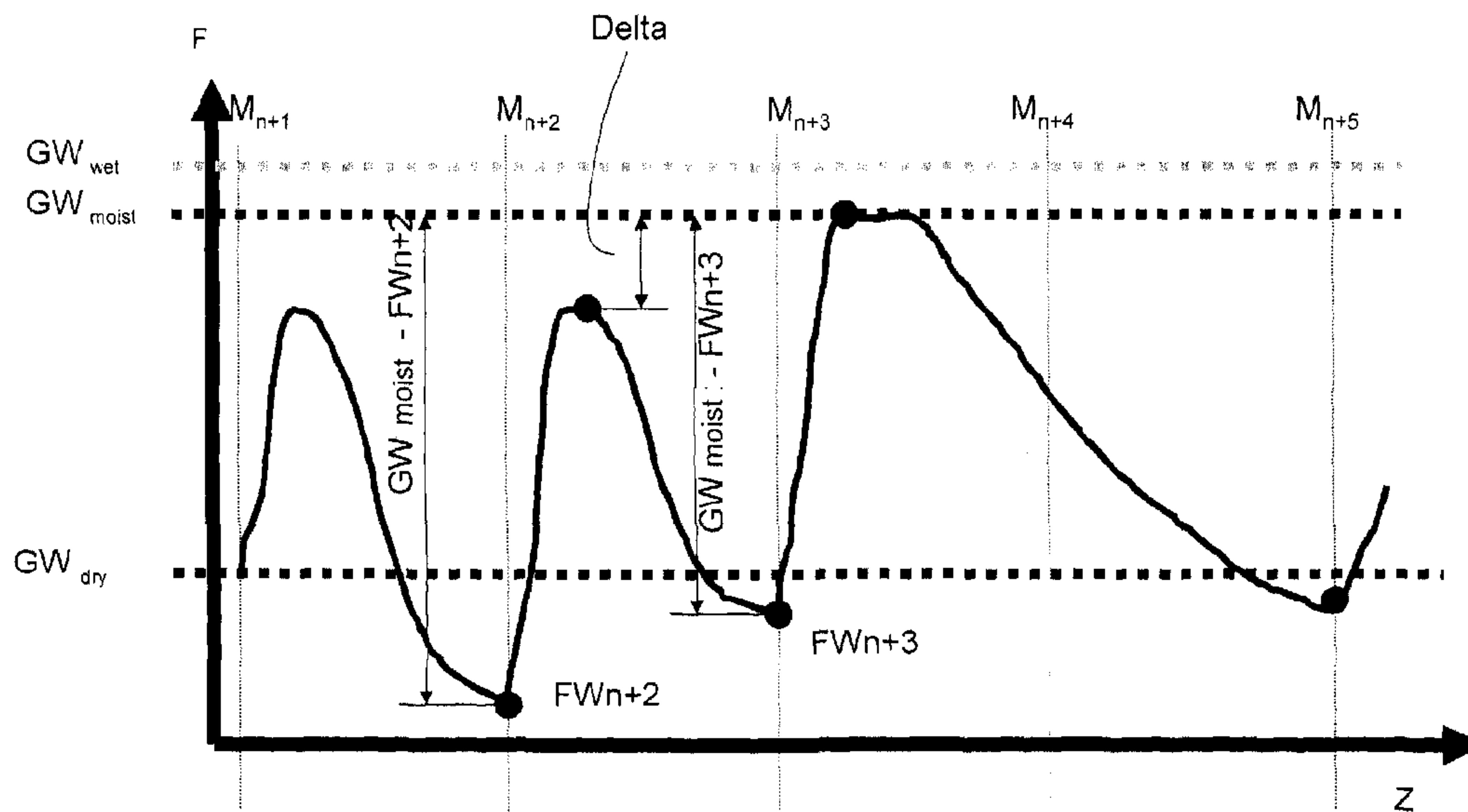




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(54) Titre : PROCÉDE ET DISPOSITIF POUR LA REGULATION AUTOMATIQUE DE L'ARROSAGE DE PLANTES  
 (54) Title: METHOD AND DEVICE FOR THE AUTOMATIC REGULATION OF PLANT IRRIGATION



(57) **Abrégé/Abstract:**

The invention relates to a method for the automatic irrigation of plants, wherein the temporal progression of soil moisture is determined from measured soil moisture values, and said progression is used for the calculation of an optimized irrigation time duration, such that both water excess in the soil and soil drying are avoided as much as possible. Preferably, the time duration of irrigation is constantly evaluated and optimized using comparisons of measured values with prespecified moisture- and dryness threshold values (GWmoist, GWdry), and automatically adjusted to changing environmental conditions and/or plant requirements.

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**ABSTRACT**

The invention relates to a method for the automatic  
5 irrigation of plants, wherein the temporal progression  
of soil moisture is determined from measured soil  
moisture values, and said progression is used for the  
calculation of an optimized irrigation time duration,  
such that both water excess in the soil and soil drying  
10 are avoided as much as possible. Preferably, the time  
duration of irrigation is constantly evaluated and  
optimized using comparisons of measured values with  
prespecified moisture- and dryness threshold values  
(GWmoist, GWdry), and automatically adjusted to  
15 changing environmental conditions and/or plant  
requirements.

## METHOD AND DEVICE FOR THE AUTOMATIC REGULATION OF PLANT IRRIGATION

### FIELD OF THE INVENTION

[0001] The invention relates to an apparatus and a method for the automatic regulation and control of an irrigation of plants. More particularly, the invention relates to an apparatus and a method for an optimized irrigation duration without water excess and without the soil drying out.

### BACKGROUND

[0002] When plants are irrigated, in particular lawns or agricultural land, use is made of irrigation systems that are controlled by a timer. The user can set, on the latter, both the instant and the duration of the irrigation, there being on the market various timers for the control of a variety of irrigation zones and with different levels of complexity.

[0003] This type of irrigation control is low in flexibility, that is to say irrigation is performed over the preset time duration and at the preset instants, irrespective of the effective need of the plants that are to be irrigated.

