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Investments and annual costs for the field irrigation

Field irrigation is of major importance for agriculture and horticulture in dry years. However, the evaluation of the temporal average over a period of several years emphasizes the favourable impact of field irrigation in terms of harvest and quality assurance as well. Therefore, necessary constructional and procedural methods for the implementation of water supply are introduced and described comprehensively. For adverse conditions the financial effort for the water supply could exceed 50 % of the overall costs for the complete irrigation facility. Consequently, the annual costs predominate the capital requirement. These operating costs amount to a sum in the range of 200 to 1,350 €/(ha • a), depending on the chosen procedure.

Keywords
Irrigation, sprinkling, capital requirement, annual costs

Abstract
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Depending on the geographical situation as well as hydrogeological and water-legislative conditions, irrigation water is withdrawn from ground or surface (rivers, lakes, canals or reservoirs) sources. There are large differences in this respect between the German states. For instance in Lower Saxony irrigation water is almost exclusively withdrawn from groundwater, in the eastern states mainly from surface water (**table 1**).

Under unfavourable conditions, ensuring water supply can represent over 50% of the investment costs for an irrigation system. The biggest differences in capital requirement for water withdrawal are depicted in **figure 1**. Capital requirement for a pipeline supply network depends on many variables, e.g. pipeline diameter and length, volume throughflow and proportion of fittings required. The approximate capital requirement can represent from 600 to 900 €/ha [1]. As well as individual water supply arrangements there are in many areas irrigation associations that charge for required irrigation water according to amount used at a price which can average 0.20 €/ m³ [2].

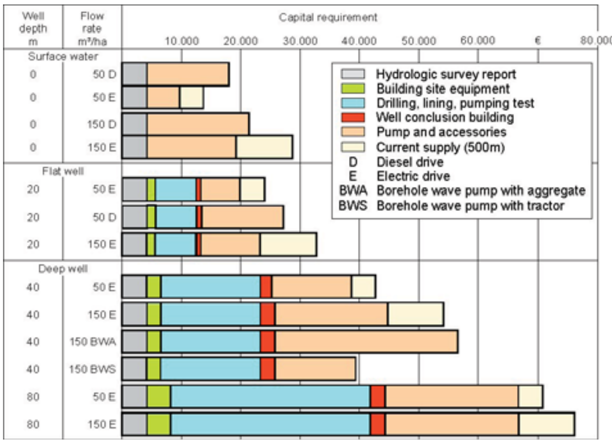
Table 1

Water sampling in Germany

Bundesland/ *Federal country*	**Grund-wasser/** *Groundwater*	**Flüsse, Seen, Kanäle/** *Rivers, lakes, channels*	**Speicher/** *Water reservoir*
		%	
Baden-Württemberg	50	40	10
Bayern	85	15	-
Brandenburg	20	70	10
Hessen	80	20	-
Mecklenburg-Vorpommern	20	80	-
Niedersachsen	90–95	5–10	-
Nordrhein-Westfalen	90	9	1
Rheinland-Pfalz (Gemüseanbau)	15	85	-
Rheinland-Pfalz (Obstanbau)	70	30	-
Sachsen	10	70	20
Sachsen-Anhalt	47	44	9
Schleswig-Holstein	50	42	8
Thüringen	5	55	40

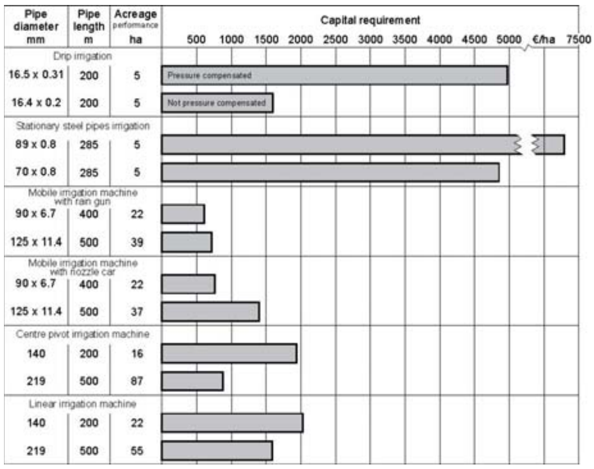
Quelle: Bundesfachverband Feldberegnung (BFVF), 1995

