of drippers is responsible to supply the required information (e.g. CV) to designers to calculate the pressure band. The following EU-values are recommended (Keller, 1990):

<table>
<thead>
<tr>
<th>Emitter Type</th>
<th>Number of emitters per plant</th>
<th>Topography/slope</th>
<th>EU (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Point source</td>
<td>≥ 3</td>
<td>≤ 2%</td>
<td>90</td>
</tr>
<tr>
<td>Point source</td>
<td>&lt; 3</td>
<td>≤ 2%</td>
<td>85</td>
</tr>
<tr>
<td>Point source</td>
<td>≥ 3</td>
<td>Undulating terrain or slope &gt; 2%</td>
<td>85</td>
</tr>
<tr>
<td>Point source</td>
<td>&lt; 3</td>
<td>Undulating terrain or slope &gt; 2%</td>
<td>80</td>
</tr>
<tr>
<td>Line source</td>
<td>Unlimited</td>
<td>≤ 2%</td>
<td>80</td>
</tr>
<tr>
<td>Line source</td>
<td>Unlimited</td>
<td>Undulating terrain or slope &gt; 2%</td>
<td>70</td>
</tr>
</tbody>
</table>

9.4.3 Flow velocity of laterals
A minimum flow velocity of 0,4 m/s at the furthest lateral end point is required (T-Tape, 1998).

9.5 Sprinkler irrigation
During the design stage, especially with portable sprinkler systems, it is important that the designer can interpret the available water holding capacity and infiltration rate of the soil.

The following norms are proposed:

9.5.1 Minimum gross application rate
Portable systems  ≥ 5mm/h
Permanent systems ≥ 4mm/h

9.5.2 Maximum pressure variation
≤ 20% (Jensen, 1983)

9.5.3 Christiansen uniformity coefficient (CU).
The CU-value of a specific sprinkler is influenced by the proposed operating pressure and spacing, and will give an indication of the uniformity of water distribution in an irrigation block. The sprinkler spacing and operating pressure are chosen from a manufacturer’s catalog, bearing in mind the norms applicable to the CU-value. The following norms are applicable for wind still conditions (Keller, 1990):

CU ≥ 85% for vegetable crops
75% ≤ CU ≤ 85% for deep rooted crops e.g. lucern
CU ≥ 70% for tree crops

When applying chemicals through the system, the CU should be ≥ 80%. For windy conditions the following adjustments should be made. Wind speed 0-5 km/h, reduces the chosen spacing by 10%.
Wind speed higher than 5 km/h; reduce the chosen spacing by an additional 2,5% for every additional 1,6 km/h wind speed.

9.6 Centre pivot

The selection of a sprinkler package is a multi-disciplinary process involving the interpretation of the infiltration capabilities of the soil and determination of irrigation requirements. The choice of specific bandwidths, pressure regulators and electrical motor for specific situations depends on the manufacturers specifications. A new index for the evaluation of emitter delivery rate on centre pivots is proposed (Van der Ryst, 1990):

\[
Emitter - CU = 100 \left[ 1 - \frac{\sum_{i=0}^{n} | f_i - q_i |}{Q} \right]
\]

Where 
- \( f_i \) = the actual delivery at outlet i on the centre pivot [l/h]
- \( q_i \) = the design delivery at outlet i [l/h]
- \( Q \) = the design flow rate for the total centre pivot [l/h]
- \( n \) = the number of outlets on the centre pivot

The following norms are proposed:

9.6.1 Christiansen uniformity coefficient (CU)

Emitter-CU \( \geq 95\% \)

9.6.2 Friction through centre pivot

\( \leq 2,5\% \) (m/100m) over centre pivot length.

9.6.3 Effective radius of end gun

75% of the wetted radius of the end gun.

9.7 Flood irrigation

Although flood irrigation appears to be a relatively simple system, it requires various design information to ensure a well-designed scheme. The infiltration rate of the soil must be thoroughly investigated and the results thereof taken into account during the planning phase of the system. A run-off control plan must be implemented to ensure that rainwater is kept away from the irrigation area. During the planning phase, remember that during construction not more than 20 cm of topsoil must be removed during the construction of beds.

The following norms are proposed:

9.7.1 Slope of beds

Slope along the length of the field must be \( < 0,7\% \) to prevent erosion unless an insitu test is done.
The slope across the width must be \( = 0\% \) for basin and border irrigation.

9.7.2 Allowable flow depth in beds

\( 50 \text{ mm} \leq \text{flow depth} \leq 150 \text{ mm} \)
10 References