[0004] So-called rain sensors are also known that, when rain is falling, measure the amount of rain and block the timer when a defined amount is exceeded so that no irrigation is performed while it is raining.

[0005] It is true that this method avoids an irrigation during or after a rain event. For example, in cool or rainless weather irrigation is performed, however, though sufficient moisture is present in the soil and there is thus no need to irrigate.

[0006] In recent years, soil moisture sensors have been connected to timers. These sensors measure the current moisture in the soil and enable the timer, and thus initiate watering, only upon falling below a critical soil moisture that can be set. Most of these

soil moisture sensors are expensive to procure and maintenance-intensive, and the measurement result depends strongly on other parameters, such as the fertilizer content. They have therefore not been able to establish themselves on the market. However, a novel soil moisture sensor that does not have these disadvantages has also been developed in accordance with WO 2006/081693.

[0007] Such an improved soil moisture sensor can now be used to prevent irrigation from being performed unnecessarily. However, the amount of water administered per watering cycle is still set by the user on the timer, and is therefore fixedly prescribed. The amount of water effectively required can, however, deviate strongly from the set amount, and it also varies with short term and long term climatic fluctuations. Experience shows that in the case of crops, in particular, once a watering duration has been set, users tend to adapt to the current climatic conditions only in exceptional cases and mostly not change it throughout the entire year.

[0008] When consideration is given to the ever more topical problems associated with rising water consumption, particularly in countries with scarce water reserves, the aspect of carefully managing water as a resource becomes very important. The avoidance of unnecessary water consumption belongs here, as well. Immense quantities of water (80% of the entire water consumption) are used globally in the irrigation of crops and green areas. It is estimated that half thereof could be saved by intelligent irrigation.

#### SUMMARY OF EMBODIMENTS OF THE INVENTION

[0009] It is therefore an object of the invention to provide an intelligent method for the control and regulation of an irrigation duration with the aid of which, with an automatically set watering duration, no excess water is poured and, on the other hand, the soil is prevented from drying out.

[0010] The method relates to an intelligent method for the control of irrigation that, on the one hand, is capable of automatically fixing an irrigation duration such that no

excess of water is poured. On the other hand, the soil is also prevented from drying out. The method is also capable of automatically compensating short term, medium term and long term temperature changes such as occur in the course of a year, preferably in such a way that an optimum amount of water is always poured even without manual intervention. When crops are irrigated they also require more and more water with increasing size and/or leaf area. The inventive method takes account of application specific conditions such as system parameters and environmental parameters, and is also capable of automatically compensating an increase in demand as described.

[0011] The method is based on a novel evaluation of the soil moisture time profile measured by a soil moisture sensor. In particular, the soil moisture sensor described in WO 2006/081693 can be used to this end. However, it is also possible to use any arbitrary soil moisture sensor that permits electronic measurement of moisture values. A sensor is then combined with the inventive electronic regulation and/or appropriate evaluation electronics, for example in the form of a chip.

[0012] The soil moisture is repeatedly measured with the aid of a soil moisture sensor and appropriate evaluation electronics in the method for the regulation and control of an automatic irrigation device. The time profile of the soil moisture is analyzed in this case before and after an irrigation operation, and an irrigation duration is calculated from a moisture value before irrigation and a moisture value after an irrigation. A system specific characteristic  $K$  is considered in the calculation of the irrigation duration, said characteristic preferably being determined in an initial calibration measurement and checked and adapted in subsequent measuring steps.

[0013] The regulation of the inventive apparatus is preferably designed such that even when environmental conditions and plant size change, on the one hand the plant is always supplied sufficiently with moisture, but on the other hand not too much water seeps unused into the soil.

[0014] A moisture scale used in this case has two limit values that can be set: in the direction “dry”, the limit value that fixes sets a minimum moisture, and the limit value that fixes sets a maximum moisture are defined by an input from the user. In the direction of higher moisture, a further limit value “wet” is reached when the soil is saturated with water. This limit value is defined in advance, that is to say is system-induced, for a sensor in use, because a sensor cannot become wetter than wet. An aim of the control is now, on the one hand, not to fall below the limit value for “dry” excessively, including over a lengthy time, so that the plants do not suffer drought damage and are not exposed to drought stress. On the other hand, however, it is also important that the limit value for “moist”, which corresponds at most to that of “wet”, be reached only for a short time, because additional water would seep away and could not be used by a plant.

[0015] In order that the local conditions relating to soil composition as well as to water ingress per unit area are taken into account from the start in a regulation, at the beginning of the method, this is, as a rule, at the start of an irrigation period, preferably a calibration measurement is carried out. In this case, a soil moisture sensor is introduced into a soil to be irrigated. It is preferably inserted to a specific depth. This depth is dependent on the position of the roots and lies in a preferred range of 5-30 cm. Irrigation is then performed briefly, preferably by an existing sprinkler or a drip fed irrigation. Depending on the soil permeability, this irrigation will be detected earlier or later by an increase in the moisture content at the sensor. The time covered up to this detection is, on the one hand, a measure of the permeability of the soil but also, on the other hand, of the water ingress at the location of the sensor.

[0016] The ratio of the difference in moisture value before the irrigation and moisture value after the irrigation to the duration of the irrigation can be regarded as a user specific characteristic K. K takes account both of the local soil composition and of the installed irrigation performance. The characteristic K tells us by how much a moisture value changes when pouring is performed for a specific duration, for example

for one minute, and with a specific amount of water. This factor  $K$  is determined automatically during the calibration step initially carried out, this corresponding in essence to a first measurement, and is used for the further measurements. It would also be possible to input an initial value of  $K$ , for example in accordance with empirical values, in advance. A subsequent regulation adapts the characteristic as appropriate to the prescribed moisture limit values.

