

Drip Irrigation and Salinity

Using SWAP to model salt accumulation on a cotton field in the Gediz basin, Turkey



M.Sc. Minor Thesis by Geert Koster

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Turkey*

Master thesis Irrigation and Water Engineering submitted in partial fulfillment of the degree of Master of Science in International Land and Water Management at Wageningen University, the Netherlands

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Abstract

The Gediz basin is a closed basin in Western Turkey with a large area of irrigated agriculture. Through an increase in the industrial and domestic water demand, irrigation water has to be used more efficient and therefore more and more farmers are switching to drip irrigation. This means field-wide leaching is no longer possible and therefore salt accumulation is a potential risk. The aim of this study is to find out whether the current rainfall regime in the Gediz basin is sufficient to leach out the salts which accumulate during drip irrigation and make sure the soil salinity threshold is not reached for the crops growing there

To answer this question, the water and salt balance for a cotton field in the Salihli Right Bank irrigation system was modelled using the agro-hydrological model SWAP using climatic data for the years 1998 to 2010. The effect of under-irrigation (meeting 80% of the crop water requirements) was also investigated. Input parameters for the model were collected from literature and online databases.

The results showed that a switch to drip irrigation for cotton in the SRB does not lead to long term salt accumulation as the rainfall amounts in winter are sufficient to leach the salts accumulating during summer. The maximum reached soil salinity is 2.11dS m^{-1} which by far does not exceed the soil salinity threshold for cotton (7.7dS m^{-1}). Under-irrigation results in an even lower soil salinity (maximum of 1.51dS m^{-1}) due to the lower input of salts while the amount of percolation doesn't significantly change. In order for the soil salinity threshold of cotton to be reached, the irrigation water salinity has to increase from 0.37dS m^{-1} to 1.38dS m^{-1} for normal irrigation and 2.76dS m^{-1} for under-irrigation.

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1. Introduction

Irrigation-led salinization is a problem all over the world endangering the sustainability of many agricultural activities. Salinization occurs due to the fact that all irrigation water contains salts. Crops take up nearly pure water for transpiration (nutrients and some specific salts are taken up by the roots) and therefore salts will remain behind and concentrate in the root zone (Letey et al., 2011). The evaporation of water from the soil surface is another cause of salinization (Karlberg and de Vries, 2004): as pure water is evaporated, salts are left behind.

The salts that affect both surface and groundwater are often a combination of sodium, calcium, potassium, magnesium, chlorides, nitrates, bicarbonates and carbonates (Provin and Pritt, 2001). A build-up of these salts makes water less suitable to crops and leads to a partial or total loss of the productive capacity of a soil, because of degradation of its chemical and physical properties. Pasternak (1987), summarizes the chemical effects of soil salinity. Firstly, soluble salts in the root-zone cause a decrease in the osmotic potential of the soil solution leading to water stress in the plant. Secondly, an excess of some particular ion can lead to a nutritional imbalance for the plant. Accumulation of specific ions (mainly Cl⁻) in plant tissue can also lead to direct toxicity. Thirdly, plants will adapt to salinity costing energy which is actually needed for growth (Pisinaras et al., 2010). If the concentration of sodium ions is too high, it will be exchanged with sufficient amounts of magnesium and calcium ions to physically affect the soil. Soil particles will be dispersed and for this, aggregation is destroyed (sodification) (Pisinaras et al., 2010). Once the level of salinity is high it is difficult and costly to remediate (Pisinaras et al., 2010).

According to the World bank (1992), salinization caused by irrigation affects about 60 million hectares, 24% of all irrigated land. On 10% of the irrigated land severe declines in productivity are observed. The area affected by salinity worldwide is said to be increasing at a rate of 1.0-1.5 million ha per year (Barghouti and Le Moigne, 1991). New irrigated areas are being degraded faster than older soils are being reclaimed (World-Bank, 1992). Arid and semi-arid areas are the most vulnerable (Karlberg and de Vries, 2004).

According to Karlberg (2004), over-irrigation is the major cause of salinization. The supply of excess water means more salts are brought onto the land and also that there is more water available for evapotranspiration (leaving salts behind). It is important to recognise the difference between continuously over-irrigating in small amounts (which leads to an increase in salinization) and sporadic surges of a lot of excess water which will actually dissolve and drain the salts either to the groundwater or channel network (leaching).

Drip irrigation is therefore seen as a solution (Nagaz et al., 2008), (Hanson and May, 2004), (Tan and Kang, 2009). Using drip irrigation, water can be supplied to the crops in correct quantities and precisely when and where the crops need it. This means fewer salts enter the soil and soil evaporation is limited (Karlberg and de Vries, 2004). Furthermore the salt tends to accumulate away from the active root zone horizontally, vertically and also at the wetting front close to the soil surface (Dasberg and Or, 1999; Shalhevet, 1994) (Hanson and May, 2004).

Even though, this might sound beneficial for the crops being irrigated at the moment, there is also another side to the story. Drip irrigation can remove salts from the active root zone but not from the soils away from the root zone. A study in California (Burt et

al., 2003) for example, showed that there was long term salt accumulation along the tree rows of many orchards irrigated with drip systems. This accumulation of salt was outside of the root-zone of these trees (such as in Figure 1) but becomes particularly important when the trees are removed and the fields are replanted. To be able to remove these salts one has to rely on periodic heavy rainfall or invest in a different method of irrigation such as surface irrigation or sprinklers.

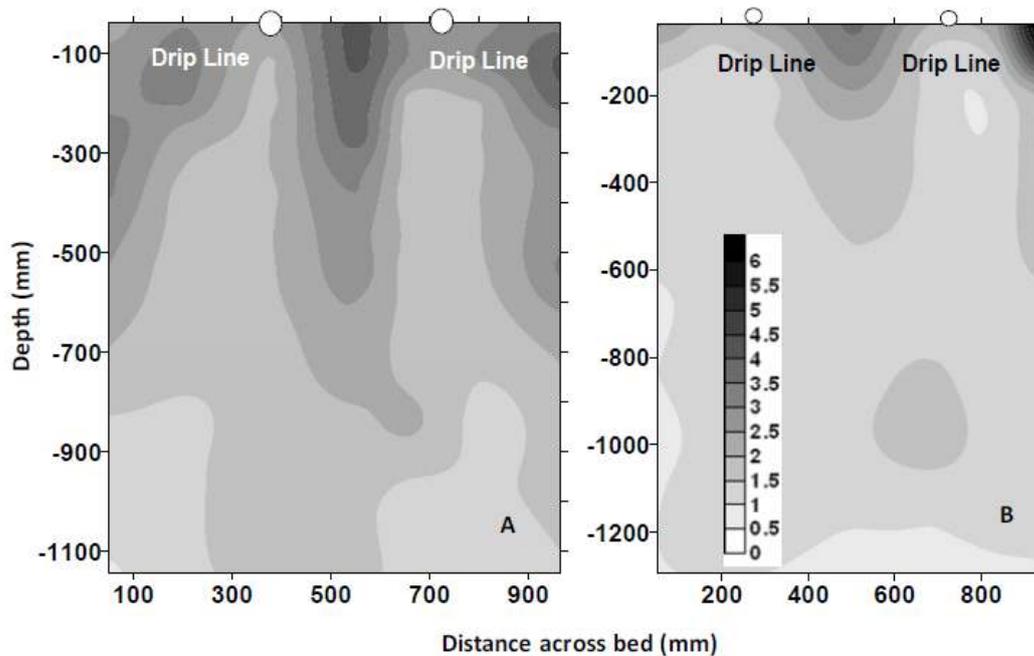


Figure 1: Salt distribution for a (A) sandy loam soil, and (B) a clay loam soil. Soil salinity units are EC_{sat} in $dS\ m^{-1}$ (Hanson and May, 2004)

1.1 Problem statement

The Gediz Basin in Turkey is a closed basin located in a semi-arid area. Around 1500km² is covered with agriculture (Kite, 2001). At the moment, irrigation uses 75% of surface water resources (Yilmaz and Harmancioglu, 2010). However, rapid urbanization in the major cities increases the domestic water demand by 2% per year and the industrial demand is growing by 10% a year (Yilmaz and Harmancioglu, 2010). Therefore, the available irrigation water is decreasing every year and the only way to safeguard the current agricultural production is by using water in a more efficient way.

At the moment, farmers are being informed on how to improve irrigation efficiencies and are offered significant subsidies to conduct water saving technologies such as drip irrigation (Yilmaz and Harmancioglu, 2010), some farmers have already made the switch (Murray-Rust and Svendsen, 2001). According to Woldegebriel (2011), this switch to drip irrigation, combined with the low rainfall and low leaching water availability, means there may be a considerable risk of salinization.

1.2 Research questions

The aim of this research is to find out whether for an average field in the Gediz basin,

the current rainfall regime is enough to leach out the salts which accumulate due to drip irrigation and keep the soil salinity beneath the threshold for the crops growing there. A second scenario in which a decrease in future water availability will limit the water gift will also be tested.

Finally, the effects of changing the irrigation water salinity will be investigated to find out what maximum salinity the irrigation water can have before the soil salinity threshold is reached for the crops growing there. It was chosen to investigate an irrigation system in the middle of the basin - the Salihli Right Bank irrigation system (SRB) - and a field planted with the most common crop grown in the area - cotton.

This paper will build on research done by Woldegebriel (2011) who found that drip irrigation is highly expanding in the area and that the Gediz basin is suffering from salinity problems. Furthermore she investigated the applicability of the SWAP model for modelling drip irrigation.

The research questions are as follows:

- Is the current rainfall regime in the SRB sufficient to leach out the salts which accumulate due to drip irrigation and make sure the soil salinity threshold for cotton is not reached?
- How will the soil salinity be affected when only 80% of the crop water requirements are met?
- What is the maximum salinity that the irrigation water can have before the soil salinity threshold for cotton is reached if no supplemental leaching water is applied
 - when crop water requirements are met?
 - when only 80% of the crop water requirements are met?

1.3 Research objectives

To answer these questions, SWAP will be used to model drip irrigation on a cotton field in the SRB using weather data for the years 1998 to 2010. The monthly soil salinity as a function of depth for these years will be observed to see whether the critical EC for cotton is exceeded in any month.

The same model will also be run with a decrease in the amount of irrigation so that only 80% of the crop water requirements are met

The irrigation water salinity will then be reduced or increased to find out what maximum salinity the irrigation water can have before the soil salinity threshold for cotton is reached for the scenario in which crop water requirements are met and the scenario in which only 80% of the crop water requirements are met.

The input parameters needed for the SWAP model will be collected from earlier publications and online databases.

1.4 Concepts

- *Soil salinity*: is defined as the concentration of totally dissolved salts in the liquid phase of the soil. In this report it will be expressed as the electrical conductivity

of the saturated paste (EC_{sat} which is measured in $dS\ m^{-1}$) as this unit is independent of the soil moisture content.

- *Irrigation water salinity*: is the electrical conductivity ($dS\ m^{-1}$) of the irrigation water.
- *Soil salinity threshold*: is the soil salinity, expressed as EC_{sat} , at which plant stress starts taking place.
- *Crop water requirement*: is defined as the potential transpiration of the crop. When only 80% of the crop water requirements are met, this therefore means the actual transpiration is 80% of the potential transpiration due to water stress.

2. Methodology

2.1 Research area

The research area is the Salihli Right Bank Irrigation system (SRB), located in the Gediz Basin in Eastern Turkey.

The Gediz basin has a total size of 17220km² and is one of the major river basins in Turkey. The river flows from mountain ranges in the East to the Aegean sea in the West, just North of Izmir: an elevation range of 2300m over a distance of 276km (Droogers and Bastiaanssen, 2001).

The basin has a Mediterranean climate consisting of hot, dry summers and mild, rainy winters (De Voogt et al., 2000). Annual precipitation in the basin ranges from over 1000mm in the mountains at the Eastern end of the basin to a low of around 500mm near the Aegean coast. Air temperatures range from 2°C at high elevations in winter to over 40°C in the interior plains in summer (Kite and Droogers, 2000b). The river shows this same typical Mediterranean hydrological regime. Peak flows occur in the winter months due to high rainfall and are followed by a period of snow melt in spring that lasts until May or June. In the summer most streams dry up with only larger rivers having small flows throughout the year (Murray-Rust and Svendsen, 2001).

The natural vegetation of the basin is mainly shrubland, maki (a mix of bay, myrtle, scrub oak and juniper trees, amongst others) and coniferous forest. The main crops produced in the basin are cotton and grapes. Next to this, cereals, vegetables and fruits, olives, tobacco and melons are also cultivated (Kite and Droogers, 2000b).

An area of 1130km² is irrigated predominantly with groundwater and water from the Gediz river which is delivered to the irrigation systems by means of three regulators. Each regulator has a right bank and left bank canal. Upstream, the Adala Regulator serves the Salihli Right Bank, Salihli Left Bank, Gökkaya, Ahmetli, and Turgutlu irrigation associations. A little further downstream, the Ahmetli Regulator serves the Gediz, Mesir, Sarikiz, Turgutlu, and Ahmetli irrigation associations; while in the delta, the Emiralem Regulator serves the Menemen Right and Left Bank irrigation associations. Storage of water is ensured by three dams: the Demirköprü (which is by far the largest), the Buldan and the Asfar (Akkuzu et al., 2007).

