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Working time requirement for different field irrigation methods

KATJA HEITKÄMPER[1], THOMAS STEHLE[2] and MATTHIAS SCHICK[2]

ABSTRACT

Prolonged dry periods are occurring with increasing frequency during the growing season due to climate change. Irrigation is, therefore, becoming more important for the improved exploitation of crop yield potential. The choice of a suitable irrigation system depends on various factors such as the crop to be irrigated, availability of water, soil condition, and topography, availability of technical and financial resources, as well as technical know-how, and manpower availability.

Three widespread irrigation methods of mobile, fixed and micro irrigation have been analysed in the geographical areas of Germany and Switzerland concerning their working time requirement for transport, assembly, operation, and dismantling. The working hours and the influencing variables were statistically analysed and integrated in a model calculation system. The results showed the working time requirement for the selected irrigation methods under modelled conditions. Regarding the required manpower, for a 1 ha plot, hose reel irrigators required 1.8 h, pipe sprinklers 9.5 h and drip irrigation systems 12.3 h total working time.

KEYWORDS: labour science; model calculation; irrigation methods

1. Introduction

Prolonged dry periods are occurring with increasing frequency during the growing season due to climate change. Irrigation is, therefore, becoming more important for the improved exploitation of crop yield potential. The choice of a suitable irrigation system depends on various factors such as the crop to be irrigated, availability of water, soil condition, and topography, availability of technical and financial resources, as well as technical know-how, and manpower availability.

In addition to the investment required and the possible applications of an irrigation system on farm, consideration should also be given to labour planning aspects when making a purchasing decision. Therefore, an up-to-date planning basis is needed for the different methods. Hardly any labour-planning data are available; most of the existing key figures are out of date. According to DIN 19655 (Deutsches Institut für Normung, 2008) five methods of field irrigation can be distinguished (Fig. 1).

According to the International Commission on Irrigation and Drainage (ICID, 2014a) in Germany a total of 540,000 ha are irrigated, which represents the 4% of the arable and permanent crop area (APC), in Switzerland app. 40,000 ha are irrigated which represents the 9.3% of the APC. Sprinkler and micro irrigation are the most common irrigation methods in Germany with over 98% of the total irrigated area (ICID, 2014b). Beyond these methods, mobile sprinkler, fixed sprinkler and drip irrigation are the most widespread methods. On large-scale farms (>20 ha) increasing use is being made of fixed rotary and linear sprinklers (Sourell, 2009).

The irrigation method is considered to be mobile when the equipment for irrigation or its parts are moved to and from the plot during the vegetation period of the irrigated crop. Pipe irrigation with fixed sprinklers and drip irrigation are considered to be fixed methods, as the irrigation equipment remains installed at the plot during the vegetation period of the crop.

This study aimed to make the relevant key figures of labour requirement for current field irrigation methods available as an aid for farmers and consultants. The focus is on the working time requirements measured in manpower hours per area (MPh/ha) for the working processes of 'transport', 'assembly', 'operation', and 'dismantling' of three selected irrigation systems, namely: hose reel irrigators, pipe irrigation with fixed sprinklers, and drip irrigation.

2. Material and Methods

Working time measurement

For the study purposes, data were collected on seventeen (17) farms with vegetable crops in Germany and Switzerland. Regarding the irrigation systems, on nine (9) farms hose reel irrigators were installed, on five (5) farms drip irrigation systems and on three (3) farms pipe systems were used. The farm size varied between 3 ha and 250 ha, while the plot sizes were ranged between 0.5 ha and 5.0 ha.

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[1] Corresponding author: Agroscope, Institute for Sustainability Sciences ISS, Tänikon 1, 8356 Ettenhausen, Switzerland. Email: katja.heitkaemper@agroscope.admin.ch

[2] Agroscope, Institute for Sustainability Sciences ISS, Tänikon 1, 8356 Ettenhausen, Switzerland.

