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# Dynamic Real-time Soil-moisture Measurement

## A Concept for Controlling Agricultural Equipment in Precision FarmingBewirtschaftung

*After preliminary trials with a modified TDR-technique, the advantages of online real-time soil moisture detection are obvious. The off-line-operated mapping system for soil moisture provided conclusive data, which can be further optimised. The beneficial system insensitivity to high levels of fertiliser application, thus not effecting the value of soil moisture detected, guarantees its use in practice. All in all, the intended dynamic measuring system is practicable, although the time needed per measurement is currently too high.*

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Besides other important factors, precision farming needs information about soil moisture, too. This appears as one of the most important factors among others, characterising a condition in the field. It decides on trafficability, causes good or bad results of sprouting, effects the efficiency of spreading fertilisers and the tractive power, been spent. Therefore it is relevant for cultivation costs. Mapping soil-moisture includes further feedback on soil-type or soil-features. So it is important to know about the actual soil-moisture, in order to improve precision and efficiency in farming. Today this is being expected from farmers by the public, but also demanded by them.

#### Methods for measuring soil-moisture

The demand for actual values of soil moisture is useful for the many tasks , whose success depends highly on current soil moisture. This induces the demand for values measured, being real-time and exact values. In the following, an overview about the different methods of field-measurement of soil-moisture will be given.

A lot of systems and methods have been invented in the past, which can only partly be used for an approach to dynamic measurement of soil-moisture. The conventional systems offer insufficient rates of measurements at high costs, high weight and/or high further expense for a practicable real-time measurement in the field.

The technique of the „*EM-38*“ device (Geonics inc.), has been adapted widespread to map soil parameters as soil moisture. The device works on an electro-magnetic basis, which enables measuring the apparent conductivity of soil. The method induces a primary electro-magnetic pulse into soil. Subsequently the intensity of the emerging electro-magnetic field is being gauged by that device. Through this apparent conductivity can be concluded, describing a relation to the soil moisture. The named method is highly dependent on ionic strength, soil temperature and texture [1]. Furthermore it encloses a vague soil volume. This method is able to give an overview on the soil condition, but is not able to give exact values of moisture at one definite point.

Measuring soil moisture with an *infrared based device* (IR-device) means measuring the changing response of reflected IR-waves of dry and wet surfaces. It consists of a transmitter-receiver-combination. Irradiance of certain wavelength is being emitted and reflected IR-waves are received by a special IR-diode. A field operation with this device is problematic, because it has to be calibrated on every new substrate, to be measured [2]. Furthermore it is necessary to cut out a soil sample for every measurement to be done. At a requested high sample density the method causes high time-requirements. A suitability for dynamic measurements can not be seen at this point of time.

Besides these methods, also *radiometric methods* of soil moisture-measuring are used. A radioactive source (radium/beryllium or americium/beryllium) is placed into the soil, where neutrons are emitted. The method is based on counting the rate of neutrons. After a large number of collisions the neutrons have lost a major part of their velocity, so they fall into thermal equilibrium with their surroundings. The mean range, which a neutron is able to cross before thermalising, mainly depends on the concentration of light atomic nuclei , with whom it can collide on the way through soil. The intensity of the remaining - non-collided neutrons can be measured, using a BF3-detector. This fact is related to the volumetric water content of soil. Besides unattached water, crystalline water and organic matters can also cause thermalising of neutrons. Measuring errors occur due to this fact and the limited range of this method within the soil. Therefore it is not easy to conclude exactly on the soil moisture, without knowing any other side-factors [3, 4].

*Time domain reflectometry* (transit time determination of a electro-magnetic wave) was originally invented, to detect cable damages. Now the TDR-technique has been adapted to detect the velocity of an electromagnetic wave spreading within a medium. Equation 1 shows that the velocity c of an electromagnetic wave is equal to the speed of light $c_0$ in a vacuum. When waves are leaving the vacuum, their velocity is only dependent on the relative permittivity $\varepsilon_r$ besides magnetic permeability $\mu_r$ of the relevant material. Magnetic permeability of most agricultural soils can be set to 1, therefore c is only dependent on the relative permittivity. Permittivity of dry, porous material ($\varepsilon_r < 5$) is significantly lower than the one of water ($\varepsilon_r = 81$). So transit time and soil moisture are directly related, mostly independent of conductivity [5].

$$c = c_0 / \sqrt{\varepsilon_r} \cdot \mu_r \qquad \text{(Gl. 1)}$$

The investigation of the current soil moisture is dependent on texture, soil-type and pore size. While measuring the soil moisture, using a TDR-device, the probe-soil contact should be as good as possible to guarantee a proper measurement. eometry and design of the sensor allows to measure a precise, relevant soil volume. The TDR-technique has decisive advantages for dynamic measurement of soil moisture, like the exactly measured relevant top soil volume and above all the independence of calibrations prior to every measurement.

