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Site specific drip irrigation with wireless sensor networks in grapevine production

Increasing world population and climate change call for improved water use efficiency in agricultural irrigation practice. Site specific drip irrigation has the potential to meet this needs, because water is optimal applied with respect to quantity and location. Since spatial information about the water demand is mandatory, a wireless soil moisture sensor network was developed to identify spatial soil water content differences. A pressure-driven flow valve was designed in order to realize independent irrigation of single dripline sectors. The investigations exemplarily took place in a drip irrigated vineyard.

Keywords
Drip irrigation, Precision irrigation, soil moisture sensor, wireless sensor network

Abstract
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Drip irrigation plays a key role in optimizing water use and distribution, since water is applied precisely and water losses (evaporation, seepage) are reduced. Site specific irrigation (precision irrigation) plays another key role. Site adapted irrigation takes spatial differences in water availability and water holding capacity of the soils into account, which both depend mainly on spatial differences in soil hydraulic properties and topography. Hence, the combination of drip irrigation and site specific irrigation is most promising for increasing water use efficiency.

Spatio-temporal information about the soil water balance are mandatory for scheduling site specific drip irrigation. In addition, technical solutions are required for its realization. Different irrigation treatments are possible for different driplines but not easily practicable along single lines.

In the framework of a research project funded by the BLE (Bundesanstalt für Landwirtschaft und Ernährung), a wireless sensor network was developed. It serves for collecting soil moisture data measured with spatially distributed soil moisture sensors as basis for site specific irrigation planning. The research took place within a dripline irrigated vineyard. A further research objective aimed on site specific drip irrigation and thus on the realization of different irrigation treatments along single driplines.

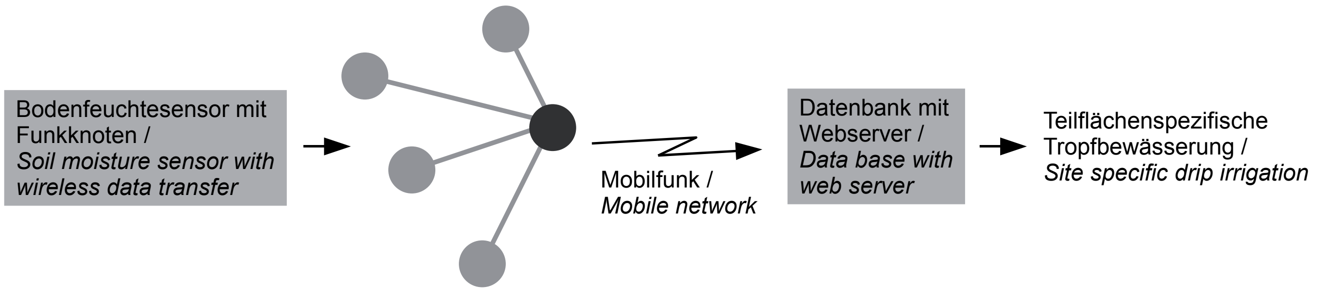
Wireless sensor network

Spatio-temporal soil moisture information can be obtained by wireless data transfer from sensors installed in sub-areas to a central station. Subsequently, sampled data of the central station is sent to a web-based data base by mobile radio. The data stored can be read out, displayed and further used for site specific irrigation planning (**figure 1**).

Soil moisture measurements were realized with dielectric sensors of the Hochschule Mannheim (**figure 2**). The electromagnetic permittivity of a soil depends mostly on its water content and can therefore be used as a measure for calculating soil water content. A sensor consists of a ring oscillator circuit on a fiberglas-strengthened printed board which will be embedded in the soil. Depending on the soil water content, the electrical permittivity is changing and as a consequence the frequency of the ring oscillator is changing as well. This frequency is counted by a micro-controller and transferred in soil water content information in which the influence of temperature is accounted for. The calculation algorithm is based either on a soil specific calibration or an empirical relation. The output of the sensor can be provided as an analog voltage or current signal or by using digital interfaces (RS485, RS232 or USB).

The wireless sensor network was developed in order to transfer the measurement results from the soil moisture sensors to the central station. It consists of wireless nodes operating in the 868 MHz-frequency range. The line of sight propagation range is up to 20 km. Even though the range is distinctly smaller in vineyards due to the attenuation effects of metal supporting wires and vegetation, it is still sufficient for the described purpose. The data transmission interval from a node to the central station can be adjusted by the user. The current supply

Fig. 1



System components for site specific drip irrigation

is realized with 4 round cells R6 which last up to one year if data is transferred every two hours.