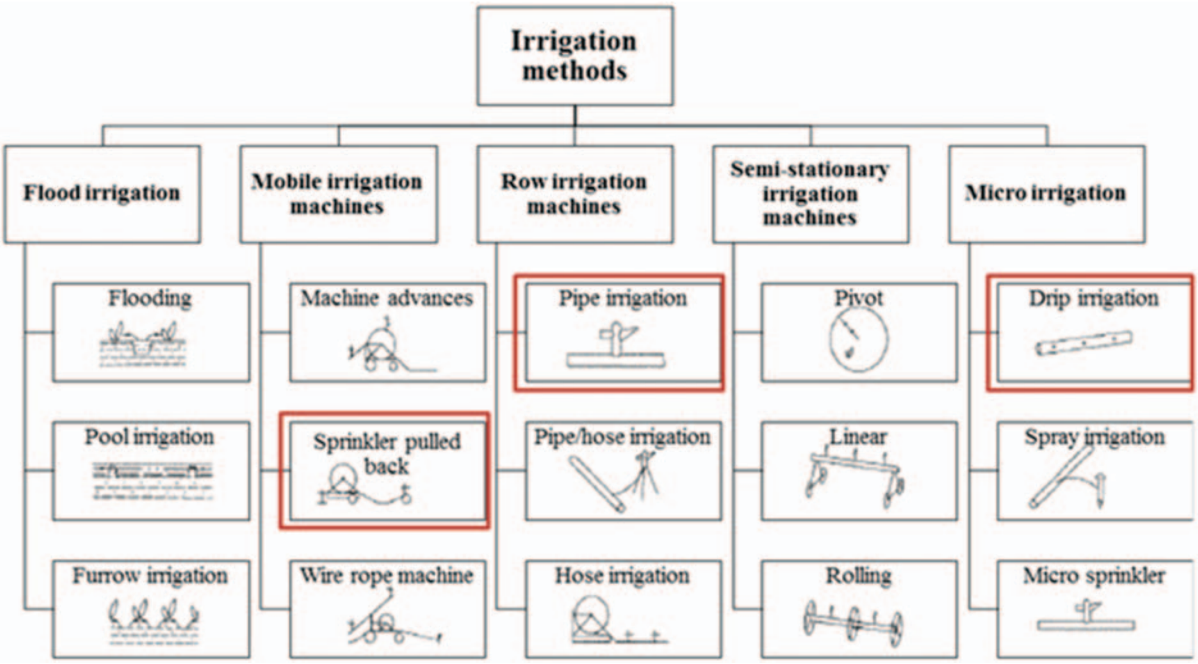

Figure 1: Overview of different methods of field irrigation (according to DIN 19655, 2008–11) (adapted from Teichert, 2009)

The working time was recorded on a work elements level in the form of direct measurements taken during observations of the performed work. Time studies were carried out in the form of flyback timing (REFA, 1972). The start and end points for each workflow segment and element were set prior to measurement. A Pocket PC (Dell Axim, Dell, USA) and a special time recording software (Ortim b3, DMC-Ortim, Germany) were used for time recording. In each case one segment of elapsed time (measured in cmin $=10^{-2}$ min) was allocated to the associated work element.

An initial evaluation of the working time studies was performed while data were collected. The arithmetic mean was continuously calculated for cyclic measurement segments. Also, at this stage, the *epsilon* value and standard deviation were already given as a measure of sample quality for the cyclic measurement segments. The values of the corresponding influencing variables of non-cyclic workflow segments have been added to the work elements during measurement. The influencing variables such as field sizes, farm to field distances, irrigation system dimensions (e.g. sprinkling width used, line spacing, sprinkler spacing), on which the model calculation is based, were also recorded during work observation on the farm.

Statistical evaluation and model calculation

For further processing, the recorded data were checked with descriptive statistical procedures (normal distribution, outlier, coincidence) (Schick, 2008).

Subsequently, the planning time values, consisting of the arithmetic means, were calculated and added to the database. The database is part of a long-term project collating planning time values for work elements across all agricultural areas. In this database, each element has a unique alphanumeric code assigned, a name with beginning and end points, and the appropriate statistical parameters, including contents description, author, and creation date. Some work elements were not measured but modelled. Therefore, for these elements the model is also included in the database.

The PROOF model calculation system was used for modelling the working time requirement of the investigated irrigation methods. PROOF is a modular system based on a spreadsheet software (Schick, 2008). The model calculation system involves the logical linking of work elements with the quantitative and qualitative influencing variables affecting them. All influencing factors are entered in the model calculation system as variables and can be altered at any time within the upper and lower bounds. A warning message is automatically displayed in the event of entries falling outside these limits (Riegel and Schick, 2007).