[0017] In a preferred embodiment of the method, the characteristic  $K$  is repeatedly checked, preferably cyclically, it also being possible for an irrigation to be performed cyclically. In this case,  $K$  is compared, preferably after a measurement that is performed after an irrigation, with an upper limit value that corresponds to a moist soil. Depending on the desired/actual value deviation,  $K$  is enlarged or reduced by a factor. Since  $K$  is inversely proportional to the irrigation duration in the present calculations, a reduction of  $K$  is apposite when the irrigation duration is to be lengthened, that is to say when, for example, a measured moisture value has not reached an upper moisture limit value after an irrigation. An enlargement of the characteristic  $K$  that therefore leads to a reduced calculated irrigation duration is apposite when an upper limit value “moist” is reached after the irrigation, but the aim is to prevent this limit value from being exceeded too far. It is preferred to choose a moisture value below a moisture limit value for a completely wet soil as an upper limit value. It is also possible thereby to determine an exceeding of the limit value.

[0018] In practice, an upper limit value that defines a water saturated state corresponds to that soil moisture for which the soil is saturated with water so far that no more water seeps into the subsoil because of gravity. This property of the soil is denoted as field capacity ( $GW_{FK}$ ). Sandy soils have a low field capacity, while soils with a high proportion of organic materials such as peat or humus have a high field capacity. Such a moisture limit value based on the field capacity can therefore lie below a limit value for a “wet” soil.

[0019] The calibration operation described above can also be used to determine such a field capacity automatically. To this end, irrigation is continued after the characteristic K has been determined over a lengthy time, for example 1-2 hours. It is to be ensured that the soil is supersaturated. After a lengthy waiting time, for example of 2-12 hours, it can be assumed that the excess water has run off into the subsoil. The moisture value is then determined again and this corresponds to the field capacity  $GW_{FK}$ , and can be stored in the system. When there is a manual input of an upper limit value "moist" that overshoots the  $GW_{FK}$ , the user can now be alerted to this circumstance, for example by an alarm report. It would also be possible for the upper limit value "moist" to be set automatically to the moisture value corresponding to the field capacity.

[0020] In a further embodiment of the method, an irrigation duration calculated automatically with a characteristic K is increased or decreased directly by a factor D, that is to say by an amount of water given in a prescribed irrigation device. Such a fixed supply or removal of water determined by concrete measurements can be advantageous when, for example, agricultural land is to be kept wet or moist or less moist over a somewhat longer time. In the case of a calculated irrigation duration, an amount of water is optimized to an optimum relationship between saving water and drying out. However, a customary moisture sensor cannot be used to distinguish between wet, somewhat too wet or much too wet. A higher supply of water through a change in the characteristic K can elude accurate monitoring. If the aim is now to keep an area moist or wet or less moist over a somewhat lengthy time, this can be achieved by the supply of, or reduction by a defined amount of water. With certain limitations, this can also be achieved by reducing or decreasing the moisture limit values.

[0021] An exceeding of a maximum amount of water on purpose, that is to say an exceeding of the amount of water that is sensible in accordance with a field capacity  $GW_{FK}$ , can, for example, be appropriate when, by way of example, the aim is to prevent

the soil from being salted. An excess of water ensures that the salt cannot accumulate in the critical root area.

[0021.01] In accordance with an aspect of at least one embodiment, there is provided a method for automatically controlling an irrigation duration, the method comprising calculating an irrigation duration using evaluation electronics and an application specific characteristic K; obtaining a soil moisture value by measuring soil moisture using a sensor after a soil irrigation operation for the calculated irrigation duration has been conducted; comparing the obtained soil moisture value with a target upper moisture limit value, using the evaluation electronics; and in the event that the obtained soil moisture value deviates from the target upper moisture limit value, applying a correction to the application specific characteristic K for being automatically accessed by an automatic irrigation device for a subsequent soil irrigation operation to automatically result in an altered irrigation duration.

[0021.02] In accordance with an aspect of at least one embodiment, there is provided an apparatus for automatically controlling plant irrigation operations using an associated irrigation device, the apparatus comprising: at least one sensor configured to repeatedly measure soil moisture of soil irrigated by the irrigation device; and an evaluation electronics configured to calculate an irrigation duration using an application specific characteristic K; wherein the apparatus is configured to alter the irrigation duration of a subsequent irrigation operation, using the evaluation electronics, by applying a correction to a previous application specific characteristic K, if a soil moisture value obtained by the at least one sensor after an irrigation operation conducted for an irrigation duration calculated using the previous application specific characteristic K deviates from a target upper moisture value.

[0021.03] In accordance with an aspect of at least one embodiment, there is provided an electronic controller for plant irrigation configured to be coordinated with a sensor for measuring soil moisture and with an irrigation device, the electronic controller comprising an evaluation electronics configured to calculate an irrigation duration using

an application specific characteristic K, wherein the electronic controller is configured to alter the irrigation duration of a subsequent irrigation operation using the evaluation electronics by applying a correction to a previous application specific characteristic K, if a soil moisture value obtained by the sensor after an irrigation operation conducted for an irrigation duration calculated using the previous application specific characteristic K deviates from a target upper moisture value.

[0021.04] In accordance with an aspect of at least one embodiment, there is provided a method for automatic control of an irrigation duration, the method comprising calculating an irrigation duration using an application specific characteristic K; measuring soil moisture using a sensor after a soil irrigation operation for the calculated irrigation duration has been accomplished to obtain a measured soil moisture value; comparing, using evaluation electronics, the measured soil moisture value with a predetermined target upper moisture limit value; and automatically controlling an irrigation duration for a subsequent soil irrigation operation by applying an adjustment to the application specific characteristic K, which is then used in the calculation of the irrigation duration for the subsequent soil irrigation operation, wherein said adjustment to the application specific characteristic K is calculated to obtain a subsequent soil moisture value, measured using the sensor after the subsequent soil irrigation operation, that is closer to the predetermined target upper moisture limit value than the measured soil moisture value.

[0021.05] In accordance with an aspect of at least one embodiment, there is provided an apparatus for automatically controlling plant irrigation operations using an associated irrigation device, the apparatus comprising at least one sensor configured to repeatedly measure soil moisture of soil irrigated by the irrigation device; and an evaluation electronics configured to calculate an irrigation duration using an application specific characteristic K; wherein the apparatus is configured to automatically control an irrigation duration of a subsequent soil irrigation operation by the aid of the evaluation electronics by comparing a target upper moisture value and a measured soil moisture

value obtained by the at least one sensor after an irrigation operation has been conducted for an irrigation duration calculated using the application specific characteristic K, and by applying an adjustment to the application specific characteristic K to effect that a subsequent soil moisture value measured by the aid of the at least one sensor after the subsequent soil irrigation operation is closer to the predetermined target upper moisture limit value than the measured soil moisture value.