The operation of the irrigation systems has been transferred from the State Hydraulic Works (in Turkish 'the Devlet Su Isleri', from here on abbreviated by 'DSI') to the WUA's in 1994 and 1995. From then it has been the task of the WUA's to determine the monthly and seasonal water requirements of the network under their control according to farmer's declarations (Akkuzu et al., 2007). This includes such information as the location, area, crop type, and the number or name of the canals to receive water, relating to the farmers' land for irrigation which has to be reported to the DSI. The DSI then determines water to be supplied to the associations during the season by evaluating the associations' demands in relation to the amount of water in the reservoir and the capacity of the canals, and in this way it forms a general irrigation plan (Akkuzu et al., 2007).

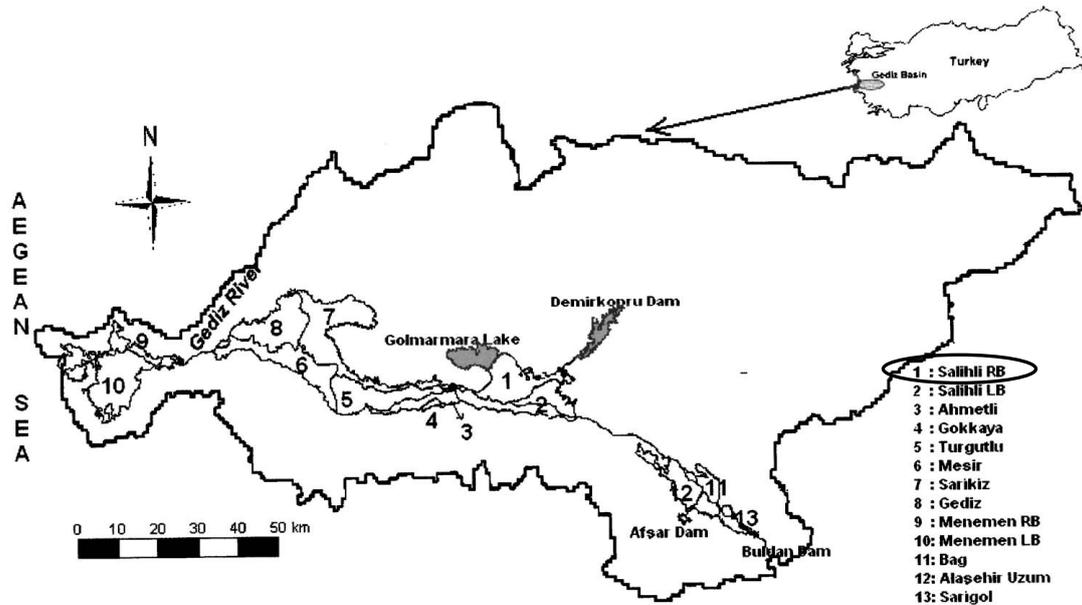


Figure 2: The Gediz basin and its irrigation systems (Akkuzu et al., 2007)

The Salihli Right Bank irrigation system (SRB) is located 5 km below Demirköprü Reservoir. The total command area is 9100ha and the irrigation system consists of one main canal, five secondaries and 125 tertiaries. The average plot size is about 2ha and the main method of irrigation is furrow irrigation. Some border irrigation is also applied. Besides an irrigation canal network of 294km there is also an extensive drainage network with a total length of 277km (Droogers et al., 2000). The main crops grown in the SRB are cotton (60%), grapes (10%) and a combination of maize and wheat (10%) (Droogers and Kite, 2001).

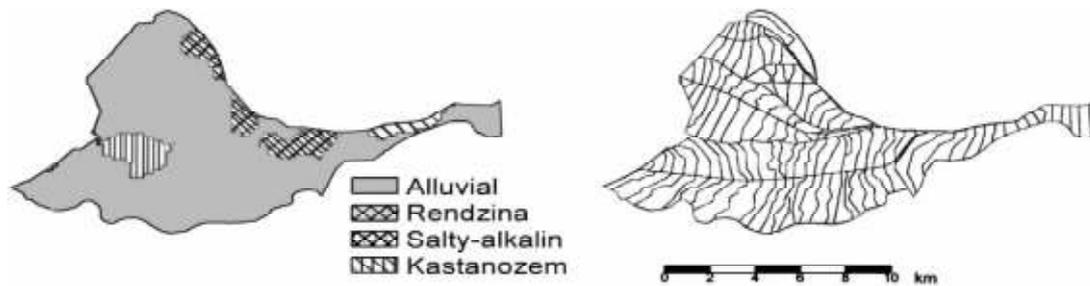


Figure 3: Soils (left) and canal network (right) and of the SRB (Droogers et al., 2000)

2.2 Model

The model that will be used is SWAP. The SWAP model is a physically based deterministic model, empirically tested to show its credibility (Kroes and Dam 2003).

The model simulates the transport of water, solutes and heat in the unsaturated zone in interaction with vegetation development (Kroes and Dam 2003). In this zone the transport processes are predominantly vertical, therefore SWAP is a one-dimensional, vertical directed model (Kroes and Dam 2003). The model uses Richards equation (based on Darcy's law and the conservation of mass principle) extended with a sink

term for water uptake by the roots to simulate soil water movement. To solve this, the soil hydraulic function of each soil layer should be known (Van Genuchten-Mualem parameters), these can be taken from tables (depending on soil texture) or can be measured in the field (Smets et al. 1997). Root water uptake is a function of the maximum root water uptake, the soil water pressure head and the salt concentration (Smets et al. 1997).

The solute transport is computed according to the principles of convection, diffusion, dispersion, adsorption and removal by lateral drainage. The model includes hysteresis, the possibility of simulating preferential flow, adsorption and decomposition processes. No distinction is made between different cations and anions and only the total amount of salts is considered (Smets et al. 1997). The upper boundary conditions are determined by the potential evapotranspiration, irrigation and precipitation (Smets et al. 1997). Bottom boundary conditions can be described with various options, e.g., water table depth, flux to groundwater or free drainage (Wesseling et al., 1991).

2.3 Model input

2.3.1 Precipitation

The daily precipitation data for the Salihli Right Bank irrigation system from 1998 to 2010 has been collected from the Tropical Rainfall Measuring Mission (TRMM) Multi-satellite Precipitation Analysis (TMPA) version 6. It intends to be the “best estimate of quasi-global precipitation from the wide variety of modern satellite-borne precipitation-related sensors” (Huffman et al., 2010). According to ground validations studies, the maximum error in TRMM precipitation data is 10% (Wolff et al., 2005).

Daily rainfall data was also available from the Menemen meteorological station (around 90km from the study area) for from October 2009 till December 2010. This was used to validate the daily rainfall records from the TRMM. The validation was done by calculating the linear correlation coefficient, the bias, the RMSE and the Nash-Sutcliffe efficiency.

The linear correlation coefficient (Equation 1) shows the correlation between the gauge observations and the satellite estimates. It ranges from -1 (perfect negative linear correlation) to 1 (perfect positive linear correlation) with 0 indicating no linear correlation. The bias (Equation 2) shows the systematic error and the RMSE (Equation 3) - which will be corrected for the bias - shows the random error. Both these parameters were calculated as percentages of the mean rainfall value. The Nash-Sutcliffe efficiency (Equation 4) represents the skill of the estimates relative to the reference data. It ranges from minus infinity (poor skill) to 1 (perfect skill) with 0 indicating that the satellite estimates are as accurate as the observed mean (Feidas, 2010).

$$r = \frac{\sum_{i=1}^n ((S_i - \bar{S}) - (G_i - \bar{G}))^2}{(n-1)\sigma_S\sigma_G} \quad (1)$$

$$BIAS = \bar{S} - \bar{G} \quad (2)$$

$$RMSE = \sqrt{\frac{1}{n} \sum_{i=1}^n (S_i - BIAS - G_i)^2} \quad (3)$$

$$Nash - Sutcliffe = \frac{\sum_{i=1}^n (S_i - G_i)^2}{\sum_{i=1}^n (S_i - \bar{G})^2} \quad (4)$$

Where S_i are the estimated satellite values, G_i are the reference gauge values, σ_S and σ_G are their standard deviations and n the number of data pairs.

2.3.2 Potential evapotranspiration

SWAP has a number of options to calculate the potential evapotranspiration. The Penman-Monteith equation is used to calculate the potential evapotranspiration from the minimum and maximum temperatures, humidity, solar radiation and wind. It allows the direct use of the Penman-Monteith equation, in which case the minimum resistance, albedo and crop height are needed, or the Penman-Monteith method as applied to a reference grass in combination with crop coefficients (Kroes et al., 2009). Another option is to use reference evapotranspiration data in combination with crop coefficients. This was the approach chosen in this study because the necessary data for the Penman-Monteith equation was not available.

The reference evapotranspiration was calculated using the modified Hargreaves equation (Equation 5) using the monthly minimum and maximum temperatures in the study area (Droogers and Allen, 2002).

$$ET_0 = 0.0013 \cdot 0.408 RA \cdot (T_{avg} + 17.0) \cdot (TD - 0.0123 P) \cdot 0.76 \quad (5)$$

Where RA = Extra-terrestrial radiation, TD = difference between maximum and minimum temperature and T_{avg} = mean temperature.

Monthly minimum and maximum temperatures were obtained from The Global Historical Climatology Network-Monthly (GHCN-M) temperature dataset, version 3. It consists of monthly surface observations from around 7000 stations from around the world, adjusted for homogeneities and quality controlled (Peterson and Vose, 1997). The nearest gauge with the necessary data range (from 1998-2010) was that in Usak, around 100km from the study area.

2.3.3 Crop model

In SWAP, one can choose between the detailed and simple crop model. The detailed crop model simulates detailed photosynthesis and takes into account water and salt stress. The simple model prescribes crop development, independent of external stress factors and is useful to provide proper upper boundary conditions for soil water movement (Kroes, 2003).

Because of a lack of input parameters and the fact that simulating crop water use is more important than accurate simulation of crop yield (Kite and Droogers, 2000a), it was decided to choose the simple crop model.

For the simple crop model the leaf area index, crop coefficient and rooting depth as function of development stage are needed. Light extinction coefficients are used to quantify the decrease of solar radiation within a canopy (Kroes et al., 2009). The leaf area index, rooting depths and light extinction coefficients for cotton were taken from an experiment undertaken in Sirsa District India and are shown in Table 1 and Table 4. The crop coefficients come from the FAO and are shown in Table 3.

Table 1: Light extinction coefficients

Coefficient	Value
K_{dir}	0.6
K_{dif}	0.75

(Dam and Malik, 2003)

Table 2: Length of development stages and other parameters for cotton in the SRB

Start growing season	1 May
Establishment (days)	20
Vegetative period (days)	35
Flowering period (days)	70
Yield formation (days)	35
Ripening (days)	20
Growth duration (days)	180
Harvest date	1 Nov
Maximum rooting depth (cm)	80
Maximum yield (kg ha ⁻¹)	4000

(Droogers et al., 2000)

Table 3: Crop coefficients for cotton

Development stage	Stage length (days)	Crop Coefficient (-)
Initial	30	0.35
Development	50	>>
Mid-season	55	1.15-1.2
Late	45	0.7-0.5

(Allen et al., 1998)

Table 4: Rooting depth and LAI for cotton

Days after planting	LAI (-)	Rooting depth (cm)
50	0.5	40
80	1.5	75
110	4.1	80
140	5.2	80

(Dam and Malik, 2003).

2.3.4 Moisture & salt stress

Actual transpiration depends on the moisture and salinity conditions in the root zone. The parameters needed to calculate the reduction of root water uptake due to water stress are the following:

- H_1 : The pressure head (cm) at which root water uptake is equal to zero due to insufficient aeration (saturation)

- H_{2u} : The pressure head (cm) above which root water uptake declines due to insufficient aeration for the upper soil layer
- H_{2l} : The pressure head (cm) above which root water uptake declines due to insufficient aeration for the lower soil layer
- H_{3l} : The pressure head (cm) from which root water extraction starts being reduced due to drought stress for low potential transpiration rates
- H_{3h} : The pressure head (cm) from which root water extraction starts being reduced due to drought stress for high transpiration rates
- H_4 : The pressure head (cm) at which root water uptake is equal to zero due to drought (wilting point)
- $ADCR_h$: Level of high atmospheric demand (cm d^{-1})
- $ADCR_l$: Level of low atmospheric demand (cm d^{-1})

The parameters needed to calculate the reduction of root water uptake due to salinity stress are the following:

- EC_{max} : EC_{sat} level (dS m^{-1}) at which salt stress takes place. The EC_{sat} is defined as the EC of the soil water at saturation water content.
- EC_{slope} : Decline of root water uptake (m dS^{-1}) due to salt stress above salinity levels of EC_{max}

Table 5 shows the used parameters which were also obtained from the Sirsa experiment.

Table 5: Moisture and salt stress parameters for cotton

Parameter	Cotton
Moisture stress	
H_1 (cm)	-1.0
H_{2u} (cm)	-22.9
H_{2l} (cm)	-22.9
H_{3l} (cm)	-1200
H_{3h} (cm)	-7500
H_4 (cm)	-16000
$ADCR_h$ (cm d^{-1})	1.0
$ADCR_l$ (cm d^{-1})	0.2
Salt stress	
Critical level, EC_{max} (dS m^{-1})	7.7
Decline per unit EC, EC_{slope} (m dS^{-1})	5.4

(Dam and Malik, 2003)

2.3.5 Interception

To calculate interception by agricultural crops, SWAP uses the Von Hoyningen-Hüne and Braden equation (Equation 6) where P_i is the intercepted precipitation (cm d^{-1}), LAI is the leaf area index, P_{gross} is the gross precipitation (cm d^{-1}), a is an empirical coefficient (cm/d) and b represents the soil cover fraction.

$$P_i = a \cdot LAI \left(1 - \frac{1}{1 + \frac{b \cdot P_{gross}}{a \cdot LAI}} \right) \quad (6)$$

Using this equation, for increasing amounts of precipitation, the amount of intercepted precipitation asymptotically reaches the saturation amount $aLAI$ (Kroes et al., 2009). For a we take the default value of 0.25 cm d^{-1} (Kroes, 2003).