Investigated irrigation methods and assumptions

The following methods were chosen by the German Association for Technology and Structures in Agriculture (KTBL) to be analysed in this project: mobile irrigation machine with mobile sprinkler, pipe irrigation with fixed sprinklers, and drip irrigation. The connection to the hydrant is the same in all three methods. Depending on the distance between the field and the hydrant, the irrigation system is connected to the hydrant by laying pipelines or hoses, in many cases even a combination of both. The lines are generally laid manually, or by machine where distances are relatively large (>100 m). The pump can be switched on by remote control, by mobile phone or directly at the pump. With older diesel-driven pumps the water pressure needs to be adjusted, particularly when several machines are simultaneously operating from the water main. In the case of new electrical installations, the above procedure is performed automatically. In the examined model, the water pressure at the pump was adjusted automatically.

Figure 2: Mobile sprinkler (Rollomat) (left), Assembly of fixed sprinkler (centre), Laying of drip irrigation (right) (source: Agroscope)

Hose reel irrigator

The hose reel irrigator, also referred to as 'Rollomat', belongs to the mobile irrigation machines. A cylindrical hose drum is hinged on a chassis (Fig. 2, left). A sprinkler trolley can be placed on the irrigator for transportation. It is either equipped with a jet spray bar or a single gun sprinkler. In the model a jet spray bar with a range of 18 m was used. At the field the sprinkler trolley was hitched to the tractor and the hose stretched across the plot. Depending on the plot size and shape the hose reel irrigator has to be moved after one strip is irrigated. The hose reel irrigator can be set up and operated by one person.

Pipe sprinkler

The second method belongs to the fixed irrigation systems. Pipe sprinklers are used mainly on relatively large farms and for crops which need repeated watering (Fig. 2, centre). Pipes of 6 m length are assembled in lines. Every 18 m a sprinkler is positioned on the pipe. The installation is usually done by two to three people.

Drip irrigation

The third method is the drip irrigation which belongs to the micro irrigation systems. In Germany and Switzerland it is used mainly for bedding and ridge cultivation crops (potatoes, asparagus, etc.). The drip hoses referred to as drip tape are laid by a combined laying and reeling device (Fig. 2, right) and can be single-row or multi-row. In the model a two row system is used to lay the tape above ground. The distance between rows depends on the crop and is assumed 1.5 m. Two persons are required for the installation.

Assumptions for the model calculation

In the calculation model the following assumptions were taken. All three methods use a hose of 300 m length to connect to the head unit and water source. The farm to field distance is 1,000 m. The rectangular plot has a field length of 141 m and width of 71 m (app. 1 ha, standardized plot defined by KTBL, 2010). The working time requirement does not include the irrigation time. All of the nine farms using drip irrigation systems for vegetables dismantle the system after one vegetation period.

3. Results

Total working time requirement

The total working time requirement for the three investigated irrigation methods considering transport, assembly, operation and dismantling varies from 1.8 h/ha for hose reel irrigation to 9.5 h/ha for pipe/sprinkler irrigation and 12.3 h/ha for drip irrigation (Fig. 3).

Processes of transport and assembly of the hose reel irrigation system require 0.6 h/ha each, while processes of operation and dismantling require 0.3 h/ha each. The mobile irrigation is the system with the least required working time. As far as pipe sprinkler irrigation is concerned, the transport is the work process with the highest working time requirement with 4.4 h/ha. This is due to the fact that pipes are usually stored on pallets and are loaded manually to the transport vehicle. Finally, the drip irrigation system requires most of the working time for assembly with 6.3 h/ha.

Working time requirement for hose reel irrigation

The hose reel irrigation system is equipped either with a jet spray bar or a single gun sprinkler. After the

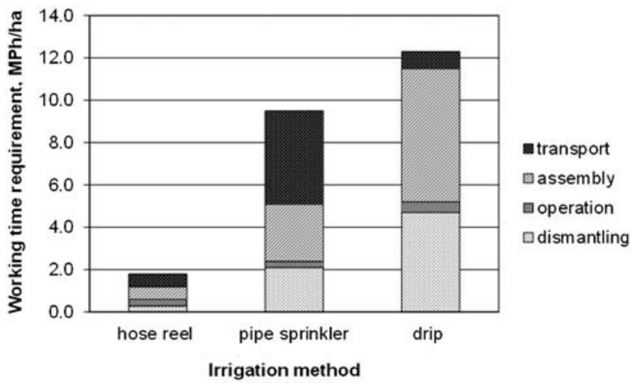

Figure 3: Total working time requirement for hose reel, sprinkler and drip irrigation. **Notes:** Plot size: 1 ha. MP: manpower