[0021.06] In accordance with an aspect of at least one embodiment, there is provided an electronic controller for plant irrigation configured to be coordinated with a sensor for measuring soil moisture and with an irrigation device, the electronic controller comprising an evaluation electronics configured to calculate an irrigation duration with the aid of an application specific characteristic K, wherein the electronic controller is configured to automatically control an irrigation duration of a subsequent soil irrigation operation by the aid of the evaluation electronics by comparing a target upper moisture value and a measured soil moisture value obtained by the sensor after an irrigation operation has been conducted for an irrigation duration calculated using the application specific characteristic K, and by applying an adjustment to the application specific characteristic K to effect that a subsequent soil moisture value measured by the aid of the sensor after the subsequent soil irrigation operation is closer to the predetermined target upper moisture limit value than the measured soil moisture value.

[0021.07] In accordance with an aspect of at least one embodiment, there is provided a method for automatically controlling an irrigation duration, the method comprising repeatedly conducting the following sequence of automatically conducted steps: obtaining a soil moisture value FW2 by measuring soil moisture using a sensor after a soil irrigation operation has been conducted; applying a correction to an application specific characteristic K, the correction depending on a deviation of the obtained soil moisture value FW2 from a predetermined target upper moisture limit value; automatically controlling an irrigation duration for a following irrigation operation, comprising calculating, using evaluation electronics, the irrigation duration for the

following irrigation operation by the aid of the corrected application specific characteristic K and in dependence of a soil moisture value FW1 obtained by measuring soil moisture using the sensor before the following soil irrigation operation.

[0021.08] In accordance with an aspect of at least one embodiment, there is provided an apparatus for automatically controlling plant irrigation operations using an associated irrigation device, the apparatus comprising at least one sensor configured to repeatedly measure soil moisture of soil irrigated by the irrigation device; and an evaluation electronics configured to calculate an irrigation duration using an application specific characteristic K; wherein the apparatus is configured to repeatedly automatically conduct the following sequence of steps: obtaining a soil moisture value FW2 by measuring soil moisture using the sensor after a soil irrigation operation has been conducted; applying a correction to the application specific characteristic K by the aid of the evaluation electronics, the correction depending on a deviation of the obtained soil moisture value FW2 from a predetermined target upper moisture limit value; wherein the apparatus is configured to alter the irrigation duration of a following irrigation operation by calculating, by the aid of the evaluation electronics, the irrigation duration for the following irrigation operation by the aid of the corrected application specific characteristic K and in dependence of a soil moisture value FW1 obtained by measuring soil moisture using the sensor before the following soil irrigation operation.

[0021.09] In accordance with an aspect of at least one embodiment, there is provided an electronic controller for plant irrigation configured to be coordinated with a sensor for measuring soil moisture and with an irrigation device, the electronic controller comprising an evaluation electronics configured to calculate an irrigation duration with the aid of an application specific characteristic K, wherein the electronic controller is configured to repeatedly automatically conduct the following sequence of steps: receiving from the sensor a soil moisture value FW2 obtained by the sensor by measuring soil moisture after a soil irrigation operation has been conducted; applying a correction to the application specific characteristic K by the aid of the evaluation

electronics, the correction depending on a deviation of the received soil moisture value FW2 from a predetermined target upper moisture limit value; wherein the electronic controller is configured to alter the irrigation duration of a following irrigation operation by calculating, by the aid of the evaluation electronics, the irrigation duration for the following irrigation operation by the aid of the corrected application specific characteristic K and in dependence of a soil moisture value FW1 obtained by the sensor by measuring soil moisture before the following soil irrigation operation.

[0021.10] In accordance with an aspect of at least one embodiment, there is provided a method for automatically controlling an irrigation duration, the method comprising calculating an irrigation duration by the aid of evaluation electronics and an application specific characteristic K; obtaining a soil moisture value by measuring soil moisture using a sensor after a soil irrigation operation for the calculated irrigation duration has been conducted; comparing the obtained soil moisture value with a target upper moisture limit value using the evaluation electronics and, in the event that the obtained soil moisture value deviates from the target upper moisture limit value, applying a correction to the application specific characteristic K to thereby result in an altered irrigation duration for a subsequent soil irrigation operation; and automatically controlling an irrigation device to perform the subsequent soil irrigation operation for the altered irrigation duration.

[0021.11] In accordance with an aspect of at least one embodiment, there is provided a method for automatic control of an irrigation duration, the method comprising: calculating an irrigation duration using an application specific characteristic K; measuring soil moisture using a sensor after a soil irrigation operation for the calculated irrigation duration has been performed, to obtain a measured soil moisture value; comparing, using evaluation electronics, the measured soil moisture value with a predetermined target upper moisture limit value; applying an adjustment to the application specific characteristic K, the adjustment determined in dependence upon a result of the step of comparing; and automatically controlling an irrigation device to

perform a subsequent irrigation operation for an adjusted irrigation duration that is calculated using the adjusted application specific characteristic  $K$ , wherein said adjustment to the application specific characteristic  $K$  is calculated for obtaining a subsequent soil moisture value, which is measured using the sensor after the subsequent soil irrigation operation is performed, that is closer to the predetermined target upper moisture limit value than the measured soil moisture value.

#### BRIEF DESCRIPTION OF THE DRAWINGS

[0022] Different stages and aspects of the method, as well as preferred embodiments of the method, are explained in more detail below with the aid of exemplary figures. In the drawing:

[0023] Fig. 1 shows the calibration measurement and the determination of the field capacity; and

[0024] Fig. 2 shows a soil moisture profile.