Fig. 1



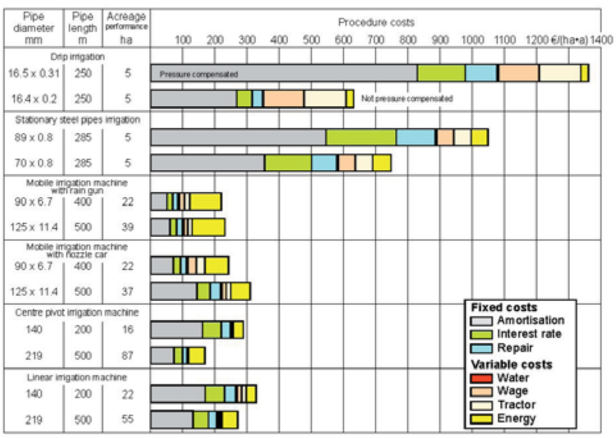
Capital requirement and structure of different pumping stations

Fig. 2



Capital requirement of different irrigation systems

Fig. 3



Costs and structure of different irrigation systems

Mobile irrigation machines with large-area rain guns

The development of plastic (polyethylene, PE) pipes which can be wound round reels has, since around 1970, enabled a further development in irrigation technology leading to mobile irrigation systems pulling a rain gun down the field or with self-propelled nozzle car, the latter system eventually failing to establish itself. For full utilisation of possible water throw distance, but above all for a good spray dissolution effect, water pressure at the hydrants must be at least 7–8 bar (4–5 bar at the rain gun). Capital requirement for machines with 400 m long, 90 mm diameter pipes and an irrigation capacity of 22 ha is approx. 610 €/ha; with 500 m, 125 mm diameter pipe and 39 ha capacity, approx. 720 €/ha (**figure 2**).

Irrigation machines with pull-in rain gun stand on the headland during irrigation. There's the possibility of laying out the PE pipeline or of pulling it out. When laying it out there's the advantage that the hose, after the fixation of the water gun car, can be gently rolled out. The hose is than wound around the reel as the rain gun car is pulled to the headland. In the case of pulling out, the irrigation machine is first of all anchored on the headland and then the rain gun car pulled out to the opposite field side whereby the hose is pulled over the surface. The irrigation pipeline and the rain gun are then pulled in by hydraulic drive (usually a turbine) and the pipe wound around the reel. Using mobile irrigation machines offers labour savings. The operation costs with 400 m of 90 mm diameter pipeline and 22 ha capacity are approx. 220 €/(ha • a); with 500 m, 125 mm diameter pipeline and 39 ha capacity approx. 250 €/(ha • a) (**figure 3**). However, they achieve poor water distribution in windy conditions and have in relationship to other systems a relatively high energy requirement, partly because of the relatively high working pressure required.

Mobile irrigation machines with nozzle car

Further developments of mobile irrigation machines with large-area water distribution have aimed at reducing the required water pressure and distributing the water through a number of nozzles on a nozzle car resulting in improved water distribution and more efficient energy utilisation. The nozzles require a pressure of only 1.5 to 2.0 bar and produce a lesser drop size with less damage potential for crop plants and soil. Well-developed applicator engineering means a working width of up to 72 m is available with hydraulic or manual folding of the boom outer arms. The entire boom oscillates horizontally, being mounted on a turntable on the car. The turntable enables the irrigation to be adjusted for effective watering of triangular areas and for avoidance of obstacles. For a machine with 400 m, 90 mm diameter pipeline and 22 ha capacity, capital requirement is approx. 760 €/ha; with 500 m, 125 mm diameter pipeline and 37 ha capacity approx. 1 400 €/ha (**figure 2**).

For irrigating even wider widths low-pressure nozzles with low jet angle are usually fitted onto boom ends. These work with 2.5 to 3.5 bar pressure and have a throw distance of around 15 m, allowing a practical throw distance of 11 m to be realised.