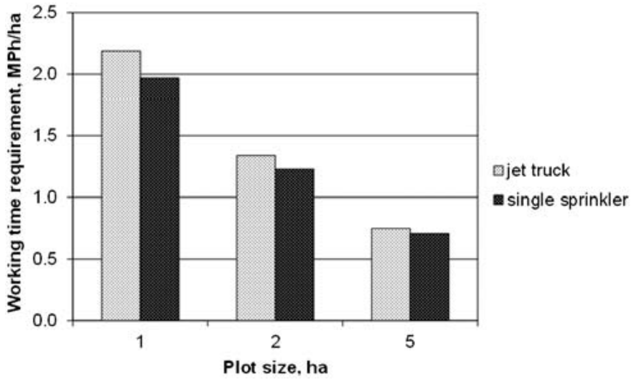

Figure 4: Comparison of working time requirement for hose reel irrigation equipped with two different sprinkler types for various plot sizes. **Notes:** Sprinkling width 30 m. MP: manpower

sprinkler trolley is lowered the jet spray bars are extended. This work is not needed on gun sprinkler trolleys. The difference in the working time required for the assembly of the jet truck compared to the single gun sprinkler is 0.2 h/ha (Fig. 4).

Working time requirement for pipe sprinkler irrigation

The pipe sprinkler irrigation system can be installed with different line spacing and sprinkler spacing. Line distances of 18 m or 24 m and sprinkler distances of 12 m or 18 m are common. The spacing affects the number of lines that have to be installed and, therefore, the working time required (Fig. 5).

A line spacing of 24 m instead of 18 m reduces the required working time for 1 ha by 17.2%. On the other hand, a sprinkler spacing of 18 m compared to 12 m reduces the working time requirement only by 2.8%, as in both cases a person has to walk along the same number of lines.

Working time requirement for drip irrigation

Plot sizes and shapes in horticulture often vary from those in agriculture. In many cases, plots are narrower in horticulture. Therefore, a second type of plot has been defined referred to as 'horticultural plot'. The plot length was 250 m and the plot width 40 m (1 ha area in total). The plot shape influences the working time requirement significantly. Figure 6 provides a comparison of the working time requirement for drip irrigation on horticultural and agricultural plots. It is shown that a plot with a greater plot length requires less working time in total, with the horticultural plot requiring 14.2 h/ha and the agricultural plot 18.1 h/ha. Especially the relative proportion of time required for connecting the drip tape to the water supply system increases in agricultural plots, as more lines have to be connected. The time saved for laying the tape in a shorter row does not compensate for the connecting of additional lines in agricultural plots.

4. Conclusions

The analysis of the three different irrigation methods showed differences in the working time requirements. The hose reel irrigator is the most flexible system and can be installed in various plots during the vegetation period. However, with the fixed irrigation methods, sprinkler and drip irrigation, it is possible to irrigate the whole plot at the same time which is essential under specific climate conditions. The decision for the appropriate irrigation method depends on many aspects, such as water requirement of the crop, water availability, soil and climate conditions, etc.

In this study, drip irrigation was found to be the irrigation method with the highest working time requirement with 12.3 h/ha under modelled conditions. Various studies have been conducted about drip irrigation compared to traditional irrigation methods. For example, Woltering (2011) mentions 1.1 h/ha per day for a 0.05 ha drip irrigated plot in Niger. According to Murali (2012) drip irrigation requires a total of 30 h for 1 ha of sugar cane for the whole vegetation period, which is only 10% of the working time required for furrow irrigation.

However, the available publications on studies of irrigation seldom focus on the working time requirement and often lack information of how labour data was taken. Usually, this data is collected using work diaries and, therefore, apply to the working time consumption of a work process including minor interruptions which can