#### DETAILED DESCRIPTION OF THE DRAWINGS

[0025] The graph in Fig. 1 shows the profile of the moisture level  $F$  against time  $Z$ . The soil moisture content is measured at regular intervals  $M_n, M_{n+1}, M_{n+2}, \dots$ . At the instant  $M_n$ , the soil moisture content is still above a set limit value  $GW_{dry}$  that corresponds to a minimum soil moisture that is to be reached. At the instant of the following measurement  $M_{n+1}$  at the instant  $t_0$ , the soil moisture content, the first moisture value  $FW_1$ , is below the set limit value  $GW_{dry}$ . An irrigation operation is correspondingly initiated and terminated at the instant  $t_1$ . The instant  $t_1$  or the irrigation duration  $t_1-t_0$  is preferably selected to be very short, for example 5 min., for a calibration measurement, in order to reliably prevent over-irrigation. At a second instant  $t_2$ , a control measurement, for example approximately  $\frac{1}{2}$  hour after the irrigation, is carried out, and a further moisture value  $FW_2$  is measured. Thereafter, the

system determines a characteristic K from the measured values in accordance with the specified formula:

$$K = \frac{FW_2 - FW_1}{t_1 - t_0}$$

The characteristic K is stored in the system.

[0026] The measurement operation can also be carried out in two or more stages,  $t_1 - t_0$  then corresponding to the total duration during which irrigation has been performed. The result of the calibration measurement is used to determine the irrigation duration for the following measurements.

[0027] After the measurement at the instant  $t_2$ , the irrigation is continued, preferably over a longer time, for example 1-2 hours, up to the instant  $t_3$ . A waiting time, preferably of several hours, is inserted thereafter. A measurement is carried out anew at the instant  $t_4$ . The measured value  $GW_{FK}$  corresponds to the field capacity. In the case of a humus rich soil, this can be equal to  $GW_{wet}$ . The determination of  $GW_{FK}$  can also be undertaken or omitted independently of the calibration measurement.

[0028] Fig. 2 shows a typical profile of the soil moisture, and the principle of a continuous correction of the irrigation duration in combination with a preceding calibration measurement.

[0029] After the calibration measurement, preferably in accordance with Fig. 1, the first regular measurement is carried out at the instant  $M_{n+2}$ . Since the current moisture value  $FW_{n+2}$  lies under  $GW_{dry}$  in the example shown, an irrigation is initiated. The irrigation duration  $BD_{n+2}$  is now calculated as follows using the measured moisture value  $FW_{n+2}$  and the characteristic K determined in accordance with the calibration measurement:

$$BD_{n+2} = (GW_{moist} - FW_{n+2})/K$$

[0030] After the irrigation, the moisture value is determined in turn by a control measurement. In the example shown, the intended target value  $GW_{moist}$  has not yet

been reached ( $\Delta > 0$ ), that is to say the irrigation duration was still too short, the factor  $K$  determined in the calibration measurement too large.

[0031] The system now calculates the irrigation duration  $BD$  for the following irrigation  $M_{n+3}$  as follows: the difference between the target value  $GW$  and the current moisture ( $GW_{moist} - FW_{n+2}$ ) before the measurement  $M_{n+2}$  is divided by a characteristic  $K$  reduced by  $x$ . As a result, a longer duration is obtained for the subsequent irrigation at the instant  $M_{n+3}$ . The corresponding formula reads as follows:

$$BD_{n+3} = (GW_{moist} - FW_{n+3}) / (K - x)$$

[0032] It is now assumed, in the example shown, that the target value  $GW_{moist}$  has been reached owing to the correction performed, and this is confirmed by a subsequent control measurement.

[0033] This would mean the target has been reached, and it is possible as shown previously to regulate further or, given conditions which are not changing, to irrigate straight away.

[0034] If  $GW_{wet}$  has been selected as an upper moisture limit value, the problem resides in the fact that it is not known whether too much water has not been given, since the sensor cannot display a "too much". It can therefore be assumed as a precaution that too much has been poured without, however, being able to know this.

[0035] The way in which this problem is solved is preferably that whenever  $GW_{wet}$  is reached a small negative deviation of specific magnitude is automatically adopted, and this is included in the calculation of the duration for the following irrigation. The characteristic  $K$  is enlarged in this case by a factor  $y$ .

[0036] The appropriate formula then reads as follows:

$$BD_{n+5} = (GW_{wet} - FW_{n+3}) / (K + y)$$

[0037] A reduction in the irrigation duration via an enlargement of  $K$  can also be desired given a selected moisture limit value  $GW_{moist}$ , for example when the aim is to keep a watering deep on purpose, by way of example in order to save as much water as possible or to keep plants not too moist as far as possible. A multiplication factor can also be selected instead of the factors  $x, y$  that are to be subtracted and added. This factor would then be correspondingly smaller or larger than 1.

[0038] Since the moisture is still high at the instant  $M_{n+4}$  in the example of Fig. 2, that is to say lies above  $GW_{dry}$ , no irrigation is initiated. However, at the instant  $M_{n+5}$ , the lower limit value  $GW_{dry}$  is undershot, and an irrigation with the calculated period  $BD_{n+5}$  is started.

[0039] Should there be rain between the measuring points  $M_n$  and  $M_{n+i}$ , this is of no consequence, since the next irrigation is only initiated once  $GW_{dry}$  is undershot. If it begins to rain just before a measurement, the measurement is interpreted in a more or less incorrect fashion depending on the amount of rain and duration, but this is automatically corrected again in the subsequent measurement.

[0040] In conventional measurement cycles, measurements are carried out, as a rule, every few hours, for example every 3-6 hours. If a measurement cycle  $M_n, M_{n+1}, \dots$  is selected to be very short, however, for example every half hour, it is possible to dispense with control measurements after an irrigation since said measurements fall into the regular measurement cycle. In the case of short measurement cycles, it should be ensured that use is made of moisture sensors with a low energy consumption.

[0041] With the aid of said regular algorithm, one is now able to set up an irrigation control which does not demand of the user any sort of knowledge relating to the nature of the soil, water input per  $m^2$  and irrigation duration. After the sensor has been placed in the soil, the system is started, calibrates itself and automatically regulates the irrigation duration so as to attain an optimum soil moisture cycle.