The application of the nozzle car technology is nowadays so well developed that irrigation with it can be a single-man operation. For machines with 400 m, 90 mm diameter pipeline and 22 ha capacity operation costs are approx. 240 €/(ha • a); with 500 m, 125 mm diameter pipeline and 39 ha capacity approx. 310 €/(ha • a) (**figure 3**).

Newer developments include the fitting of nozzle cars with trailing hoses [3]. The nozzle car design is retained and at around 0.5 m spacings half-inch hoses reaching the ground are attached. The hose ends allow free egress of water. The aim of this further development is to leave crop plants dry for phytosanitary reasons and to further reduce energy requirement.

Circle spray irrigation machines

The circle spray irrigation machine is an automatic irrigation system comprising a pipeline rotating from a single pivot point, the pipeline being supported by a number of self-propelled towers. Main components are: the central tower, the pipeline-bearing traverses with overhang, the driving towers with electric drive and the nozzles for water distribution. The working radius of such a system is usually between 300 and 500 m. As standard equipment for extending the irrigation radius a boom-end irrigation nozzle is fitted which can be activated or not (overhang 15 m and irrigation throw distance 10 m). This extension has its own booster pump. The irrigated area then represents 33–87 ha. Capital requirement for a 200 m, 140 mm diameter pipe with 16 ha capacity is approx. 1 940 €/ha; with 500 m, 219 mm diameter pipeline with 87 ha capacity, approx. 880 €/ha (**figure 2**).

Water supply is directly at the central tower in the middle of the system from either a well or hydrant connection with supply pipeline. Requirement for a uniform and good water distribution is equipage with rotating baffle plate nozzles that are hung under the traverse at 3–4 m intervals. The drive axles have good overrun and climbing characteristics so that they can without problem drive over not only potato or asparagus drills but also successfully cope with field surface slopes of up to 10 %. For machines with 200 m, 140 mm diameter pipeline and 16 ha capacity operational costs are approx. 290 €/(ha • a); with 500 m, 219 mm diameter pipeline and 87 ha capacity approx. 170 €/(ha • a) (**figure 3**).

Centre pivot irrigation machines

Centre pivot irrigation machines are comparable in technical construction with circle spray irrigation ones. The only differences are in operational procedure and energy and water supply. Basically, through the continual forward movement quadrangular fields can be irrigated with pass lengths of 400 to 1 200 m according to field set-up. The centre pivot irrigation system can have a width of 500 m with one-sided water intake. For a system with 200 m, 140 mm diameter pipeline and 22 ha capacity capital requirement is approx. 2 040 €/ha; for 500 m, 219 mm pipeline and 55 ha capacity approx. 1 590 €/ha (**figure 2**).

Following the irrigation of a strip there's the possibility of reversing the machine to the original starting position with or without watering taking place. A non-irrigation run is not absolutely necessary but when water is also applied on the return run the areas last irrigated are the first to be watered. The return journey without irrigation can be executed fairly rapidly (with 100 m/ha). The centre pivot system can avoid immediately returning over the same strip of field because there's the possibility through the one-side water supply – as with a circle spray system – of swinging the boom round 180° around the central point of water and energy supply. With 200 m, 140 mm diameter pipeline systems with 22 ha capacity operational costs are approx. 330 €/(ha • a); with 500 m, 219 mm diameter pipelines and 55 ha capacity approx. 270 €/(ha • a) (**figure 3**).

Pipeline sprinkler irrigation systems

The pipeline sprinkler irrigation systems belong to the group utilising row irrigation procedures. These mainly take the form of one or more irrigation pipelines connected to a main supply pipe. Galvanised steel sheet 70 or 89 mm diameter pipes are used with rapid coupling systems. Operational length can run to 400 m and capital requirement for 285 m, 89 mm diameter pipeline with 5 ha capacity approx. 7 290 €/ha and approx. 4850 €/ha for 285 m, 70 mm diameter pipelines for 5 ha (**figure 2**).

