Working Time Requirement for Different Field Irrigation Methods

Katja Heitkämper[1], Thomas Stehle[1], Matthias Schick[1]
[1]Agroscope Research Station ART, Tänikon 1, CH-8356 Ettenhausen, Switzerland
Corresponding author e-mail: katja.heitkaemper@art.admin.ch

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, not only in the special and intensive crop sector but also in the area of cereals, specifically maize. Various irrigation methods are available, depending on the crop grown and conditions on the farm. A distinction is made between mobile and fixed systems of field irrigation. Besides pipe sprinkling and watering with mobile sprinklers, drip irrigation is becoming particularly important from the perspective of water resource conservation. It is used mainly for bedding and ridge cultivation crops (potatoes, asparagus, etc.). On large-scale farms with over 20 ha increasing use is also being made of fixed rotary and linear sprinklers (Sourell, 2009).

In a project run by Agroscope Reckenholz-Tänikon Research Station (ART) and the German Association for Technology and Structures in Agriculture (KTBL) three widespread irrigation methods of mobile, fixed and micro irrigation have been analyzed concerning their working time requirement for transport, assembly, operation and dismantling. Time measurements were carried out on farms in Germany and Switzerland. The working hours and the influencing variables were statistically analyzed and integrated in a model calculation system. The results from the model calculation show the working time requirement for the selected irrigation methods under modeled conditions. For a 1 ha plot hose reel irrigators require a total working time of 1.8 MPh/ha, pipe sprinklers 9.5 MPh/ha and drip irrigation systems 12.3 MPh/ha.

Keywords: working time requirement, model calculation, irrigation methods

1. INTRODUCTION

The choice of a suitable irrigation system depends on various factors such as the crop to be irrigated, availability of water, soil condition, topography, availability of technical and financial resources as well as technical know-how and last not least availability of manpower.

In addition to the investment required and the possible applications of an irrigation system on a farm, consideration should also be given to labor planning aspects when making a purchasing decision. Therefore, an up-to-date planning basis is needed for the different methods. Hardly any

Katja Heitkämper. “Working Time Requirement for Different Field Irrigation Methods”. International Commission of Agricultural and Biological Engineers, Section V. CIOSTA XXXV Conference “From Effective to Intelligent Agriculture and Forestry”, Billund, Denmark, 3-5 July 2013. The authors are solely responsible for the content of this technical presentation. The technical presentation does not necessarily reflect the official position of the International Commission of Agricultural and Biosystems Engineering (CIGR), and its printing and distribution does not constitute an endorsement of views which may be expressed. Technical presentations are not subject to the formal peer review process by CIGR editorial committees; therefore, they are not to be presented as refereed publications.

labor planning data are available; most of the existing key figures are out of date. The aim of the present study is to make the appropriate key figures for current field irrigation methods available as an aid to farmers and consultants.

According to DIN 19655 (Deutsches Institut für Normung, 2008) five methods of field irrigation can be differentiated (Fig. 1):