[0042] All that the user needs to set as a function of the plants to be irrigated are the two limit values GWdry and GWmoist. The system can be fashioned such that a table presented by the system can be used to select sensible values that are then taken over as constants.

[0043] The determination of the measurement cycles can be performed in a way similar to the timers currently available. The latter mostly permit the setting of the start time and the duration of an irrigation, it also being possible by installing a photodiode to record the day/night cycle and, correspondingly, to determine the beginning of an irrigation by day or at night. Moreover, the minimum duration between two irrigations can be defined.

[0044] In the limit case, problems can arise owing to the inflexible stipulation of the minimum duration between, for example three irrigations, for example three day cycles, that is to say irrigation every third night, by way of example. Specifically, this means when supply of water stored in the ground is insufficient in a phase of high temperature or given crops with a very high water requirement in order to meet the requirement of this time, the result being that drought stress occurs for the plants.

[0045] The regulation described here can, however, recognize such a case very easily and preferably shorten the duration between two cycles automatically. For example, if the moisture value at the time of measurement undershoots a specific critical dry limit value several times in succession, although the regulation has respectively adapted the irrigation duration upwards, this is a clear indication that the irrigation cycle has been selected to be excessively long. In such a case, the system can, for example, make a report, or automatically reduce the cycle duration. It is appropriate to display or report, in particular, if an irrigation cycle is permanently prescribed in a system, for example, because of weather conditions (sun), because of use (meadow or swimming pool) or because of regulations (irrigation only at specific times). If, for example, a moisture limit value "dry" is then undershot several times, it is not permissible to increase the irrigation duration on the basis of the external conditions.

List of reference symbols and formulae:

**M<sub>n</sub>, M<sub>n+1</sub>...** Moisture measurement n, n+1, ... at predetermined, regular time intervals

**t<sub>0</sub>, t<sub>1</sub>, t<sub>2</sub>...** Instants at which an action is initiated and stopped (for example measurement, start/stop of an irrigation, etc....)

**F** Moisture value (of a substrate, for example, earth, lawn etc.)

**FW<sub>1</sub>, FW<sub>2</sub>** First, second measured moisture value

**GW<sub>dry</sub>** Limit value “dry” that can be set

**GW<sub>moist</sub>** Limit value “moist” that can be set

**GW<sub>FK</sub>** Moisture limit value corresponding to the field capacity

**GW<sub>wet</sub>** Fixed limit value “wet”

characteristic **K** =  $(FW_2 - FW_1) / (t_1 - t_0)$

System characteristic that is determined by calibration measurement and takes account of user specific details

Irrigation duration **BD** =  $(GW_{moist} - FW) / K$

Irrigation duration calculated with the aid of measured and determined values

**x,y** Correction factors for K for the optimized calculation of the irrigation duration after an excessively short or excessively long irrigation

## CLAIMS

What is claimed is:

1. A method for automatically controlling an irrigation duration, the method comprising

- calculating an irrigation duration using evaluation electronics and an application specific characteristic K;

- obtaining a soil moisture value by measuring soil moisture using a sensor after a soil irrigation operation for the calculated irrigation duration has been conducted;

- comparing the obtained soil moisture value with a target upper moisture limit value, using the evaluation electronics; and

- in the event that the obtained soil moisture value deviates from the target upper moisture limit value, applying a correction to the application specific characteristic K for being automatically accessed by an automatic irrigation device for a subsequent soil irrigation operation to automatically result in an altered irrigation duration.

2. The method according to claim 1, comprising

- obtaining a further soil moisture value by measuring soil moisture using the sensor before the subsequent soil irrigation operation is carried out; and

- carrying out the subsequent soil irrigation operation only if the obtained further soil moisture value is lower than a dry limit value.

3. The method according to claim 2, comprising inputting into the evaluation electronics the target upper moisture limit value and the dry limit value, wherein the target upper moisture limit value and the dry limit value are user-selected values.

4. The method according to any one of claims 1-3, wherein the applying the correction to the application specific characteristic K is accomplished:

- by enlarging K to  $K+y$  with an absolute value y or to  $k*y$  with a factor  $y > 1$ , in the event that the obtained soil moisture value reaches the target upper moisture limit value, thereby reducing the irrigation duration for the subsequent soil irrigation operation; and

- by reducing K to  $K-x$  with an absolute value x or to  $k*x$  with a factor  $x < 1$ , in the event that the obtained soil moisture value does not reach the target upper moisture limit value, thereby increasing the irrigation duration for the subsequent soil irrigation operation.

5. The method according to any one of claims 1-4, wherein an initial calibration measurement is conducted in which an initial application specific characteristic K, used for calculating an irrigation duration for a next soil irrigation operation conducted after an initial soil irrigation operation, is derived from a moisture value measured before the initial soil irrigation operation and a moisture value measured after the initial soil irrigation operation.

6. The method according to any one of claims 1-4, comprising inputting into the evaluation electronics a user-selected initial application specific characteristic K used for calculating an irrigation duration for an initial soil irrigation operation.

7. The method according to any one of claims 1-6, wherein the application specific characteristic K indicates by how much the soil moisture changes when watering is performed for a specific duration and with a specific amount of water.

8. The method according to any one of claims 1-7, comprising automatically controlling an irrigation device to perform the subsequent soil irrigation operation for the altered irrigation duration.

9. The method according to any one of claims 1-8, comprising automatically performing the subsequent soil irrigation operation for the altered irrigation duration, the altered irrigation duration being calculated using the corrected application specific characteristic  $K$ , and wherein the correction to the application specific characteristic  $K$  is calculated to obtain a subsequent soil moisture value, measured using the sensor after the subsequent soil irrigation operation, that is closer to the target upper moisture limit value than the measured soil moisture value.

10. An irrigation method comprising performing soil irrigation operations for irrigation durations which are automatically controlled according to the method of any one of claims 1-9.