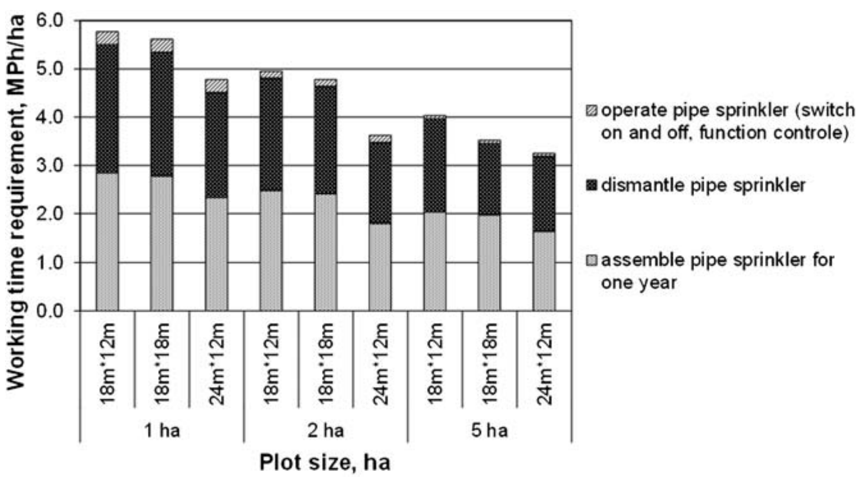

Figure 5: Working time requirement for pipe sprinkler irrigation with different line and sprinkler spacing. **Notes:** Line spacing (m) x sprinkler spacing (m). MP: manpower

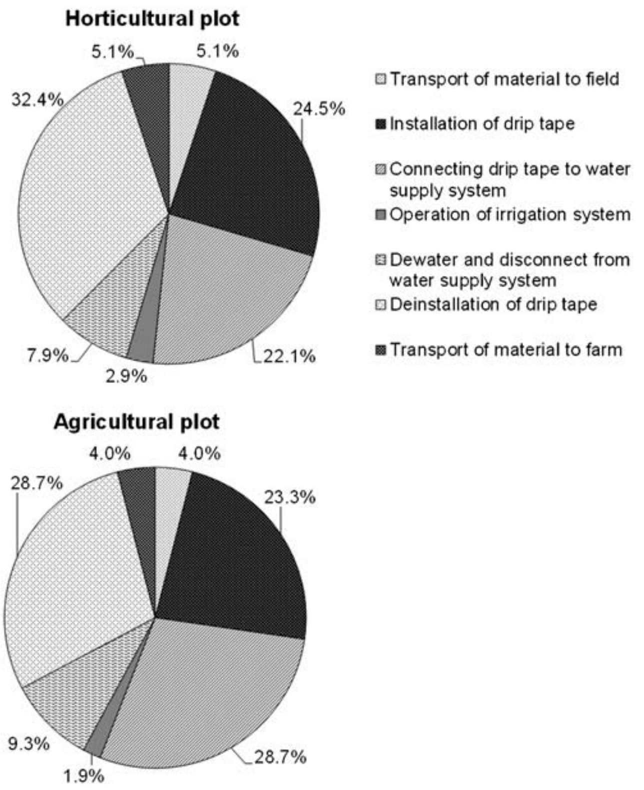

Figure 6: Comparison of working procedures as relative proportions of total working time requirement when drip irrigating horticultural and agricultural plots, drip pipe spacing 0.75 m. **Notes:** Total working time requirement horticultural plot 14.2 MPh/ha. Total working time requirement agricultural plot 18.1 MPh/ha. MP: manpower)

have various origins, e.g. malfunctions, waiting time, rest time, etc. The PROOF model calculation system computes the working time requirement, which means only the time exclusively needed to perform the work according to the best practice is given. This is probably the reason for differences of data reported in other studies.

Another aspect is the useful life of the irrigation system. According to the farmers involved in the project all systems can be used over a period of up to 30 years and more when being well maintained. Especially, when drip irrigation is used in permanent crops such as wine and fruit trees, the annual working time requirement is reduced to regular controls and annual maintenance.

This study demonstrated the potential and the limits of cost-effective plant production from a labour-economics point of view. Qualitative aspects of irrigation that are also significant for high productivity and cost-effective working methods will have to be considered in a future study.

About the authors

Katja Heitkämper is a researcher working in the Work, Buildings and System Evaluation research group at Agroscope Institute for Sustainable Siences (ISS) in Tänikon, Switzerland. Since 2004, her research focuses on the data collection, evaluation and modelling of working time requirement for agricultural work and production processes.

Thomas Stehle is a researcher working in the Work, Buildings and System Evaluation research group at Agroscope ISS in Tänikon, Switzerland. Until 2013, he was mainly involved in the development of a decision-support tool for labour planning in agriculture. He is currently working on a project dealing with efficiency improvements in mechanical weed management in root crops.

Prof. Dr. habil. Matthias Schick is head of the Work, Buildings and System Evaluation research group at the Agroscope ISS in Tänikon, Switzerland. He has worked at Agroscope for over 20 years. His research areas include project- and process management in relation to working-time requirements, working-time planning, ergonomics, safety at work and the development of decision-support tools. He also heads projects on animal husbandry and work procedures in hill farming. In this function, he is responsible for more than 25 researchers, 250 publications and more than 50 yearly speeches, lectures and presentations.

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