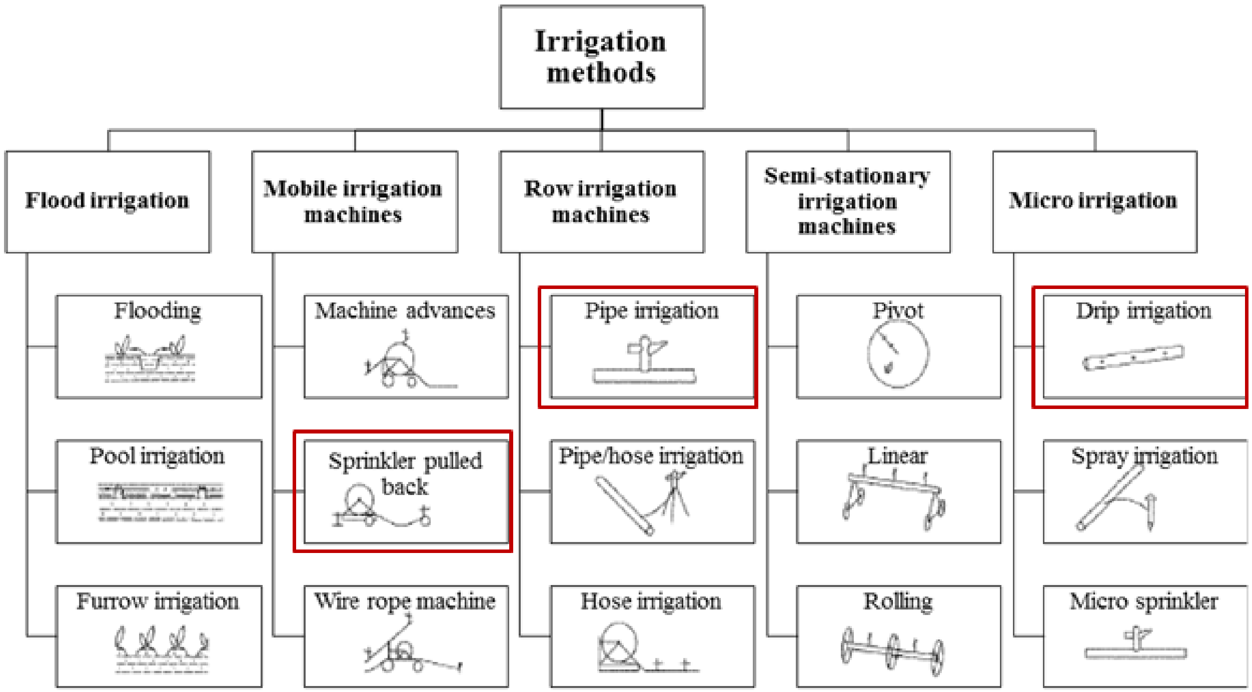

Figure 1. Different methods of field irrigation (according to DIN 19655, 2008-11) modified after Teichert, 2009.

The methods mobile irrigation with mobile sprinkler, pipe irrigation with fixed sprinklers and drip irrigation were analysed in this study.

2. MATERIAL AND METHODS

2.1 Working Time Measurement

Working time was recorded on work element level in the form of direct measurements taken during observations of work on 17 farms. 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) and special time recording software (Ortim b3) was used for time recording. In each case one segment of elapsed time (measured in cmin = 1/100 min) was allocated to the associated work element.

An initial evaluation of the working time studies was performed while data was being 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 (sprinkling width used, line spacing, sprinkler spacing, etc.), on which the model calculation is based, were also recorded during work observation on the farm.

2.2 Statistical Evaluation and Model Calculation

For further processing, the recorded data is first prepared in tabular form, and then examined with non-problem-oriented test procedures (normal distribution, outlier, coincidence). In the absence of normal distribution, a one-sided logarithmic transformation is carried out as a basis for the following problem-oriented test procedures and regression calculations (Schick, 2008).
Next, the analyzed data are transferred in the form of planning-time values and functions to a planning-times database table, with each element being assigned a unique alphanumeric code, a name with beginning- and end points, and the appropriate statistical parameters, including contents description, author, and creation date.

The PROOF model calculation system is used for modeling the working time requirement of the investigated irrigation methods. PROOF is a modular system based on table calculation software (Schick, 2008). The continuing calculation of working-time requirement values on the level of work processes is performed with the built-in model calculation system. This 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).

2.3 Investigated Irrigation Methods and Assumptions

The three methods mobile sprinkler, fixed sprinkler and drip irrigation are the most widespread in Germany (Sourell, 2009). These were chosen by the KTBL to be analyzed in this project. The working processes “transport”, “assembly”, “operation” and “dismantling” of these three methods differ from each other, whereas the connection to the hydrant is the same. 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 from a 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. Newer electrical installations do this automatically. In the model the water pressure at the pump is adjusted automatically.

2.3.1 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 is used. At the field the sprinkler trolley is 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.

Figure 2. Left: mobile sprinkler (Rollomat), center: assembly of fixed sprinkler, right: laying of drip irrigation (source: ART).

2.3.2 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, center). 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 persons.

2.3.3 Drip irrigation

The third method is the drip irrigation which belongs to the micro irrigation systems. 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.

2.4 Further Assumptions for the Model Calculation

In the calculation model 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 1000 m. The rectangular plot has a field length of 141 m and width of 71 m (approx. 1 ha, standardized plot defined by KTBL, 2010). The working time requirement does not include the irrigation time.

3. SELECTED RESULTS AND DISCUSSION

3.1 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 MPh/ha for hose reel irrigation to 9.5 MPh/ha for pipe/sprinkler irrigation and 12.3 MPh/ha for drip irrigation (Fig. 3).