2.3.6 Irrigation

In SWAP two irrigation methods can be specified: surface or sprinkler. The main difference between the two is that with sprinkler irrigation the model assumes that water will first be intercepted by the crop before it reaches the soil (Kroes, 2003). With surface irrigation (just like with drip irrigation) this is not the case. For this reason, surface irrigation was chosen.

Another choice can be made between specifying 'fixed irrigation applications' and 'irrigation scheduling'. The option 'fixed irrigation applications' means the exact irrigation timing and depth have to be specified beforehand, the option 'irrigation scheduling' lets SWAP calculate the irrigation timing and depth based on set criteria – this second option was chosen. Through trial and error, the necessary criteria for irrigation depth and timing were found that created schedules supplying 100% and 80% of the crop water requirements respectively.

To make the irrigation schedule even more realistic it was chosen to also set a maximum irrigation depth which is equal to the maximum capacity of the drip irrigation system. A quick calculation showed that the maximum daily evapotranspiration between 1998 and 2010 was seen to be 7mm, the maximum capacity of the drip irrigation system was therefore set to be a daily gift of 8mm (to account for inefficiencies).

The application efficiency (E_a) of the created schedules was tested using Equation 7:

$$E_a = \frac{T_a}{I + P_n} \quad (7)$$

where I is the total irrigation depth during the irrigation season, P_n is the net precipitation during the irrigation season and T_a is the actual transpiration during the irrigation season.

100% Crop water requirements

To simulate drip irrigation supplying 100% of the crop water requirements, it was attempted to get a schedule which caused no water stress but also as little percolation as possible.

Through trial and error it was found that to get such a schedule, the model has to simulate irrigation whenever 25% of the total available soil moisture is depleted with an irrigation depth that is enough to bring the soil moisture content back to field capacity minus 55mm.

For the 12 modelled years, this yielded an average application efficiency of 95% meaning only 5% was lost (mainly to evaporation). This is very comparable to other drip irrigation systems (Anyoji and Wu, 1994).

80% Crop water requirements

An irrigation schedule supplying 80% of the crop water requirements was defined as a schedule resulting in the actual transpiration of the crop being 80% of the potential transpiration due to water stress.

Through trial and error it was found that to get such an irrigation schedule, the model has to simulate irrigation whenever 80% of the total available soil moisture is depleted with an irrigation depth that is enough to bring the soil moisture content back to field capacity minus 100mm.

For the 12 modelled years, this yielded an average application efficiency of 100%.

2.3.7 Initial soil moisture condition, solute concentration, and groundwater EC.

As there was no data available on the initial soil moisture and solute concentrations, it was decided to use the output of an earlier SWAP simulation. It was assumed that the years before 1998 had similar rainfall and evaporation as 1998-2010. Therefore using the rainfall and evaporation data of 1998-2010, drip irrigation was modelled and the final soil moisture and solute concentrations as function of depth were used as input for the new simulation from 1998-2010.

The salt concentration of the groundwater was assumed to be equal to the average salt concentration of the percolating water of this SWAP simulation. This is equal to 0.597 dS m⁻¹. This means the assumption is made that the groundwater system beneath the SRB is a slow flowing system which is only made up of water percolating from the SRB and is not affected by the inflow of groundwater from upstream regions.

2.3.8 Ponding, runoff and run-on

In SWAP, surface runoff is modelled when the water storage in the ponding layer exceeds the critical depth of $h_{0,threshold}$ using the following equation:

$$q_{runoff} = \frac{1}{\gamma} \cdot \left(\max(0, (h_0 - h_{0,threshold}))^\beta \right) \quad (8)$$

Where h_0 is the ponding depth of water on the soil surface, γ is a resistance parameter and β is an exponent in the empirical relation (Kroes et al., 2009).

For this research, realistic, dynamic simulation of surface runoff is not important. Only the effect of surface runoff on the soil water balance is of interest. Therefore, rough default estimates for the parameters γ and β be used of 0.5 and 1 respectively (Kroes et al., 2009). The maximum height of ponded water in well-maintained soils in the Netherlands ranges between 0.5 - 2cm (Kroes et al., 2009). For the SRB a high end estimate of 2 cm is used. Run-on is neglected in this simulation

2.3.9 Soil evaporation

The soil evaporation is reduced according to the maximum water flux which the soil can deliver. The method of Black is used to calculate this with the following equation:

$$\sum E_a = \beta_1 t_{dry}^{0.5} \quad (9)$$

where $\sum E_a$ is the cumulative actual evaporation during a drying cycle, β_1 is a soil specific parameter characterizing the evaporation process and t_{dry} is the time after a significant amount of rainfall. For our simulation, the default soil evaporation coefficient of $0.35 \text{ cm d}^{-0.5}$ was used (Kroes et al., 2009).

2.3.10 Soil profile & parameters

The water flow in the unsaturated zone of this soil profile is modelled using the Richards' equation. To numerically solve this equation though, known relations between θ (volumetric water content), h (soil water pressure head) and K (hydraulic conductivity) are needed. The Mualem-Van Genuchten relations describe these soil hydraulic functions (Kroes et al., 2009). Using the soil texture (% clay, silt and sand), the organic matter content and the dry bulk density, the parameters for the Mualem-Van Genuchten relations can be found using the Staring series (Wosten et al., 1994) and the soil hydraulic functions can be calculated so that the Richards' equation can numerically be solved.

According to (Droogers et al., 2000), there are four different soil types in the SRB. The major soil type covering 86% of the system are alluvial soil formed from deposits by streams. They have a medium texture, good drainage conditions and are very productive (Droogers et al., 2000). This is reinforced by (Droogers and Kite, 2001) who describes a field in the SRB as one with a loamy soil and water leaving the system through drains and deep percolation.

The soil parameters from The Harmonized World Soil Database (FAO et al., 2009), were in agreement with these descriptions and were therefore used to obtain the parameters for the Mualem - Van Genuchten relations from the Staring series.

Table 6: Soil parameters for the SRB

	Topsoil 0cm to -30cm	Subsoil -30cm to -100cm
Sand Fraction (%)	40	40
Silt Fraction (%)	40	40
Clay Fraction (%)	20	20
USDA Texture Classification	Loam	Loam
Reference Bulk Density (kg/dm ³)	1.4	1.4
Organic matter content (%)	1.89	0.69

(FAO et al., 2009)

2.3.11 Hysteresis, Media scaling and Preferential flow

Hysteresis refers to the difference in the soil hydraulic functions between wetting and drying soils. This however does not play a large role the calculation of the solute and water balance (Kroes, 2003) so will not be taken into account.

Due to macropores in soils, soil water may largely bypass the unsaturated soil domain due to preferential flow (Kroes, 2003). However, the necessary detailed parameters to take this into account were not available and therefore preferential flow is not modelled.

A media scaling option is available to take into account the spatial variability of the water balance components (Kroes, 2003). Because we want to calculate the average solute concentration in the soil and not how this can be spatially distributed over a field this is for us of no importance.

2.3.12 Maximum rooting depth

The maximum rooting depth allowed by the soil profile is 80cm (Droogers et al., 2000)

2.3.13 Bottom boundary section

With SWAP, a large variety of lower boundary conditions can be selected. According to Droogers, Bastiaansen et al (2000), the most suitable one for the SRB is a flux dependant one where the flux to or from an aquifer is a function of the groundwater level and the resistance of a semi-confining layer. The fluctuation of the hydraulic head of the semi-confined aquifer was said to be between 225cm and 275cm for January and July respectively with an average of 250cm (Droogers et al., 2000). The resistance of the semi confining layer was said to be a 100 days (Droogers et al., 2000).

2.3.14 Solute section

In case conservative solutes like salts are simulated we need only to consider the transport processes convection, diffusion, dispersion and passive uptake by plant roots (Kroes et al., 2009). Decomposition does not occur. Furthermore because we only look at the effect of soluble salts, we did not take into account adsorption.

At most field conditions we may neglect the effect of diffusion with respect to dispersion and therefore may specify $D_{dif} = 0$ (Kroes et al., 2009). The parameter dispersion length, L_{dis} , depends on the scale over which the water flux and solute convection are averaged, the water flux, and the texture to some extent (Vanderborght and Vereecken, 2007). Taking into account the vertical travel distance of around 250cm and the medium texture, the dispersion length was averaged at 6cm. The uptake of salt by crops was assumed to be negligible.

SWAP supports two methods to account for the residence time of solutes in the saturated zone. The first one by proper distribution of the lateral drainage flux over the saturated compartments (in the case of heterogeneous groundwater flow or multi-level drainage), the second one as viewing the saturated zone as one mixed reservoir (In case of a homogenous aquifer and fully penetrating field drainage at one level) (Kroes et al., 2009). As the field drainage is not fully penetrating and the groundwater flow probably

not homogenous the first method was chosen. The solute concentration in the groundwater was taken as a boundary condition for upward flow.

The salt concentrations in the Gediz river were measured by Kumru (2001) and shown in Figure 4. The concentrations are highest in volcanic areas between Kula in the East (at around 300km) and the Demirköprü reservoir in the West (at around 200km) and at the mouth of the river where it mixes with sea water. The off take of the SRB is located 176,5km from the mouth of the river, just beneath the Demirköprü dam where the river water has a specific conductance of around $365\mu\text{S cm}^{-1}$ which is equal to 0.37 dS m^{-1} . The salt concentration of rainwater was taken to be 0.015dS m^{-1} (Suttar, 1990).

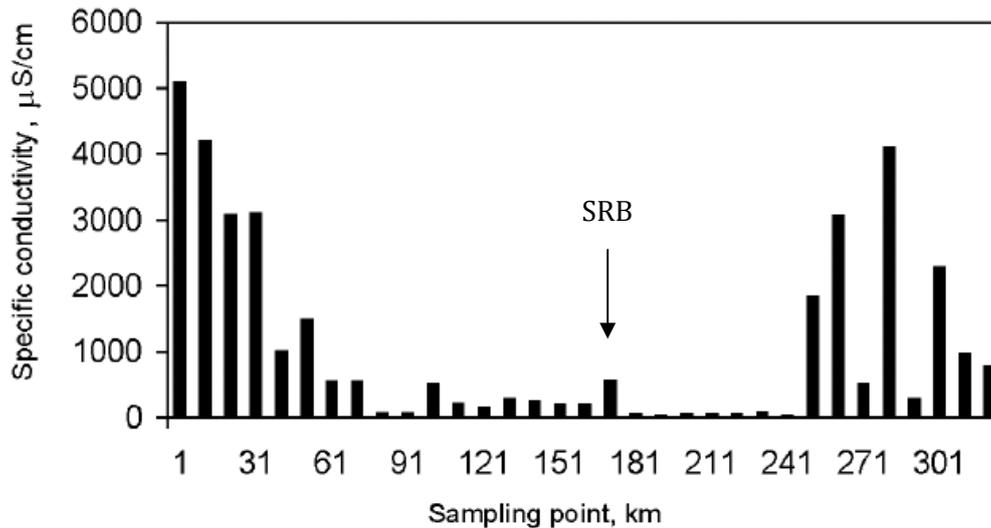


Figure 4: The specific conductivity values of the water samples of the Gediz river from the ocean (left side) to the source (right side) (Kumru, 2001)

2.3.15 Drainage

Since the groundwater level is at a large average depth of 2.50m and drip irrigation was shown not to raise it into the rooting depth of the crops, drainage is not necessary and therefore was not modelled.

2.4 Model output

The output of SWAP is given as the actual salt concentration in the liquid phase. This is converted to the electrical conductivity of the saturated paste (EC_{sat}) as this unit is independent of the soil moisture content and allows us to compare the salinity levels with the salinity threshold. To do so, firstly the salt concentration in the liquid phase was converted to the salt concentration in the saturated paste by using Equation 10.

$$c_{sat} = c_{act} \frac{\theta_{act}}{\theta_{sat}} \quad (10)$$

where c_{act} is the actual salt concentration in the liquid phase, θ_{act} is the actual volumetric soil water content and θ_{sat} is the saturated volumetric soil moisture content (Kroes et al., 2009).

The electrical conductivity of the saturated paste was then calculated using Equation 11.

$$EC_{sat} = ac_{sat}^b \quad (11)$$

where a and b are empirical coefficients. As the exact composition of the salt is unknown, default values for an average TDS mixture were taken of 1.492 and 1 for a and b respectively (Kroes et al., 2009).

2.5 Irrigation water salinity threshold

To find out what the maximum salinity is that the irrigation water can have, the soil salinity was modelled using different irrigation water salinities for the scenario in which crop water requirements are met and the scenario in which only 80% of the crop water requirements are met.

3. Results

3.1 Validation precipitation

As explained in section 2.3.1, the satellite precipitation estimates were validated using rain gauge data from the Menemen Meteorological Station (which was available for only two years). The reliability of the satellite estimates are shown by the parameters in Table 7. It can be seen that the systematic bias error is relatively small – there is a slight overestimation of rainfall of 7.48%. However the random error (bias corrected RMSE) is huge – especially for the data on a daily scale. This also gives a low correlation coefficient and Nash-Sutcliffe efficiency. When we look at data on a larger, monthly time scale the random error is acceptable leading to a good correlation coefficient and Nash-Sutcliffe efficiency.