11. An apparatus for automatically controlling plant irrigation operations using an associated irrigation device, the apparatus comprising:

- at least one sensor configured to repeatedly measure soil moisture of soil irrigated by the irrigation device; and
- an evaluation electronics configured to calculate an irrigation duration using an application specific characteristic  $K$ ;

wherein the apparatus is configured to alter the irrigation duration of a subsequent irrigation operation, using the evaluation electronics, by applying a correction to a previous application specific characteristic  $K$ , if a soil moisture value obtained by the at least one sensor after an irrigation operation conducted for an

irrigation duration calculated using the previous application specific characteristic K deviates from a target upper moisture value.

12. An irrigation method comprising automatically controlling plant irrigation using an apparatus according to claim 11.

13. An electronic controller for plant irrigation configured to be coordinated with a sensor for measuring soil moisture and with an irrigation device, the electronic controller comprising an evaluation electronics configured to calculate an irrigation duration using an application specific characteristic K, wherein the electronic controller is configured to alter the irrigation duration of a subsequent irrigation operation using the evaluation electronics by applying a correction to a previous application specific characteristic K, if a soil moisture value obtained by the sensor after an irrigation operation conducted for an irrigation duration calculated using the previous application specific characteristic K deviates from a target upper moisture value.

14. An irrigation method comprising conducting irrigation operations with the aid of an electronic controller according to claim 13.

15. A method for automatically controlling an irrigation duration, the method comprising repeatedly conducting the following sequence of automatically conducted steps:

- obtaining a soil moisture value FW2 by measuring soil moisture using a sensor after a soil irrigation operation has been conducted;

- applying a correction to an application specific characteristic K, the correction depending on a deviation of the obtained soil moisture value FW2 from a predetermined target upper moisture limit value; and

- automatically controlling an irrigation duration for a following irrigation operation, comprising calculating, using evaluation electronics, the irrigation duration for the following irrigation operation by the aid of the corrected application specific characteristic K and in dependence of a soil moisture value FW1 obtained by measuring soil moisture using the sensor before the following soil irrigation operation.

16. An irrigation method comprising performing soil irrigation operations for irrigation durations which are automatically controlled according to the method of claim 15.

17. An apparatus for automatically controlling plant irrigation operations using an associated irrigation device, the apparatus comprising

- at least one sensor configured to repeatedly measure soil moisture of soil irrigated by the irrigation device; and

- an evaluation electronics configured to calculate an irrigation duration using an application specific characteristic K;

wherein the apparatus is configured to repeatedly automatically conduct the following sequence of steps:

- obtaining a soil moisture value FW2 by measuring soil moisture using the sensor after a soil irrigation operation has been conducted; and

- applying a correction to the application specific characteristic K by the aid of the evaluation electronics, the correction depending on a deviation of the obtained soil moisture value FW2 from a predetermined target upper moisture limit value;

- wherein the apparatus is configured to alter the irrigation duration of a following irrigation operation by calculating, by the aid of the evaluation electronics, the irrigation duration for the following irrigation operation by the aid of the corrected application specific characteristic K and in dependence of a soil moisture value FW1 obtained by measuring soil moisture using the sensor before the following soil irrigation operation.

18. An irrigation method, the method comprising irrigating plants, wherein the irrigating is automatically controlled by the aid of an apparatus according to claim 17.

19. An electronic controller for plant irrigation configured to be coordinated with a sensor for measuring soil moisture and with an irrigation device, the electronic controller comprising an evaluation electronics configured to calculate an irrigation duration with the aid of an application specific characteristic K, wherein the electronic controller is configured to repeatedly automatically conduct the following sequence of steps:

- receiving from the sensor a soil moisture value FW2 obtained by the sensor by measuring soil moisture after a soil irrigation operation has been conducted; and

- applying a correction to the application specific characteristic K by the aid of the evaluation electronics, the correction depending on a deviation of the received soil moisture value FW2 from a target upper moisture limit value;

- wherein the electronic controller is configured to alter the irrigation duration of a following irrigation operation by calculating, by the aid of the evaluation electronics, the irrigation duration for the following irrigation operation by the aid of the corrected application specific characteristic K and in dependence of a soil moisture value FW1 obtained by the sensor by measuring soil moisture before the following soil irrigation operation.

20. An irrigation method comprising conducting irrigation operations with the aid of an electronic controller according to claim 19.