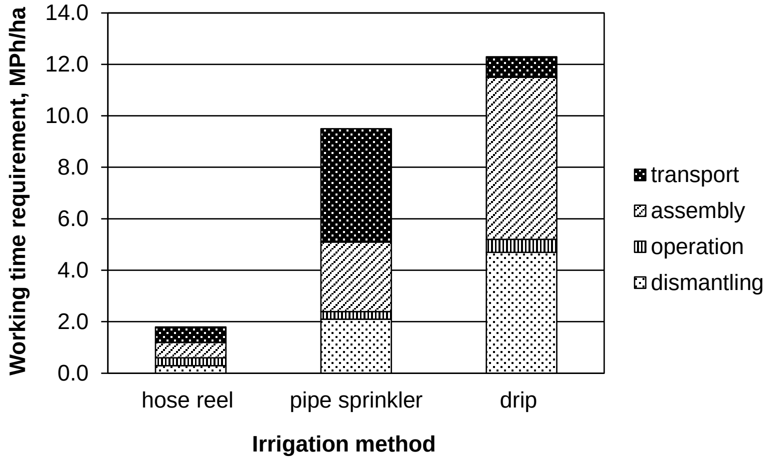

Figure 3. Total working time requirement for hose reel, sprinkler and drip irrigation (plot size: 1 ha).

Transport and assembly of the hose reel irrigation system require 0.6 MPh/ha each for a plot size of 1 ha, operation and dismantling 0.3 MPh/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 MPh/ha. This is because the 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 MPh/ha.

3.2 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 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 MPh/ha (Fig. 4).

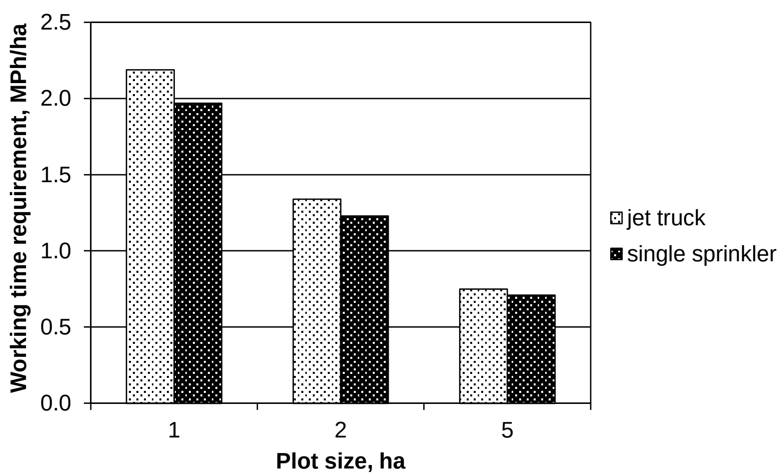

Figure 4: Comparison of working time requirement for hose reel irrigation equipped with two different sprinkler types on various plot sizes (sprinkling width 30 m).

3.3 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 18m or 24m and sprinkler distances of 12m or 18m are common. The spacing affects the number of lines that have to be installed and therefore the working time required (Fig. 5)

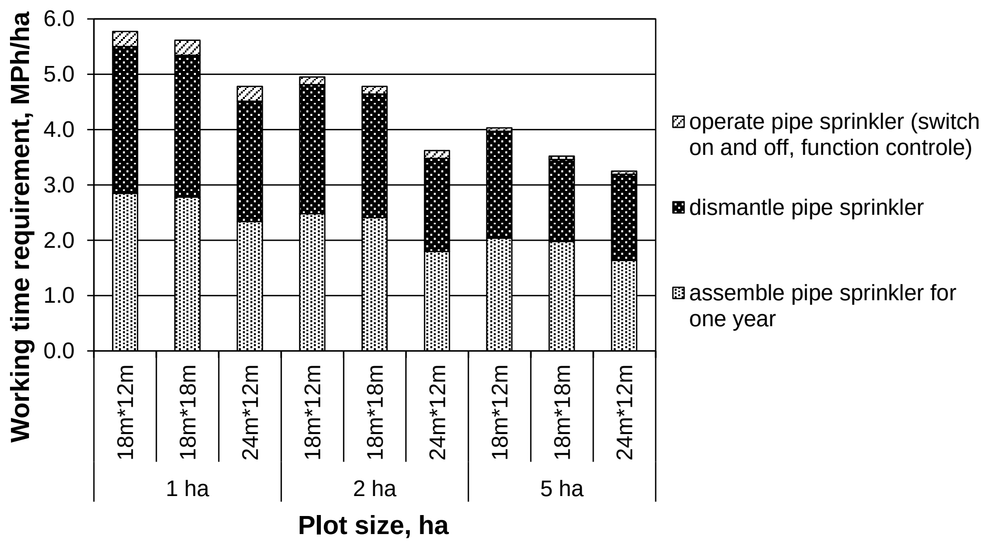

Figure 5. Working time requirement for pipe sprinkler irrigation with different line and sprinkler spacing (line spacing, m x sprinkler spacing, m).