The layout depends mainly on the irrigation pipeline diameter, its length and the sprinklers used as well as the throw distance of the nozzles attached. Pipeline irrigation uses low-pressure sprinklers with irrigation intensity of 3–7 mm/h at a water pressure of approx. 5 bar at the hydrant and approx. 2.5 bar at the sprinkler. The high labour cost and input during lay-out have led to the systems often being permanently laid out during vegetation and only dismantled at end of season. Operational costs for 285 m, 89 mm diameter pipeline with 5 ha capacity are approx. 1 020 €/(ha • a); for 285 m, 70 mm diameter pipelines and 5 ha capacity approx. 750 €/(ha • a) (**figure 3**).

Drip irrigation systems

As a rule, drip irrigation features three system modules/components which can be added to or reduced according to system and application conditions.

1. The head unit contains armatures such as control valve, magnet valve, pressure regulator, filter element, water flow meter and fertiliser mixing equipment.
2. The supply system features main and distribution pipelines as well as connection fitments.
3. The drip system consists of drip piping, drip hoses or individual drip emitters.

There's fundamental differentiation between three layout systems:

- Above ground on the field surface (or within drills) e.g. with potatoes or strawberries.
- Above ground and suspended as with vines.
- Underground as with asparagus.

With uneven surfaces the uniformity of water distribution can be insufficient. If the height difference is greater than 1–2 m pressure compensating systems can ensure a good water distribution in the system. Capital requirement with pressure compensating systems with 200 m, 16.5 mm diameter pipes and 5 ha capacity is around 4 970 €/ha; non pressure compensating systems with 200 m, 16.5 mm diameter pipes and 5 ha capacity around 1 600 €/ha (**figure 2**).

Drip irrigation is a so-called micro-irrigation system, allowing very precise supplementary watering with relatively limited energy input in horticultural and agricultural crops with working pressure of 1 to maximum 4 bar. Costs with a pressure compensating system and 200 m, 16.5 mm diameter pipeline with 5 ha capacity: approx. 1 360 €/(ha • a); same-size systems with no pressure compensation, around 630 €/ (ha • a) (**figure 3**).

Irrigation control

Field irrigation in Germany is still mainly carried out according to individual farm experience. Because of increasing energy costs and/or limitations to supplementary water availability the objective control of irrigation is increasingly gaining in importance. Under this can be understood the control of irrigation according to reproducible criteria regarding amount of water per individual irrigation as well as time of application, e.g. according to soil moisture content or moisture balance calculation for the location. The methods used have to ensure that water use is kept as low as possible without impairing crop yield or quality. There are four basic methods for controlling or regulating irrigation:

- Depending on the climatic moisture balance
- On the basis of soil moisture measurements
- According to measurements at the crop plant
- Through application of complex plant-environment system models

Further information regarding the different control methods is detailed in [4].

Conclusions

Irrigation is one of the most expensive inputs in agriculture. Alongside capital requirement for the equipment, the working time required also plays an important role in the selection of suitable equipment. The new KTBL databank offers additional information on working time requirement and operational costs [2].

In general one can say that drip and pipeline sprinkler irrigation are the main systems applied in fruit and vegetable production. After laying out, they represent labour-saving systems. Pipeline sprinkler irrigation is also the only irrigation technique that can be used for crop frost-protection. Drip irrigation additionally enables a precise delivery of liquid fertiliser. In arable production mobile irrigation systems with their acceptable labour time requirements are the better choice for individual irrigation operations. The technology is well developed and new developments regarding the nozzle cars save energy and reduce phytosanitary problems. The stationary circle spray and centre pivot irrigation machines are investments for large areas (> 20 ha). They are the economically most advantageous irrigation technique for large areas in the same location and are increasingly used in farming.

The best results come from applying objective irrigation control on large areas with similar ground conditions that can be uniformly managed. With smaller areas such an approach is relatively expensive. Currently in such conditions control based upon soil moisture sensors or according to climatic moisture balance (e.g. Geisenheimer control) is recommended.

The new purchase of a complete irrigation plant is very expensive and requires thorough planning and installation. For this reason all irrigation types must be considered and their economic viability investigated for the area in question to ensure a competitive field irrigation system. In order to achieve the right decision on method of ensuring water availability and technology for its application expert advice is usually required.

Literature

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