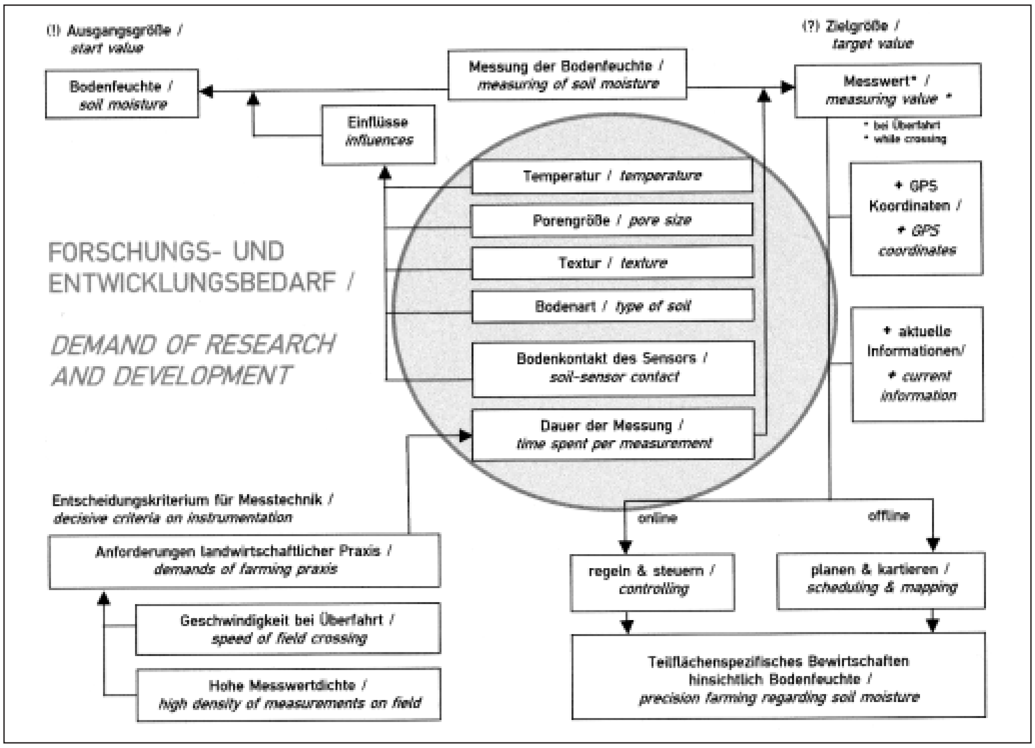

*Fig. 1: Concept of a dynamic soil moisture sensor*

#### Experiments

First laboratory trials showed a neglible influence of electric conductivity on the measured values of soil moisture. The range of deviation even stays within the usual ± 3% for this kind of TDR-probes [6], even at high conductivity (*Fig. 1*). So soil moisture can be detected via TDR-probes in the field, even at a high levels of fertilising and therefore at high electric conductivity. First concepts of prototypes for manual measurements at stop-and-go operation in the field already contained the GPS (global positioning system) generating information of the current position. The system was used offline to map soil moisture in the fields. A further development of fully mobile and dynamic probes will produce a continuous measuring of soil moisture during operation. With this, specific control of farm machines will be possible. Controls are e.g. conceivable for the pressure of tires, seeding rate, fertilising intensity. By taking into account further parameters like wind-speed, soil- and air-temperature, controls can be even more specify (*Fig. 2*). At this moment the measured values in the field are not reaching the same quality-stage than the laboratory values did before. In the field the measured values ranged between < 1 % and 15 % variation, compared to the gravimetrically determined moisture data values. The range of minimum and maximum soil moisture was up to 21 % difference under homogeneous field conditions. Suitable tools for dynamic soil moisture measurement are currently being designed and tested. IMKO as the partner in this project takes over the development of a faster TDR-device, which can perform as much measurements as needed within the crossing of the field at normal working speeds and thus to perform measurements of soil moisture measurements in the relevant volume of the top soil. Basis for this approach is the TRIME-technology, which will be further refined within this project. On the other side there is a need for research on the probes, concerning sensor-soil contact during the measurements and crossing of the field. As only a very thin air layer volume can be accepted, in order to guarantee a proper measurement, optimal soil-sensor contact is needed. To verify the measured values, soil samples will additionally be taken, in order to measure the exact soil moisture in the laboratory. In order to allocate the detected soil moisture later on a field-map, GPS-co-ordinates are written on the same data-set as the detected soil moisture (*Fig. 3*).

## Literature


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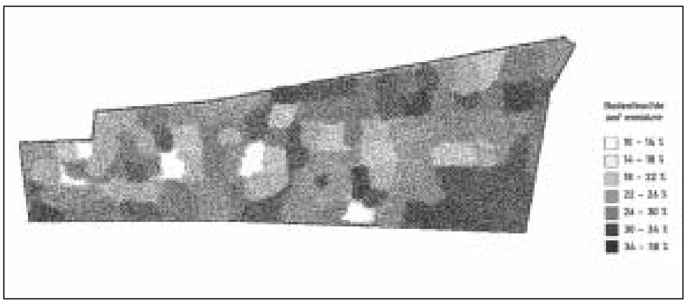
*Fig. 2: Distribution of soil moisture measured within a field*