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

3.4 Working Time Requirement for Drip Irrigation

Plot sizes and shapes in horticulture often vary from those in agriculture, mostly they are narrower. Therefore a second type of plot has been defined referred to as “horticultural plot”. The plot length is 250m and the plot width 40m (= 1ha). The plot shape influences the working time requirement significantly. Figure 6 shows a comparison of the working time requirement for drip irrigation on horticultural and agricultural plots. It is shown that a plot with the greater plot length requires less working time in total, horticultural plot 14.2 MPh/ha, agricultural plot 18.1 MPh/ha. Especially the relative proportion of time required for connecting the drip tape to the water supply system increases in agricultural plots, because 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.

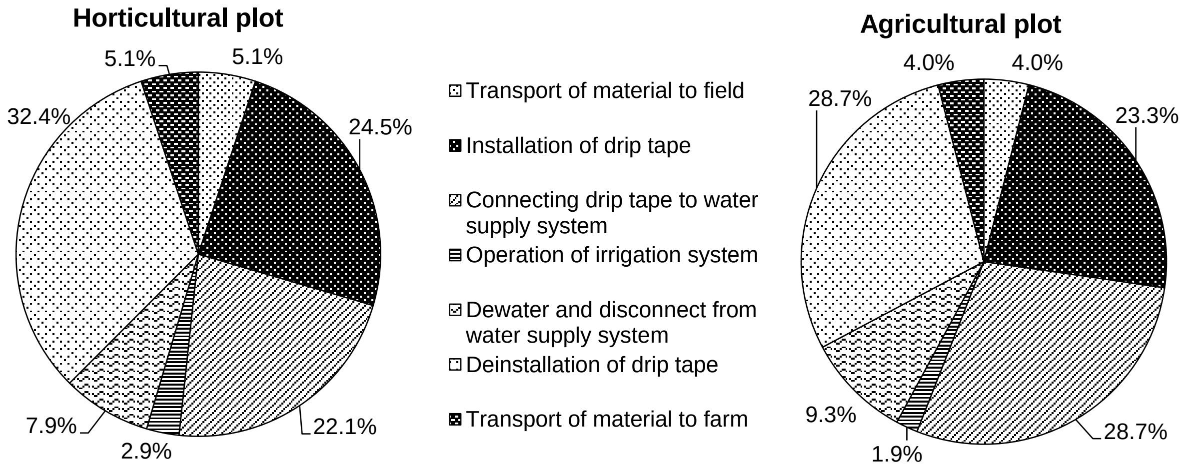

Figure 6. Comparison of working procedures as relative proportions of total working time requirement when drip irrigating horticultural and agricultural plots, drip pipe spacing 0.75 m (total working time requirement horticultural plot 14.2 MPh/ha, total working time requirement agricultural plot 18.1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

4. CONCLUSION

The decision for the appropriate irrigation method depends on many aspects such as water requirement of the crop, water availability, soil condition, etc. Analysis of the data collected in the PROOF model calculation system demonstrates the potential and the limits of cost-effective plant production from a labour-economics' point of view. Qualitative aspects that are also significant for high productivity and cost-improving working methods will have to be considered in a separate study.

5. REFERENCES

Deutsches Institut für Normung e. V. 2008. DIN 19655 Bewässerung - Aufgaben, Grundlagen, Planung und Verfahren.

KTBL (ed.). 2009. Datensammlung Feldbewässerung. Betriebs- und arbeitswirtschaftliche Kalkulationen. Darmstadt.

REFA. 1972. Methodenlehre des Arbeitsstudiums. Teil 1, Grundlagen. Carl Hanser Verlag, München, 2. Edition.

Riegel, M., Schick, M. 2007. Working time requirement in agriculture – recording method, model calculation and work budget. Society for Engineering in Agriculture, 2007 National Conference. Agriculture and Engineering – Challenge Today, Technology Tomorrow. 23.-26. September, 2007 Adelaide, South Australia. Editors T. Banhazi and C. Saunders, p. 328.

Schick, M. 2008. Dynamische Modellierung landwirtschaftlicher Arbeit unter besonderer Berücksichtigung der Arbeitsplanung. Ergonomia-Verlag, Stuttgart.

Sourell, H. 2009. Bewässerungstechnik: Wasserverteilung mit Blick in die Zukunft, Freilandberegnung. Tagungsband zum Statusseminar im Forum des vTI. Braunschweig, 9. und 10. Februar 2009. Landbauforschung, Special Issue 328.

Teichert, A. 2009. Freiland Tropfbewässerung im Gemüsebau und weiteren Gärtnerischen Kulturen. Tagungsband zum Statusseminar im Forum des vTI. Braunschweig, 9. und 10. Februar 2009. Landbauforschung, Special Issue 328.