These parameters show us that the satellite product gives us reliably monthly rainfall estimates however, the shown daily variation is unreliable. For the aim of this study this is still acceptable because it does not matter on what exact date the rain falls as long as we know in what general period (e.g. month) it is falling. Therefore it was decided to still use the daily satellite estimates as input for the model.

Table 7: Parameters showing reliability of satellite rainfall estimates

	Linear correlation coefficient (r)	Bias (%)	Bias corrected RMSE (%)	Nash-Sutcliffe efficiency
Daily	0.38	7.48	326.74	-4.34
10-day	0.63	7.48	107.99	0.36
Monthly	0.87	7.48	29.65	0.81

3.2 Soil salinity

3.2.1 Meeting 100% of crop water requirements

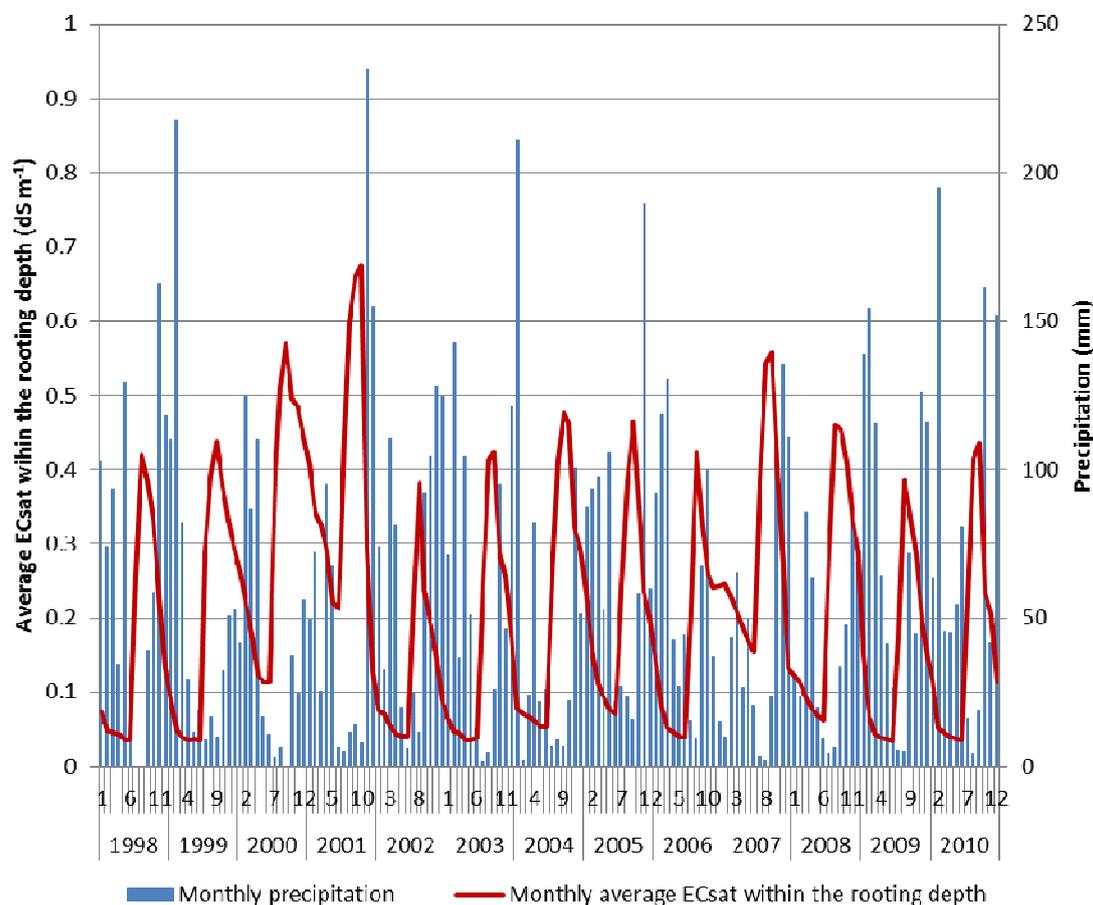


Figure 5: Monthly average soil salinity within the rooting depth (expressed as EC_{sat}) and monthly precipitation

Figure 5 shows the measured monthly precipitation (mm) and the modelled monthly average EC_{sat} within the rooting depth ($dS\ m^{-1}$). As can be seen from Figure 5 there is a clear annual fluctuation in soil salinity. The highest levels of salinity are found at the end of the growing season (around October), and the lowest levels of salinity are found after the winter rains (May). Overall the levels of salinity vary between $0.05\ dS\ m^{-1}$ and $0.20\ dS\ m^{-1}$ just after winter and between $0.40\ dS\ m^{-1}$ and $0.65\ dS\ m^{-1}$ just after summer.

Furthermore, when looking at the salinity levels between 1998 and 2010, no increasing or decreasing trend can be found. Therefore it seems to be, at least from 1998 to 2010, that the rainfall amounts in the SRB are enough to leach out the salts accumulating through drip irrigation during the growing seasons.

We should keep in mind however that Figure 5 only shows the averages for the whole rooting depth (80cm). The actual soil salinity at certain depths can be a lot larger or smaller. Figure 6 shows the soil salinity as function of depth for October 2001. During this year and month, the maximum soil salinity occurred which was $2.11\ dS\ m^{-1}$ at a depth of 65cm. The critical EC_{sat} for cotton is $7.7\ dS\ m^{-1}$ (Dam and Malik, 2003). This threshold has therefore by far not been exceeded.

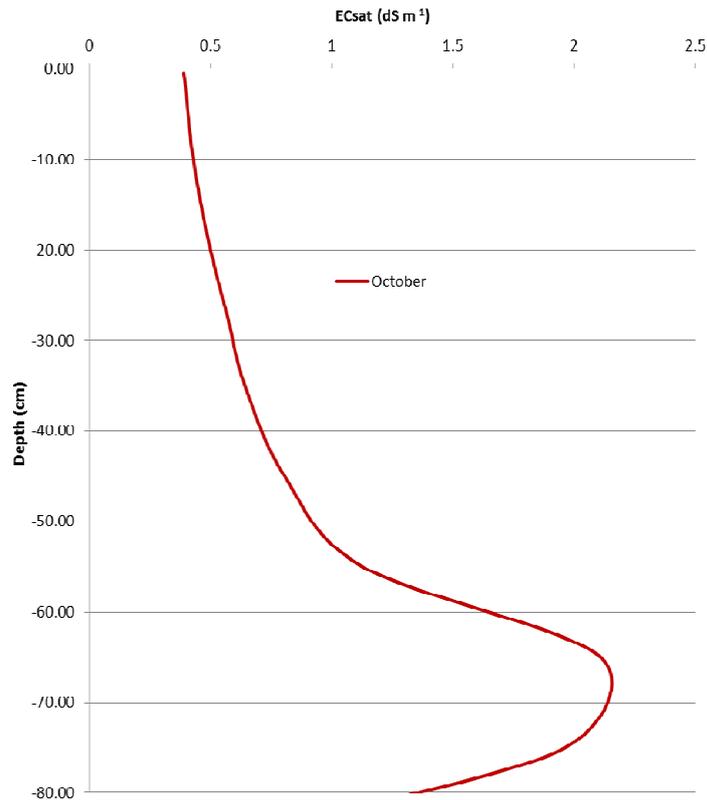


Figure 6: Soil salinity (expressed as EC_{sat}) as function of depth, October 2001

A closer analysis of Figure 5 shows, that as we would expect, there is a large dependency between precipitation and average soil salinity. Especially the rain falling during the winter is important as this rain leaches out the salts which have accumulated during the irrigation season before. As soon as the amount of rainfall in winter is low, the average soil salinity after winter (at the start of next irrigation season) is higher than the year before. This means that during the next irrigation season, more salt will build up, giving a higher soil salinity peak at the end of the irrigation season than the previous year as well. This can be seen very clearly in the years 2000 and 2001.

Figure 4 shows a close up of the hydrological years 2000/2001 and 2001/2002. It can be clearly seen that due to little winter precipitation in 2000/2001, the accumulated salts are leached relatively slowly and the soil salinity after the winter rains (in May 2001) is higher than the soil salinity the year before (May 2000). The large amount of winter precipitation during the winter of 2001/2002 leaches the accumulated salts a lot quicker and also to a much lower level (similar to the level of May 2000).

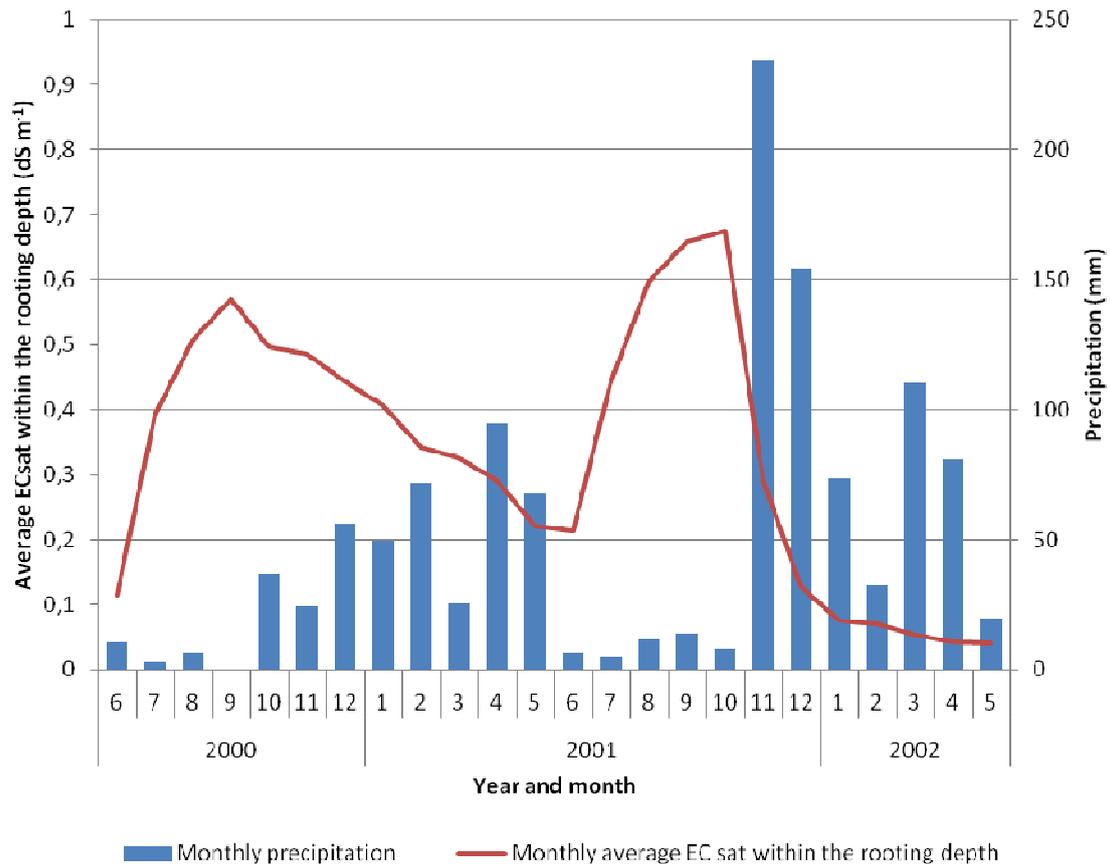


Figure 7: Monthly average soil salinity within the rooting depth (expressed as EC_{sat}) and monthly precipitation for 2000 to 2002

The water and solute balances of the hydrological years 2000/2001 and 2001/2002 are shown in Table 8 and 9. It can be seen that in both years the irrigation water input (and therefore the salt input) is similar. The precipitation in 2001/2002 is a lot higher than in 2000/2001. We can therefore see that the flux to the groundwater is also a lot higher in 2001/2002 and the associated amount of leached salts as well.

Table 8: Water balance for the hydrological years 2000/2001 and 2001/2002 (100% of crop water requirements)

Input (cm)		Output (cm)	
2000/2001			
Precipitation	39.6	Runoff	0
Irrigation	51.8	Interception	0.7
Change in storage	2.9	Evaporation	31.4
		Transpiration	55.2
		Flux to groundwater	7.0
Total	94.3	Total	94.3
2001/2002			
Precipitation	79.9	Runoff	2.9
Irrigation	50.9	Interception	1.0
Change in storage	-2.5	Evaporation	31.3
		Transpiration	56.4
		Flux to groundwater	36.7
Total	128.3	Total	128.3

Table 9: Solute balance for the hydrological years 2000/2001 and 2001/2002 (100% of crop water requirements)

year	Flux top (mg cm ⁻²)	Flux bottom (mg cm ⁻²)	Change in storage (mg cm ⁻²)
2000/2001	13.1	-2.5	11.6
2001/2002	13.3	-12.5	0.8

Figure 8 shows plots of winter rainfall versus soil salinity at the end of winter, winter rainfall versus soil salinity at the end of summer and of summer rainfall versus soil salinity at the end of summer. It can be seen that there is a clear (slightly exponential) relation between winter precipitation and soil salinity after winter and after the following summer. Especially when winter rainfall is below 400mm is there insufficient leaching and a risk of excessive salt accumulation the summer afterwards. Only if this happens two or more winters in a row is there a chance that salinity thresholds for certain crops are reached. The relation between summer rainfall and the soil salinity after summer can be seen to be a lot weaker.