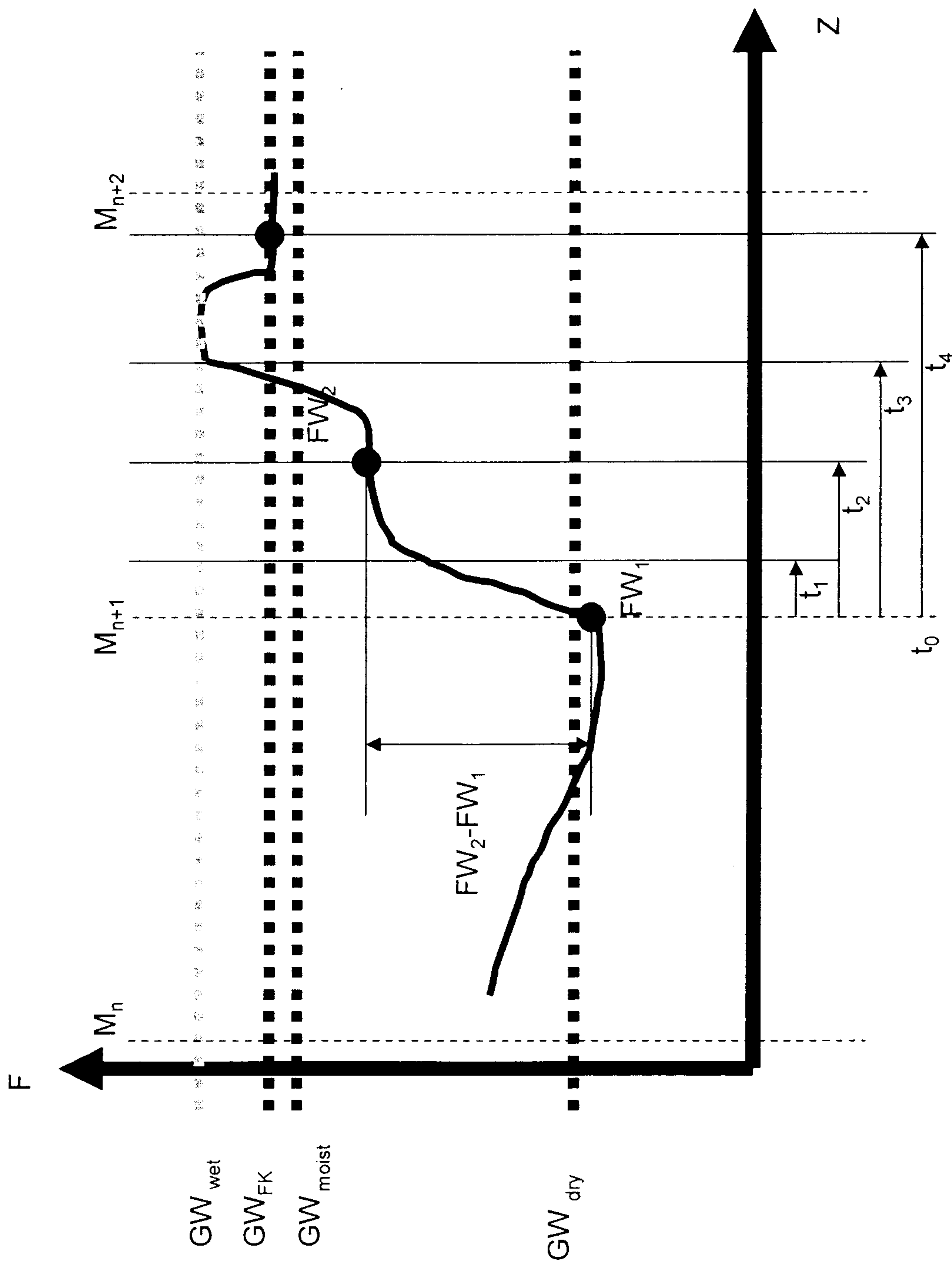


Fig.1

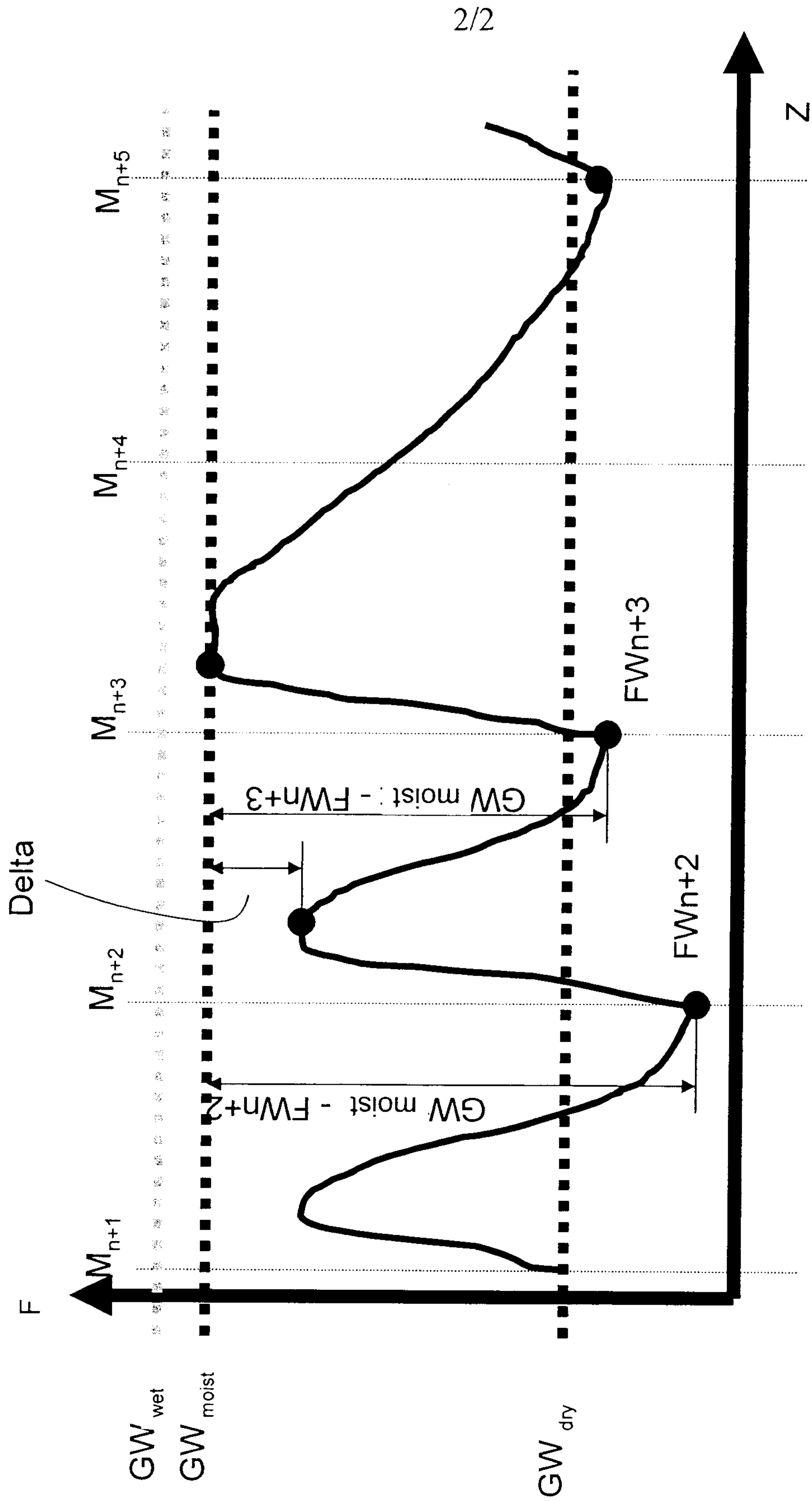


Fig.2