The measurements are stored by the central station and subsequently sent to the data base via mobile radio. The data of the data base can be accessed and analysed with a web-based user interface. Additionally it is also possible to send back irrigation commands to the central station using a web-server. Access to the irrigation controls in the field is possible with different interfaces at the central station (RS232, RS485 via converter, digital interface with 0-5 V I/O and 8 channels).

Site specific drip irrigation – water as an information carrier

Farmers already carry out site specific drip irrigation by subdividing the dripline in independent dripline sectors (ds). The single ds are fed with water through a supply hose. However, water flow to the ds has to be controlled with hand valves. Automation presupposes the use of solenoid valves, whose use is hindered by distinctly higher costs and complexity (wiring or wireless signal transfer).

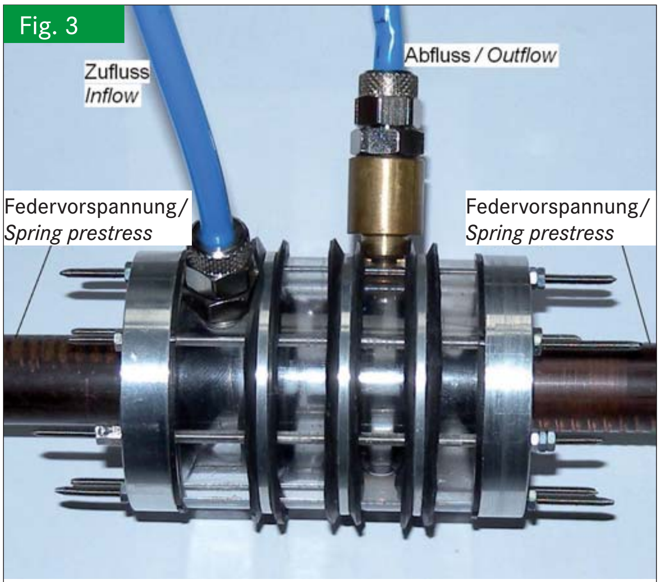
The objective of the research project was to find an alternative to hand or solenoid valves. Pressure-driven flow valves (fv) were developed. They promise low costs, easy handling and low maintenance, because water is used as information carrier (**figure 3**) for fv operation. In general the fv is locked but able to switch within a predefined water pressure range. The flow water pressure range can be adjusted with springs and thus be adapted to the given on site situation. By using several fv it is possible to irrigate single ds independently just by changing the flow water pressure in the supply hose.

The pressure loss at the fv is influenced by the flow rate but independent from the prevailing water pressure. The effective pressure loss was found to be negligible (Δp = 0,03 bar) at a small flow rate of 20 l/h (10 drippers with 2 l/h each) but increased distinctly if 40 drippers (flow rate = 80 l/h) were used (Δp = 0,38 bar). The pressure loss is construction-related and can be reduced by increasing the flow channel cross section within the fv.

Fig. 2

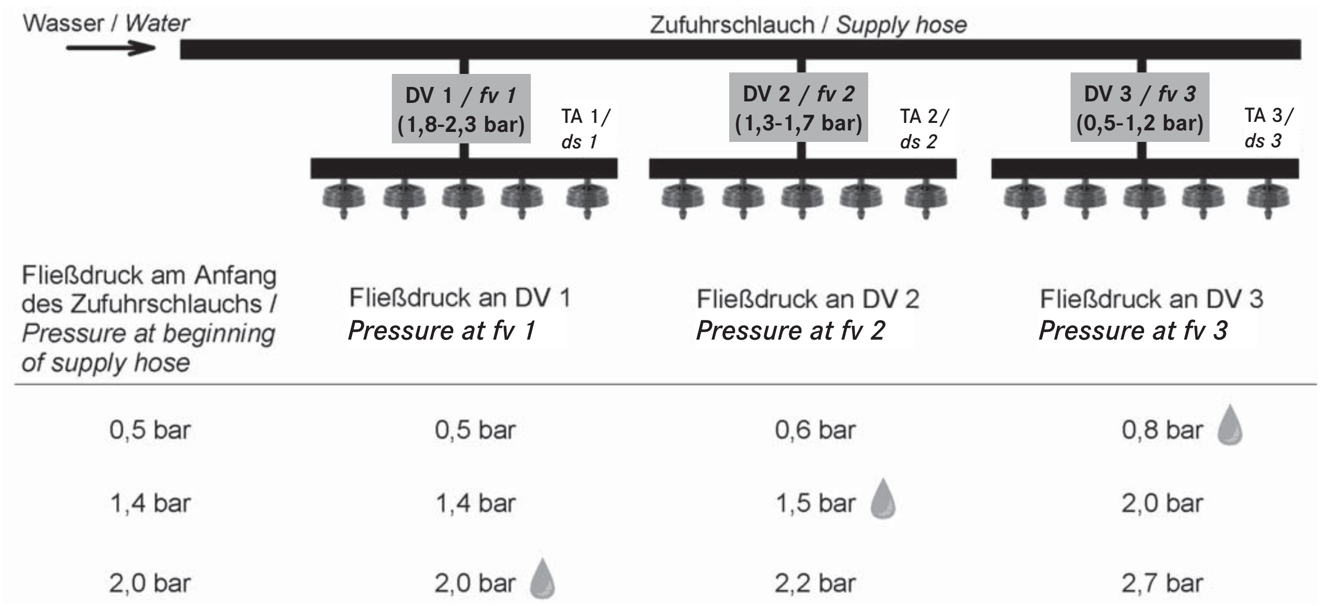
Soil moisture sensors (left) and wireless node for data transfer of soil moisture data (right)