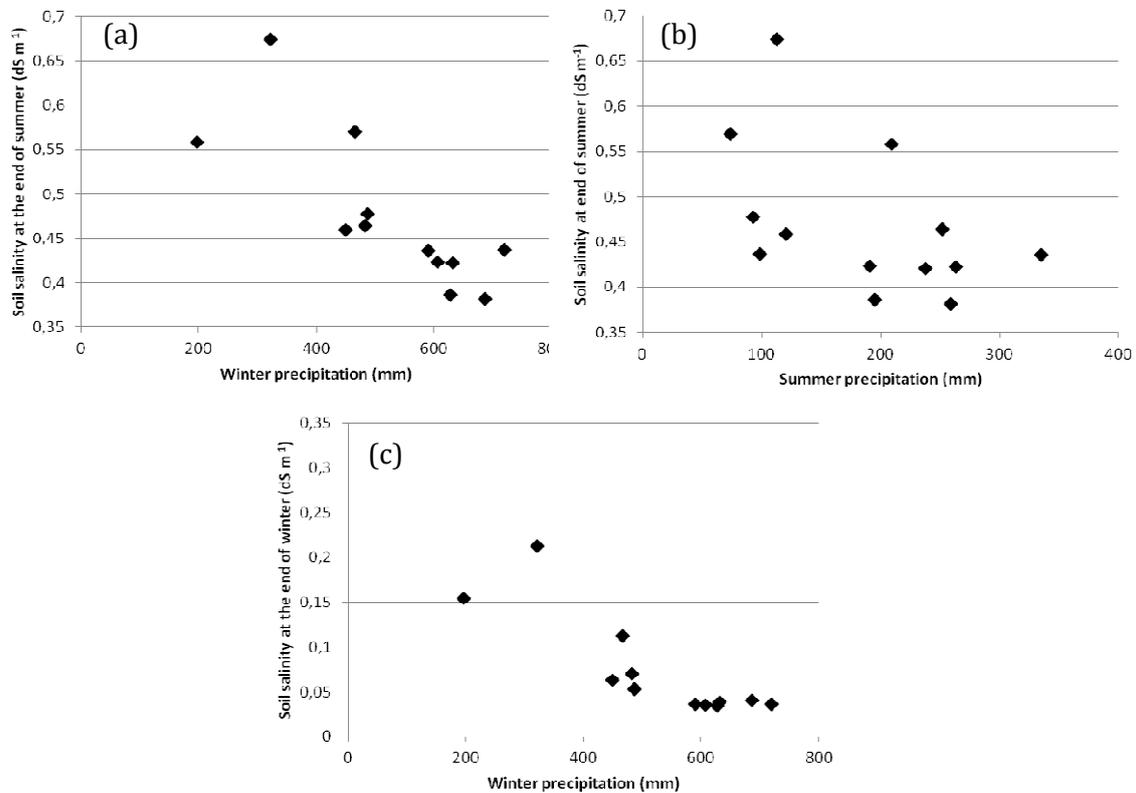


Figure 8: Plots showing (a) winter precipitation versus soil salinity at the end of winter, (b) winter precipitation versus the soil salinity at the end of summer, and (c) summer precipitation versus soil salinity at the end of summer

These observations are emphasized by the correlation coefficients which are shown in Table 8. It can be seen that the correlation coefficient of winter rainfall versus soil salinity after winter and that of winter rainfall versus soil salinity after the next summer are indeed high. Subsequently the correlation coefficient of soil salinity during winter versus soil salinity during the next summer is also high.

Table 8: Correlation coefficients between rainfall and soil salinity

	Correlation coefficient
Winter rainfall versus soil salinity at the end of winter	-0.84
Summer rainfall versus soil salinity at the end summer	-0.49
Winter rainfall versus soil salinity at the end of summer	-0.80
Soil salinity during winter versus soil salinity during next summer	0.96
Soil salinity during summer versus soil salinity during next winter	0.20

Summer rainfall seems to have very little effect on the average soil salinity within the rooting depth – even though little summer rainfall means more irrigation is needed so that the input of salts is larger. Apparently the leaching effect of rainfall is much more important in defining the soil salinity than the input of salts through irrigation water.

It is also interesting to note that there is no correlation between the soil salinity during summer/growing-season and the soil salinity during next winter. This can be very clearly seen in the winter of 2001/2002 during which the highest salt concentration that occurred within these 12 years was leached to the same extent as in most other years. Apparently it cannot be said that larger salt concentrations take longer/are harder to leach. Looking at the modelled process this is quite logical. The processes having the largest effect on solute flux is convection – which is directly proportional to the solute concentration. This means a higher solute concentration also leads to faster leaching.

3.2.2 Meeting 80% of crop water requirements

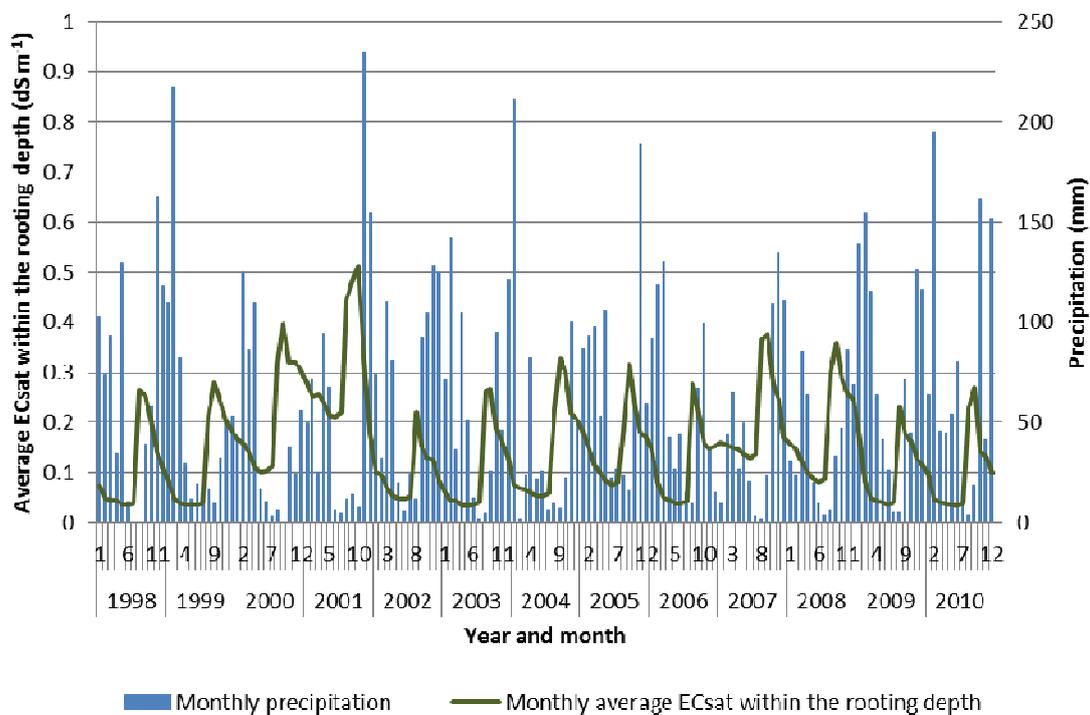


Figure 7: Monthly average soil salinity within the rooting zone (expressed as EC_{sat}) and monthly precipitation

Figure 7 shows the measured precipitation and the modelled average soil salinity when only 80% of the crop water requirements are met. The same general pattern can be observed as before and again no increasing or decreasing trend can be seen from 1998 to 2010. The soil salinity after winter still varies between 0.05dS m^{-1} and 0.20dS m^{-1} is therefore not affected by a decrease in irrigation. The average soil salinity after the growing season has however decreased with a value of 1.5dS m^{-1} and now varies between 0.25dS m^{-1} and 0.5dS m^{-1} .

Figure 8 shows the soil salinity as function of depth for October 2001, the month and year during which the maximum EC_{sat} was found. Comparing this with Figure 5 shows us, that as expected, the total salinity has decreased significantly due to the decrease in supplied salts through irrigation. The maximum soil salinity now has a value of only 1.51dS m^{-1} . The figure also shows us that due to the decrease in irrigation water, the salinity front moves down the soil profile slower and therefore more salts have accumulated higher up in the soil profile.

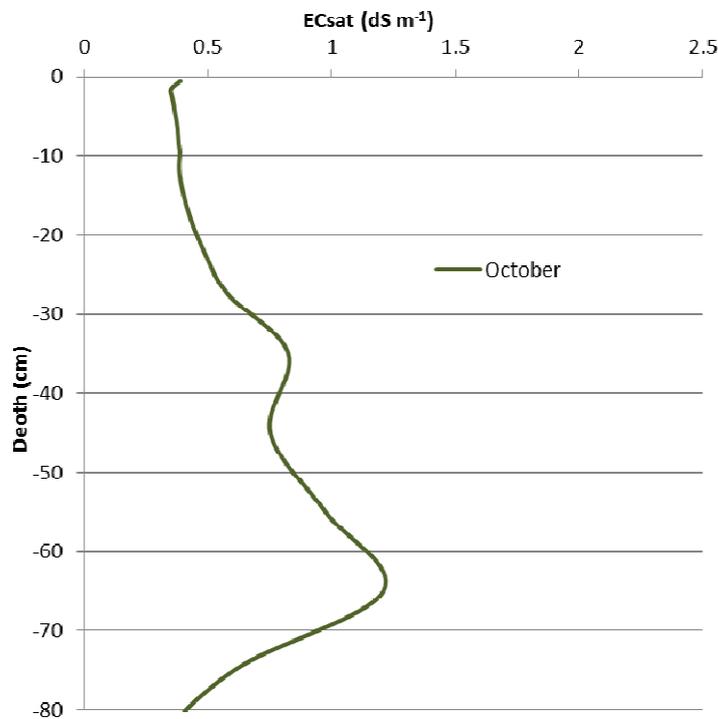


Figure 8: Soil salinity (expressed as EC_{sat}) as function of depth, October 2001

Intuitively the decrease in soil salinity during summer might seem strange as a decrease in irrigation usually leads to a decrease in leaching water and therefore to an increase in the soil salinity. In this case however the drip irrigation schedule was setup in such a way that as little irrigation water is lost through percolation as possible (see section 2.3.6). The amount of percolation during the growing season was therefore already very small when 100% of the crop water requirements were being met. Supplying less water (only 80% of the crop water requirements) therefore does not cause a significant change to the amount of percolation during the growing season. The main effect of the decreased supply in irrigation water is therefore decreased supply of salts and therefore a decreased salt accumulation.

The water and solute balances of the hydrological years 2000/2001 and 2001/2002 when 80% of the crop water requirements are met are shown in Tables 9 and 10. It can be seen that for both hydrological years, the irrigation input has decreased from around

50cm to 20cm (compared to when 100% of the crop water requirements were met). In both hydrological years this has led to a decrease in percolation. In 2001/2002 for example, percolation decreased from around 37cm to around 21cm (compared to when 100% of the crop water requirements were met). In terms of solute flux this means a decreased input of around 8mg cm⁻² both years while the bottom outflow has only decreased by around 3mg cm⁻² in 2000/2001 and by around 5mg cm⁻² in 2001/2002. This clearly explains the increase in soil salinity when only 80% of the crop water requirements are met.

Table 9: Water balance for the hydrological years 2000/2001 and 2001/2002 (80% of crop water requirements)

Input (cm)		Output (cm)	
2000/2001			
Precipitation	39.6	Runoff	0
Irrigation	20.8	Interception	0.7
Change in storage	10.8	Evaporation	25.6
		Transpiration	42.9
		Flux to groundwater	2.0
Total	71.2	Total	71.2
2001/2002			
Precipitation	79.9	Runoff	1.1
Irrigation	22.4	Interception	1.0
Change in storage	-6.6	Evaporation	29.2
		Transpiration	43.9
		Flux to groundwater	20.5
Total	95.7	Total	95.7

Table 10: Solute balance for the hydrological years 2000/2001 and 2001/2002 (80% of crop water requirements)

year	Flux top (mg cm ⁻²)	Flux bottom (mg cm ⁻²)	Change in storage (mg cm ⁻²)
2000/2001	5.5	0.6	4.9
2001/2002	6.3	-8.3	-2.0

3.3 Irrigation water salinity threshold

It was found that for the soil salinity threshold of cotton to be reached, the irrigation water salinity had to be 1.38dS m⁻¹ when crop water requirements are met and 2.76dS m⁻¹ when only 80% of the crop water requirements are met.

4. Discussions

Because SWAP is a one-dimensional model, what has actually been modelled is the lateral average salt concentration as function of depth. SWAP assumes the whole field surface is wetted equally so that water and solutes only flow vertically. In actual fact irrigation water and the salts are only applied at the dripper meaning the water and salts will flow vertically and laterally – two dimensional. Salt will accumulate on the borders of the wetting pattern (away from the root zone) and therefore there is lateral variation.

For this reason, the conclusion that the soil salinity threshold for cotton (7.7dS m^{-1}) has not been reached anywhere does not necessarily hold true. In actual fact the concentration in the rooting zone itself is lower than the results say and the concentration at the borders of the wetting pattern is higher. The concentration at the borders of the rooting wetting pattern may therefore exceed the threshold of 7.7dS m^{-1} .

Figure 11 shows the difference between the actual and modelled situation.

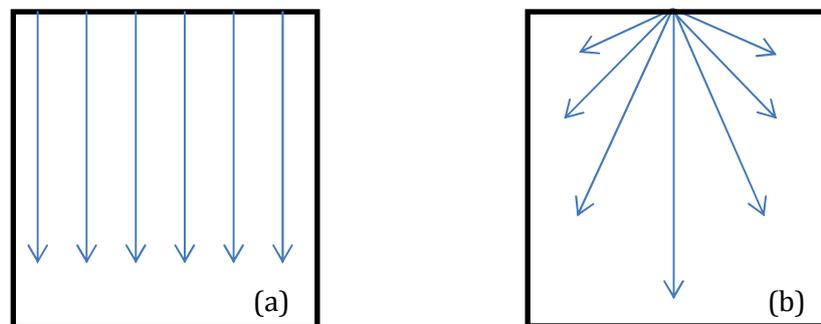


Figure 11: (a) modelled water and solute movement, (b) actual water and solute movement

In the rainy winter period afterwards however, the rain does fall evenly on the whole field meaning the water and solute movement can be seen as one-dimensional. Furthermore, since the most important modelled process is convection (which is directly proportional to the solute concentration); a rainfall event will vertically move down a certain salt concentration by a same distance whether that salt concentration is large or small. Therefore, the modelled salt concentrations at the end of the winter are accurate and we can still conclude that the amount of rainfall in the SRB is sufficient to leach out the salts accumulating during the growing seasons.

Another consequence of the two dimensional water movement is a phenomena known as “localized leaching” (Hanson et al., 2009). As the water flux is concentrated exactly beneath the dripper, the downward flux of water (and therefore also of solutes) is larger exactly beneath the dripper than further away. Therefore, when the laterally averaged flux is modelled (as we did) the results might indicate that there is no leaching while in actual fact, due to the localized leaching effect there is. However, as this localised leaching would only reduce the actual salt concentration in the soil, it does not harm our conclusion that the soil salinity threshold for cotton has not been reached.

A limitation in this study is the missing knowledge in regard to the composition of the salts in the irrigation water. For this reason, an average composition was assumed to convert the salt concentrations into values of electrical conductivity. Moreover, due to the unknown composition we only looked at the danger of soluble salts (leading to a

decrease in the osmotic potential and therefore to water stress). Problems related to the excessive presence of certain minerals were not taken into account. One such problem is sodification (adsorption of an excess of sodium ions in comparison to magnesium and calcium ions). The fact that quite some salts are added to the soil in the irrigation season and that leaching in the rainy season does not solve sodification means the risk in the Gediz basin is considerable.

As it was not possible to collect primary data in the study area itself, the reliability and accuracy of the data used as input for the model is also a concern. The daily precipitation data from the TRMM was shown to have a significant random error and the daily evapotranspiration data is calculated from monthly (not daily) temperature data from a station 100km away. LAI and rooting depth values for cotton have been taken from another case study (Sirsa, India) so also these might not hold true for the Gediz system in Turkey. The parameters for the Mualem-Van Genuchten relations have been obtained using the Staring series (Wosten et al., 1994) which has been collected for Dutch soils. Therefore the conditions for Turkish soils could be different. Lastly the salt concentration in the groundwater was taken to be the concentration of water leached in the previous twelve years. This however depends on the flow of this groundwater. In a fast flowing groundwater system, this leached water will quickly be replaced by water from upstream and this assumption might therefore not hold true.

Finally, the soil salinity in the SRB has only been modelled using rainfall data from 1998 to 2010. Even though we can test the effect of decreased irrigation amounts and increased irrigation water salinity, we do not know what climate will do in the future and therefore we could not test this. The projections for the Gediz basin are a temperature increase in summer and winter and a precipitation decrease in all months but especially spring and autumn (Ozkul, 2009). Soil salinity will therefore probably rise in future and if rainfall will remain sufficient to leach the salts which accumulate during the growing seasons is unknown.

5. Conclusion

Assuming climatic conditions and river water salinity will not dramatically change in the future, the following conclusions can be drawn for cotton in the SRB:

- A change to drip irrigation without leaching will not lead to exceedance of the soil salinity threshold for cotton within the rooting zone whether 100% or 80% of the crop water requirements are met.
- A change to drip irrigation without leaching will not lead to long-term accumulation of salts whether 100% or 80% of the crop water requirements are met. Field wide water application through e.g. sprinkler or basin irrigation for leaching will therefore not be necessary.
- Supplying less irrigation water (80% of the crop water requirements instead of 100%) decreases the salt accumulation during the growing season because the input of salts decreases while percolation stays roughly the same.
- There is a large dependency between winter rainfall and soil salinity after winter and also after the subsequent summer/irrigation-season.
- Especially when winter rainfall is below 400mm is there insufficient leaching and a risk of excessive salt accumulation the summer afterwards
- Summer rainfall does not have much influence on the soil salinity.
- Assuming crop water requirements will continue to be met, in order for the soil salinity threshold to be reached, the salt concentration of the irrigation water would have to reach a value of around 1.38dS m^{-1} .
- Assuming only 80% of the crop water requirements will continue to be met, in order for the soil salinity threshold to be reached, the salt concentration of the irrigation water would have to reach a value of around 2.76dS m^{-1} .

6. Recommendations for further research

Regarding irrigation induced salinity in the Gediz Basin, there is still a lot to of research that can be conducted. A few important remaining questions and research possibilities are given below:

- What is the composition of salts in the ground- and river water? Using this knowledge, the risk of sodification and crop toxification by other chemicals can be analysed.
- What is the groundwater system like? Understanding this will allow us to predict how the salt concentration of this groundwater will react to irrigation and drainage on the surface.
- What is the salinity risk in other irrigation systems in the Gediz basin? The situation in the Gediz basin is not the same everywhere: the salt concentration of the river and groundwater increase as one gets closer to the ocean (Kumru, 2001) and soil properties also show variations.
- How is the salt distributed within the soil? A two dimensional model such as HYDRUS might be able to provide us this information.
- How will climate change affect the soil salinity?
- Cotton is quite a salt tolerant crop. How are other crops which are grown in the area affected by soil salinization?

7. Annex

Annex 1: Table giving a summary of the used parameters and their sources

Section	Parameter	Value	Unit	Parameter explanation	Source
Ponding, runoff and runoff	PONDMX	2.0	cm	In case of ponding, minimum thickness for runoff	Estimation
	RSRO	0.5	d	Drainage resistance for surface runoff	Default
	RSROEXP	1.0	-	Exponent in drainage equation of surface runoff	Default
Soil evaporation (reduction To max. Darcy flux and to max. Black)	CFBS	1.0	-	Coefficient to derive E _{pot} from E _{Tref}	Default
	COFRED	0.35	Cm ⁻² d ⁻³	Soil evaporation coefficient of Black	Default
	RSIGNI	0.5	Cm d ⁻¹	Minimum rainfall to reset method of Black	Default
Soil hydraulic functions	ORES	0.00	-	Residual water content	(FAO et al., 2009)
	OSAT	0.43	-	Saturated water content	
	ALFA	0.0065	cm ⁻¹	Shape parameter alfa of main drying curve	
	NPAR	1.325	-	Shape parameter n	
	KSAT	1.54	cm d ⁻¹	Saturated vertical hydraulic conductivity (fitted in unsaturated exp.)	
	LEXP	-2.161	-	Exponent in hydraulic conductivity function	
	ALFAW	0.013	cm ⁻¹	Alfa parameter of main wetting curve in case of hysteresis	
	H_ENPR	0	cm	Air entry pressure head	
	KSATEXM	5	cm d ⁻¹	Saturated vertical hydraulic conductivity (real value)	
	ORES2	0.01	-	Residual water content	
	OSAT2	0.48	-	Saturated water content	
	ALFA2	0.0097	cm ⁻¹	Shape parameter alfa of main drying curve	
	NPAR	1.257	-	Shape parameter n	
	KSAT2	2.12	cm d ⁻¹	Saturated vertical hydraulic conductivity (fitted in unsaturated exp.)	
	LEXP2	-2.879	-	Exponent in hydraulic conductivity function	
	ALFAW2	0.0194	cm ⁻¹	Alfa parameter of main wetting curve in case of hysteresis	
	H_ENPR2	0	cm	Air entry pressure head	
	KSATEXM2	5	cm d ⁻¹	Saturated vertical hydraulic conductivity (real value)	
Rooting depth	RDS	80	cm	Maximum rooting depth allowed by the soil profile	(Droogers et al., 2000)
Bottom boundary condition (calculating Bottom)	SWBOTB-3RESVERT	1		Suppress vertical hydraulic resistance	Default
	SWBOT-B3IMPL	0		explicit solution	Default
	SHAPE	1.0	-	Shape factor to derive	(Droogers,

flux from hydraulic head of deep aquifer, using a sine function)				average groundwater level	(Bastiaansen et al., 2000)
	HDRAIN	-250.0	cm	Mean drain base to correct for average groundwater level	
	RIMLAY	100.0	d	Vertical resistance of aquitard	
	AQAVE	-250.0	cm	Average hydraulic head in underlying aquifer	
	AQAMP	25.0	cm	Amplitude hydraulic head sinus wave	
	AQTMAX	1.0	d	First time of the year with maximum hydraulic head	
	AQPER	365.0	d	Period hydraulic head sinus wave	
Solute section	CPRE	0.01	mg cm ⁻³	Solute concentration in precipitation	(Suttar, 1990)
	LDIS	6	cm	dispersion length	(Vanderborght and Vereecken, 2007)
	BDENS	1400	mg cm ⁻³	dry soil bulk density	(FAO et al., 2009)
	LDIS2	6	cm	dispersion length	(Vanderborght and Vereecken, 2007)
	BDENS2	1400	mg cm ⁻³	dry soil bulk density	(FAO et al., 2009)
	CDRAIN	0.4	mg cm ⁻³	solute concentration in groundwater	Previous simulation
Crop development	LCC	180	d	Length of the crop cycle	(Droogers et al., 2000)
Light extinction	KDIF	0.60	-	Extinction coefficient for diffuse visible light	(Dam and Malik, 2003)
	KDIR	0.75	-	Extinction coefficient for direct visible light	
Soil water extraction by plant roots	HLIM1	-1.0	cm	No water extraction at higher pressure heads	(Dam and Malik, 2003)
	HLIM2U	-22.9	cm	h below which optimum water extr. starts for top layer	
	HLIM2L	-22.9	cm	h below which optimum water extr. starts for sub layer	
	HLIM3H	-1200.0	cm	h below which water uptake red. starts at high Tpot	
	HLIM3L	-7500.0	cm	h below which water uptake red. starts at low Tpot	
	HLIM4	-16000.0	cm	No water extraction at lower pressure heads	
	ADCRH	1.0	cm	Level of high atmospheric demand	
	ADCRL	0.2	cm	Level of low atmospheric demand	
Salt stress	ECMAX	7.7	dS m ⁻¹	ECsat level at which salt stress starts	(Dam and Malik, 2003)
	ECSLOP	5.4	dS m ⁻¹	Decline of root water uptake above ECMAX	
	C2ECa	1.492	-	coefficient a to convert concentration to EC	Default

	C2ECb	1.0	-	exponent b to convert concentration to EC	
	C2ECf	1.0	-	factor f to convert concentration to EC	
Interception	COFAB	0.25	cm	Interception coefficient Von Hoyningen-Hune and Braden	Default
Irrigation	CIRRS	0.645	mg cm ⁻³	Solute concentration of scheduled irrig. water	(Kumru, 2001)
	phField-capacity	-100.0	cm	Pressure head at field capacity	Default
LAI	DVS 0.56	0.5	-	LAI as function of development stage	(Dam and Malik, 2003)
	DVS 0.89	1.5			
	DVS 1.22	4.1			
	DVS 1.56	5.2			
	DVS 2.00	4.0			
Rooting depth	DVS 0.56	40.0	cm	Rooting depth as function of development stage	(Dam and Malik, 2003)
	DVS 0.89	75.0			
	DVS 1.22	80.0			
	DVS 1.56	80.0			
	DVS 2.00	80.0			
Crop coefficients	DVS 0.33	0.33	-	Crop coefficient as function of rooting depth	(Allen et al., 1998)
	DVS 0.61	0.775			
	DVS 0.89	1.20			
	DVS 1.50	1.20			
	DVS 1.75	0.90			
	DVS 2.00	0.60			

Annex 2: Tables showing input temperature data (Source: The Global Historical Climatology Network-Monthly temperature dataset, version 3)

Month	Minimum monthly temperature per year (°C)													
	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Jan	8.5	9.5	2.0	10.2	5.9	9.8	5.0	8.7	5.1	8.8	6.7	7.8	8.3	7.9
Feb	10.6	7.0	6.5	9.2	13.6	3.5	7.5	6.3	7.2	9.0	8.4	6.8	9.9	9.6
Mar	8.7	12.5	10.7	17.7	14.0	9.6	13.7	11.8	11.6	13.2	14.3	10.1	14.0	12.4
Apr	18.9	15.6	17.9	16.5	15.1	14.7	16.9	16.6	18.0	15.4	17.4	16.8	17.9	15.1
May	22.6	21.1	25.4	21.5	22.7	25.2	21.3	22.3	21.8	25.3	21.8	21.9	23.2	20.6
Jun	26.7	26.3	27.6	29.0	27.5	28.5	26.6	25.5	26.8	28.8	28.4	27.9	26.0	25.9
Jul	32.0	31.7	33.1	33.4	30.9	30.5	30.8	30.7	30.1	33.1	31.7	30.5	31.5	31.9
Aug	33.0	31.1	30.8	32.4	29.4	32.2	29.5	31.1	33.2	32.2	33.5	30.4	34.5	31.0
Sep	25.9	25.6	26.7	27.2	23.8	25.3	27.6	25.2	25.8	27.1	25.9	24.6	27.9	28.9
Oct	22.5	21.8	19.9	22.1	19.9	20.9	22.2	18.1	19.9	21.4	19.4	22.2	17.6	17.6
Nov	14.9	14.9	18.3	12.1	16.4	15.3	13.6	11.4	13.3	12.7	15.4	14.4	19.0	-
Dec	8.5	12.0	9.1	6.1	6.3	8.7	9.2	9.5	10.1	8.1	6.2	10.3	11.3	-