Fig. 3



Pressure-driven flow valve (fv). Water flow through the fv is disabled but possible within a predefined water pressure range adjusted with springs.

Fig. 4



Sketch of the on-farm irrigation experiment (LVWO Weinsberg). Water is fed to the supply hose on plateau position. The dripline sectors (ds) 1 to 3 are irrigated independently by switching the pressure-driven flow valves (fv) 1 to 3 with different water pressures in the supply hose (actual irrigation is indicated with a water drop)

Detailed measurements of flow rates through fv revealed that they differ within the flow pressure ranges. Maximum flow rates were measured in the middle of the flow pressure range, while minimum flow rates were observed close to the opening and closing pressures. However, these differences are minor (< 1 % of the average flow rate) so the influences of slight water pressure changes in the supply hose can be neglected in practice.

The general applicability of the developed fv was verified with irrigation experiments in a vineyard (**figure 4**). 50 vines spread along a slope with 20 meter altitude difference were irrigated. The slope was subdivided in 3 dripline sectors (ds).

The ds 1 (upper slope) 2 (middle slope) and 3 (lower slope) covered 15, 16 and 19 vines. At each vine one dripper (pressure compensated, 2 l/h) was installed. Water was fed to the supply hose on plateau position (upper slope). The used fv were adjusted to flow pressure ranges of 0,5–1,2 bar (fv 3), 1,3–1,7 bar (fv 2) and 1,8–2,3 bar (fv 1).

Static water pressure at lower slope position was 2 bar higher than at upper slope, because of the altitude difference. Friction pressure losses during the irrigation experiment counteracted this static water pressure increase, why flow water pressure differences between upper and lower slope were smaller.

Irrigation started with a flow water pressure of 0,5 bar at plateau position (beginning of the supply hose). At fv 1 and fv 2 the measured flow water pressures were 0,5 bar and 0,6 bar, respectively. However, the flow pressure ranges of these fv were set higher so ds 1 and ds 2 did not irrigate. In contrast to ds 1 and ds 2, irrigation was performend in ds 3, because flow water pressure at fv 3 (0,8 bar) was within the adjusted flow pressure range (0,5–1,2 bar). The flow water pressure at plateau position was subsequently increased to 1,4 bar, which resulted in a closing of fv 3 but opening of fv 2. Finally the flow water pressure at plateau position was increased to 2,0 bar. This resulted in a closing of fv 2 but opening of fv 1.

Conclusions

Spatio-temporal information about the soil water balance is a prerequisite for efficient and site specific irrigation planning. The developed system components (soil moisture sensor and wireless sensor network) demonstrated robust and energy efficient soil moisture measurements and data collection and thus are suited for long-lasting battery-driven use in agriculture. The measurements are sent by mobile radio to a data base. That way it is possible to control both measurements and sensor network at the computer workstation. In addition, irrigation can be manually triggered or automatically conducted with a web-based irrigation control.

The developed pressure-driven flow valves allow site specific irrigation along single driplines. However, additional costs and planning efforts are necessary because a pressure management needs to be incorporated, which accounts for friction pressure losses, topography and changing flow rates (different amount of drippers). Because flow water pressure is the decisive measure of the presented solution, there is still the need to develop an automatic pressure reducing device, if site specific drip irrigation with the presented pressure-driven flow valves shall be automated.

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