Month	Minimum temperature per year (°C)													
	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Jan	-1.0	0.0	-5.9	0.4	-3.0	3.3	-1.9	0.2	-2.8	-1.4	-3.2	-0.1	0.7	-0.7
Feb	-0.2	-0.5	-2.2	0.1	1.1	-3.2	-1.8	-1.1	-1.0	-0.1	-1.9	0.7	1.9	0.1
Mar	-1.1	1.4	-1.2	5.5	3.6	-1.1	1.3	1.2	2.1	2.0	3.5	0.5	3.1	1.3
Apr	6.8	4.7	7.4	6.0	5.8	4.0	5.4	5.1	6.8	3.8	5.9	5.7	5.8	4.4
May	11.4	9.1	11.9	9.4	9.0	11.3	8.4	9.5	8.8	11.7	8.1	8.9	9.4	8.3
Jun	12.7	13.3	12.7	13.3	13.6	14.0	12.6	12.1	12.5	14.1	14.0	13.6	13.7	11.9
Jul	16.5	16.8	16.5	17.8	17.0	15.5	15.9	16.0	15.4	17.7	15.8	16.7	17.1	16.2
Aug	18.0	17.0	16.0	17.9	16.0	16.6	14.7	16.4	14.0	17.4	17.6	15.6	19.0	16.1
Sep	11.9	11.1	11.2	11.8	12.0	11.4	12.2	11.0	12.2	12.3	2.5	11.5	13.2	13.4
Oct	8.6	9.0	7.3	7.7	8.1	8.2	9.2	6.6	8.6	9.3	7.9	9.8	7.4	5.7
Nov	5.3	3.2	4.3	3.7	4.2	4.2	3.5	2.5	2.3	4.2	4.9	3.2	6.9	-
Dec	1.5	2.6	-0.6	0.3	-0.9	0.8	0.6	0.8	-0.6	-0.4	-1.8	2.7	2.9	-

Annex 3: Table showing input precipitation data (Source: Tropical Rainfall Measuring Mission Multi-satellite Precipitation Analysis version 6)

Date	Precipitation per year (mm)												
	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
01-01	0.00	0.00	6.24	0.00	29.35	31.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00
02-01	0.00	0.00	11.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.73	0.00	0.00
03-01	5.17	31.11	0.00	0.00	0.00	0.00	5.78	0.00	0.00	1.32	0.00	4.08	0.00
04-01	0.00	7.72	0.00	0.00	26.40	0.00	8.09	0.00	0.00	0.00	0.00	11.88	0.00
05-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.52	0.00	0.00	12.06	0.00
06-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	34.14	0.00
07-01	0.00	0.00	0.00	0.00	4.14	0.00	0.00	0.00	7.48	0.00	0.00	0.00	0.00
08-01	0.00	0.00	0.00	0.00	1.78	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
09-01	0.00	0.00	0.00	0.00	10.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.38	0.00	0.00	0.00
11-01	0.00	7.93	0.00	0.00	1.61	11.64	23.19	2.07	0.00	0.00	0.00	0.00	0.00
12-01	0.00	8.74	0.00	0.00	0.00	10.74	0.00	1.06	0.00	0.00	3.50	0.00	0.00
13-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.86	0.00	0.00	0.00	0.00	0.00
14-01	0.00	0.00	10.38	25.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	23.22	0.00
15-01	0.00	0.00	6.24	7.99	0.00	0.00	0.00	0.00	0.00	0.00	6.42	0.00	0.00
16-01	5.88	0.00	0.00	0.00	0.00	0.00	10.00	0.00	0.00	0.00	0.00	6.90	0.00
17-01	0.00	0.00	2.10	0.00	0.00	0.00	0.00	0.00	0.00	0.39	0.00	0.00	10.68
18-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19-01	0.00	0.00	5.34	0.00	0.00	17.34	0.00	0.00	13.09	0.00	0.00	0.00	0.00
20-01	39.59	0.00	0.00	0.00	0.00	0.00	10.69	0.00	0.00	0.00	10.19	0.00	0.00
21-01	0.00	0.00	0.00	0.00	0.00	0.00	22.36	0.00	0.00	0.00	0.00	0.00	0.00
22-01	29.22	0.00	0.00	0.00	0.00	0.00	20.62	25.77	0.00	0.00	0.00	0.00	42.30
23-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.47	0.00	32.64	0.00
24-01	0.00	0.00	0.00	0.00	0.00	0.00	3.47	0.00	8.56	0.00	0.00	0.00	0.00
25-01	0.00	0.00	0.00	0.00	0.00	0.00	78.91	16.07	17.94	0.00	0.00	2.40	0.00
26-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.80	0.00	9.06	0.00
27-01	22.77	0.00	0.00	0.00	0.00	0.00	0.00	11.72	0.00	1.70	3.43	2.40	5.76
28-01	0.00	24.89	0.00	0.00	0.00	0.00	0.00	7.16	28.45	1.64	0.00	0.00	0.00
29-01	0.00	29.56	0.00	0.00	0.00	0.00	28.03	16.07	0.00	2.26	0.00	0.00	0.00
30-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.83	0.00	0.00	0.00	0.00
31-01	0.00	0.00	0.00	16.15	0.00	0.00	0.00	5.41	0.00	0.00	3.86	0.00	5.10
01-02	2.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	57.70	0.00	0.00	0.00	0.00
02-02	26.94	0.00	0.00	26.47	0.00	14.50	0.00	22.56	0.00	2.53	1.28	0.00	19.02
03-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.42	0.00	0.00	0.00	0.00	0.00
04-02	2.40	0.00	5.82	0.00	0.00	0.00	0.00	0.00	14.42	0.00	1.28	0.00	0.00
05-02	38.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.64	0.00	0.00
06-02	2.40	0.83	0.00	0.00	0.00	0.00	0.00	0.00	12.85	4.91	0.00	0.00	1.75
07-02	0.00	107.72	0.00	0.00	0.00	97.86	0.00	0.00	8.69	8.90	0.00	0.00	0.00
08-02	0.00	6.16	0.00	0.00	0.00	0.00	0.00	0.00	3.45	0.96	0.00	2.26	5.03
09-02	0.00	8.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.72	0.00	0.00	0.00
10-02	0.00	0.00	0.00	0.00	3.41	0.00	0.00	0.00	0.00	2.68	2.25	0.00	53.54
11-02	0.00	0.00	0.00	0.00	0.00	8.73	0.00	0.00	0.00	1.62	0.00	43.25	0.00
12-02	0.00	12.21	0.00	0.00	0.00	8.49	0.00	0.00	0.00	6.27	0.00	25.90	0.00
13-02	1.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	34.21	17.74
14-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.97	0.00	5.99	0.00
15-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.87	3.40	0.00	0.00
16-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.58	0.00	0.00
17-02	0.00	76.68	0.00	0.00	0.00	13.03	0.00	3.54	0.00	1.97	0.00	0.00	0.00
18-02	0.00	3.21	117.48	0.00	0.00	0.00	0.00	7.86	0.00	0.00	0.00	0.00	0.00
19-02	0.00	0.00	0.69	0.00	0.00	0.00	0.00	10.26	0.00	0.00	0.00	10.86	31.68

20-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	42.35
21-02	0.00	1.72	0.69	0.00	0.00	0.00	0.00	0.00	2.79	0.00	0.00	0.00	5.17
22-02	0.00	0.00	0.00	23.68	0.00	0.00	0.00	0.00	3.25	0.00	0.00	0.00	0.00
23-02	0.00	0.00	0.00	0.00	28.89	0.00	0.00	0.00	0.00	7.18	0.00	0.00	0.00
24-02	0.00	0.83	0.00	0.00	0.00	0.00	0.00	0.00	6.40	0.00	1.63	0.00	0.00
25-02	0.00	0.00	0.00	21.71	0.00	0.00	0.00	0.00	0.00	1.01	3.96	25.27	3.13
26-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.54	0.00	0.00	0.00	6.45	0.00
27-02	0.00	0.00	0.00	0.00	0.00	0.00	1.80	9.06	0.00	0.00	0.71	0.00	15.41
28-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.09	0.00	0.00	0.00	0.00
29-02	-	-	0.00	-	-	-	0.00	-	-	-	0.64	-	-
01-03	0.00	0.00	0.00	0.00	0.71	0.00	0.00	10.00	0.00	0.00	0.00	1.78	0.00
02-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.40	0.00	1.13	1.78	0.90
03-03	0.00	0.00	3.66	0.00	1.00	0.00	0.00	0.00	1.98	0.00	0.00	2.88	0.00
04-03	0.00	0.00	0.00	0.00	1.13	9.39	3.08	0.00	1.98	0.00	0.00	6.04	0.00
05-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.99	2.41	0.00	1.04	4.76	0.00
06-03	0.00	0.00	0.00	0.00	0.87	0.00	0.00	30.27	0.00	0.47	0.00	54.50	0.00
07-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.93	1.20	9.74	10.78
08-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.34	5.05
09-03	4.03	0.00	0.00	0.00	0.00	0.00	1.37	4.11	0.00	0.00	0.00	0.00	1.58
10-03	2.09	0.00	0.00	0.00	0.00	0.00	1.56	0.00	0.00	4.51	0.00	0.00	0.00
11-03	0.00	0.00	0.00	0.00	41.40	0.00	0.00	1.36	54.71	2.50	0.00	0.00	0.00
12-03	0.00	0.00	0.00	0.00	4.44	0.00	0.00	0.00	2.21	0.00	1.13	0.00	0.00
13-03	0.00	0.00	0.00	0.00	0.00	0.71	0.00	0.00	2.21	1.54	0.00	0.00	0.00
14-03	0.00	0.00	0.00	16.56	0.00	0.00	0.00	0.00	33.91	0.00	5.97	0.00	0.96
15-03	5.72	0.00	0.00	0.00	0.00	0.00	1.17	1.29	0.00	0.93	0.31	0.00	0.00
16-03	4.34	0.00	0.00	0.00	0.58	0.00	0.00	1.69	0.00	1.57	1.11	0.00	0.00
17-03	0.00	0.00	29.64	0.00	0.00	14.84	0.00	1.29	0.00	1.69	0.00	0.00	1.97
18-03	0.00	45.96	0.00	0.00	3.58	0.00	0.00	1.06	5.86	0.00	3.90	1.51	3.90
19-03	0.00	0.00	0.00	0.00	0.00	0.00	0.44	0.00	0.00	2.94	4.94	0.00	1.42
20-03	0.00	0.00	0.00	0.00	14.84	1.08	0.00	0.00	0.00	0.96	20.82	0.00	1.72
21-03	0.00	0.00	0.00	0.00	0.00	1.08	2.93	0.00	0.00	1.60	23.59	9.97	1.20
22-03	0.00	0.00	0.00	0.00	0.00	2.26	0.59	2.85	0.00	13.99	0.00	0.00	1.28
23-03	0.00	0.00	0.00	5.38	31.11	1.08	0.00	2.12	8.96	6.57	0.93	0.00	1.39
24-03	0.00	14.91	0.00	0.00	1.78	1.46	0.00	0.86	0.00	1.08	0.62	3.06	1.39
25-03	5.96	0.00	0.00	0.00	0.00	0.67	0.64	0.86	0.00	1.08	3.30	9.92	0.00
26-03	71.20	0.00	0.00	0.00	0.00	0.00	1.86	0.00	1.20	0.00	0.00	0.00	1.37
27-03	0.00	14.54	0.00	0.00	0.00	1.57	7.72	0.00	1.98	0.00	14.52	0.00	2.38
28-03	0.00	4.35	0.00	0.00	0.00	0.52	1.03	0.00	6.25	1.48	0.56	2.29	1.31
29-03	0.00	2.62	53.29	3.34	0.00	0.54	0.88	14.34	0.00	1.05	0.00	3.06	0.00
30-03	0.00	0.00	0.00	0.00	0.00	0.00	0.98	0.00	0.00	0.64	0.00	0.00	2.18
31-03	0.00	0.00	0.00	0.00	8.84	1.01	0.00	19.38	0.00	19.90	0.42	0.00	4.53
01-04	0.00	0.00	2.73	7.08	0.00	9.92	14.65	0.00	1.32	0.00	0.00	0.00	1.10
02-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.20	1.07	7.86	1.00
03-04	0.00	0.00	4.33	0.00	3.97	0.00	0.68	0.00	0.00	0.85	1.26	0.00	1.21
04-04	0.00	1.72	1.27	0.00	0.00	0.00	0.79	0.40	3.16	4.07	6.71	0.75	0.00
05-04	0.00	0.00	16.21	0.00	0.00	1.85	0.53	0.00	0.00	4.27	3.85	8.17	0.00
06-04	0.00	0.00	2.00	0.00	0.00	0.00	0.58	0.35	10.07	0.48	3.54	9.71	5.11
07-04	0.00	0.00	2.73	0.00	0.00	0.00	1.08	5.77	0.00	0.33	1.56	0.00	0.82
08-04	0.00	0.00	0.00	0.00	0.00	0.00	0.78	6.74	4.44	0.00	0.65	0.00	0.00
09-04	0.00	2.00	1.27	0.00	0.00	0.00	0.58	0.48	0.00	0.46	5.06	0.88	0.00
10-04	15.19	0.00	10.62	0.00	0.00	0.00	0.36	0.57	0.54	0.00	4.22	0.00	0.00
11-04	0.58	3.68	0.00	0.00	0.00	5.44	0.41	1.04	0.35	4.09	0.00	2.98	4.70
12-04	0.00	1.47	0.00	0.00	1.80	0.00	4.68	1.87	1.61	0.00	1.77	0.75	1.31
13-04	0.00	0.00	7.38	19.25	4.13	4.38	4.37	0.64	0.63	0.73	1.10	0.75	0.00

14-04	9.61	0.00	0.00	4.00	0.00	0.00	0.88	10.73	1.11	0.56	0.70	8.83	2.42
15-04	0.00	0.00	0.00	0.00	21.96	0.00	0.00	12.20	1.61	0.00	0.00	2.53	0.00
16-04	0.00	0.00	9.27	0.00	12.54	0.00	0.00	0.64	0.00	0.00	2.59	1.12	0.65
17-04	0.00	14.01	13.40	2.58	0.00	19.24	2.27	1.26	0.84	0.00	4.73	1.29	0.00
18-04	0.00	0.00	8.27	4.76	11.85	60.29	11.42	0.55	2.91	0.88	9.19	1.26	0.00
19-04	2.49	0.00	0.00	0.00	0.00	3.09	0.00	0.29	0.35	0.00	0.00	0.37	4.11
20-04	0.00	0.00	0.00	9.84	0.00	0.00	10.92	0.00	0.44	0.40	0.00	1.56	1.28
21-04	0.00	0.00	0.00	10.52	0.00	0.00	4.29	3.13	0.80	0.00	1.56	0.77	2.03
22-04	0.00	0.00	15.20	0.00	0.00	0.00	0.00	1.26	0.00	1.31	2.08	4.14	0.21
23-04	0.00	0.00	4.93	7.82	2.01	0.00	0.00	0.90	1.72	0.49	0.00	0.81	0.00
24-04	0.00	0.00	0.00	0.00	14.55	0.00	0.00	0.00	0.90	1.15	1.38	1.26	2.85
25-04	6.40	4.39	0.00	0.00	2.38	0.00	12.58	0.77	0.41	1.28	1.38	0.00	0.00
26-04	0.00	0.00	10.29	0.00	0.00	0.00	6.20	2.09	1.92	0.81	2.12	1.26	13.49
27-04	0.00	0.00	0.00	0.00	3.70	0.00	4.11	0.20	1.52	0.82	4.97	1.48	0.60
28-04	0.00	2.09	0.00	0.00	1.01	0.00	0.00	0.99	2.40	0.00	2.12	2.12	0.97
29-04	0.00	0.00	0.00	0.00	1.16	0.00	0.00	0.00	2.85	1.23	0.00	0.99	1.14
30-04	0.00	0.00	0.00	28.92	0.00	0.00	0.00	0.00	0.47	1.20	0.00	2.27	0.00
01-05	0.00	0.00	0.00	0.00	0.58	0.00	3.21	0.00	3.86	2.18	0.00	0.65	0.93
02-05	0.00	0.00	4.64	0.00	0.31	0.00	0.97	1.54	0.67	0.00	0.43	15.79	0.68
03-05	20.20	0.00	7.43	0.00	0.22	0.25	1.13	1.52	0.36	0.79	0.00	0.78	1.14
04-05	18.53	0.00	0.00	0.00	0.49	0.32	2.46	2.51	4.14	0.98	1.45	0.98	0.67
05-05	1.90	0.00	0.00	0.00	0.69	0.52	3.04	0.00	0.77	0.36	0.00	1.78	1.56
06-05	0.00	0.00	0.00	11.02	0.00	0.95	0.75	0.00	2.03	0.00	0.00	0.00	9.56
07-05	0.00	0.00	0.00	12.91	0.00	0.79	0.16	4.08	2.62	4.84	0.00	0.98	0.40
08-05	3.55	0.00	0.00	7.57	0.00	0.79	0.18	3.50	0.95	1.71	0.00	0.92	1.49
09-05	30.11	0.00	0.00	0.00	0.00	1.99	0.00	0.95	0.86	0.90	0.00	0.39	1.42
10-05	9.64	0.00	0.00	0.00	0.00	0.77	0.42	0.95	1.09	1.64	0.86	0.00	0.71
11-05	0.00	0.00	0.00	0.00	0.00	0.79	0.00	0.51	0.00	0.36	1.43	1.05	1.11
12-05	2.02	0.00	0.00	36.22	0.00	0.79	0.00	5.72	0.54	0.79	2.02	0.00	0.60
13-05	0.00	0.00	4.46	0.00	9.64	0.90	1.03	3.37	0.12	0.84	0.72	0.53	0.00
14-05	0.00	0.00	0.00	0.00	0.00	0.45	0.11	2.87	0.24	0.79	1.49	0.78	2.81
15-05	0.00	0.00	0.00	0.00	0.00	10.73	0.00	1.52	2.20	0.39	0.00	0.66	14.22
16-05	17.56	0.00	0.00	0.00	0.00	0.26	0.44	3.25	0.00	0.39	0.00	0.53	1.87
17-05	14.36	0.91	0.00	0.00	1.74	0.00	1.60	1.52	0.30	2.99	0.72	0.00	1.11
18-05	0.00	0.16	0.00	0.00	0.00	0.33	3.40	0.00	0.78	2.38	1.74	0.00	4.15
19-05	2.27	0.00	0.00	0.00	0.00	0.00	0.46	7.27	0.65	7.71	1.29	6.15	0.00
20-05	0.00	0.64	0.00	0.00	0.58	0.00	0.54	2.12	0.69	1.26	0.47	3.84	0.00
21-05	0.00	0.00	0.00	0.00	3.74	0.00	0.28	3.13	0.59	0.00	1.15	1.34	3.21
22-05	0.00	0.31	0.00	0.00	0.64	0.00	0.00	0.00	0.57	0.89	0.00	0.51	3.11
23-05	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.00	0.00	2.56	0.00	0.00	0.70
24-05	0.00	9.65	0.00	0.00	0.00	3.55	0.20	1.15	0.25	11.68	0.00	0.00	0.20
25-05	0.00	0.00	0.00	0.00	0.22	1.11	0.32	4.06	0.00	0.00	0.58	1.12	0.40
26-05	9.23	0.00	0.00	0.00	0.82	0.00	0.00	9.84	0.30	3.38	1.14	0.00	0.54
27-05	0.00	0.00	0.00	0.00	0.00	0.00	0.13	4.00	0.00	0.00	1.31	0.53	1.21
28-05	0.00	0.00	0.00	0.00	0.00	1.86	0.14	17.25	0.38	0.00	0.00	0.00	0.60
29-05	0.00	0.00	0.00	0.00	0.00	17.06	0.24	6.30	0.36	0.00	0.00	0.72	0.00
30-05	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.42	0.00	1.56	0.99	0.00
31-05	0.00	0.00	0.00	0.00	0.31	6.75	0.14	16.67	1.07	0.00	1.43	0.26	0.00
01-06	0.00	0.00	0.00	0.64	1.23	1.15	0.00	2.20	0.00	0.00	0.00	0.53	4.41
02-06	0.00	0.00	0.00	0.00	0.00	0.85	0.00	0.00	0.00	0.00	0.43	1.82	2.86
03-06	3.34	0.00	0.00	0.00	0.28	0.00	0.00	0.00	0.36	0.00	0.68	1.40	0.00
04-06	0.00	0.00	0.00	0.00	0.29	0.00	0.00	0.15	2.06	0.48	0.00	0.00	0.00
05-06	0.00	0.00	0.00	0.00	0.17	0.00	0.87	0.00	0.22	3.16	0.00	1.65	1.70
06-06	0.00	0.00	5.76	0.00	0.00	0.19	0.00	0.80	1.33	0.00	0.00	0.84	8.78

07-06	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.30	1.40	1.90	0.00	0.61	12.25
08-06	0.00	0.00	0.00	0.00	1.35	0.00	0.00	1.08	0.00	0.00	0.00	0.38	0.00
09-06	0.00	0.00	0.00	0.00	0.11	7.28	0.57	0.55	17.66	1.21	3.97	1.18	20.72
10-06	3.48	0.00	0.00	0.00	0.22	0.00	0.00	0.47	0.71	3.53	0.00	3.08	0.00
11-06	3.97	0.00	0.00	0.00	0.16	0.00	0.00	8.03	0.00	0.97	0.74	0.38	0.00
12-06	0.00	3.90	0.00	0.81	0.54	0.00	0.43	0.95	0.75	0.86	0.37	1.01	3.57
13-06	0.00	3.97	0.00	0.00	0.09	0.04	0.51	0.60	7.86	0.00	0.55	0.53	1.12
14-06	0.00	5.10	0.00	1.12	0.00	0.04	0.00	0.00	0.71	0.48	0.19	1.22	0.80
15-06	0.00	0.00	0.00	0.00	0.23	0.13	0.43	0.00	0.37	0.00	0.00	1.68	0.00
16-06	0.00	0.00	0.00	0.00	0.22	0.10	0.00	0.25	1.13	0.38	0.63	2.55	0.96
17-06	0.00	0.00	0.00	0.00	0.00	0.70	1.00	0.00	0.50	0.77	0.00	1.66	0.00
18-06	0.00	0.00	0.00	0.00	0.00	0.04	12.36	0.00	0.73	0.00	0.32	0.53	0.00
19-06	0.00	0.00	2.38	0.74	0.19	0.00	0.00	0.70	0.00	0.86	0.37	1.30	2.52
20-06	0.00	0.00	0.00	0.00	0.37	0.11	0.74	0.00	0.30	1.04	0.35	1.44	1.12
21-06	0.00	0.46	0.00	3.19	0.00	0.14	0.00	0.13	0.00	0.00	0.00	0.28	1.45
22-06	0.00	4.55	2.48	0.00	0.00	0.93	0.00	0.68	1.11	0.31	0.00	0.23	2.35
23-06	0.00	1.20	0.00	0.00	0.00	0.00	0.00	1.85	0.90	0.00	0.00	0.41	11.36
24-06	0.00	0.00	0.00	0.00	0.00	0.17	5.72	0.00	0.30	0.00	0.00	0.46	1.31
25-06	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.71	0.40	0.55	0.00	0.00
26-06	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	4.75	0.20	0.00	0.53	0.00
27-06	0.00	0.00	0.00	0.00	0.00	0.00	0.51	0.55	0.00	1.52	0.00	0.00	0.71
28-06	0.00	0.00	0.00	0.00	0.00	0.22	0.00	0.00	0.00	1.26	0.00	0.61	0.96
29-06	0.00	0.00	0.00	0.00	0.00	0.10	1.96	0.00	0.00	0.00	0.00	0.00	0.00
30-06	0.00	0.00	0.00	0.00	0.43	0.14	0.68	2.68	0.30	1.22	0.25	0.00	1.84
01-07	0.00	1.71	0.00	0.00	0.00	0.10	0.27	0.00	0.23	0.12	0.00	0.17	0.53
02-07	0.00	0.00	0.00	0.00	0.00	0.42	0.30	0.00	0.68	0.12	0.29	0.00	0.53
03-07	0.00	0.00	0.00	1.07	0.00	0.12	0.28	1.65	5.84	0.37	0.00	0.00	0.47
04-07	0.00	0.00	0.00	0.00	0.00	0.17	0.11	0.69	0.00	0.36	1.35	0.00	0.91
05-07	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.51	1.29	0.34	0.20	0.00	0.71
06-07	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.78	0.52	0.07	0.00	0.00	0.62
07-07	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.06	0.20	0.00	0.00
08-07	0.00	0.00	0.00	0.00	0.00	0.00	0.35	0.00	0.35	0.00	0.00	0.00	0.00
09-07	0.00	0.00	0.00	0.00	9.69	0.07	0.39	0.27	0.08	0.10	0.00	0.36	0.00
10-07	0.00	0.00	0.00	0.00	1.01	0.00	0.17	1.56	0.12	0.17	0.00	0.00	0.00
11-07	0.00	0.00	0.49	0.00	3.77	0.00	0.20	0.15	0.00	0.13	0.00	0.00	0.18
12-07	0.00	0.00	0.00	2.26	4.69	0.00	0.00	1.11	0.00	0.07	0.00	0.00	0.00
13-07	0.00	0.00	0.82	0.00	0.91	0.11	0.00	0.00	0.00	0.00	0.12	0.00	0.95
14-07	0.00	0.00	0.82	0.00	0.00	0.00	0.58	0.00	0.00	0.00	0.03	2.04	0.44
15-07	0.00	0.00	0.00	0.92	0.00	0.00	0.44	16.07	0.00	0.13	0.12	0.00	0.00
16-07	0.00	0.00	0.00	0.00	0.09	0.00	0.22	0.00	0.00	0.31	0.00	0.00	0.00
17-07	0.00	2.77	0.00	0.74	0.00	0.12	0.52	0.15	0.91	0.00	0.00	0.36	0.00
18-07	0.00	3.87	0.00	0.00	0.00	0.00	0.00	0.00	0.69	0.45	0.23	0.00	0.00
19-07	0.00	0.00	0.00	0.00	0.13	0.11	0.00	0.63	0.00	0.03	0.23	0.36	7.86
20-07	0.00	0.00	0.00	0.00	0.00	0.00	0.47	0.00	0.00	0.00	0.00	0.00	0.18
21-07	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.45	0.00	0.00	0.09	0.24	0.00
22-07	0.00	0.00	0.00	0.00	0.22	0.00	0.80	0.81	0.23	0.00	0.37	0.16	0.00
23-07	0.00	0.00	0.00	0.00	0.11	0.04	0.44	0.30	0.00	0.00	0.00	0.00	0.00
24-07	0.00	0.53	0.00	0.00	0.00	0.36	0.00	0.51	0.35	0.31	0.23	0.17	1.59
25-07	0.00	0.00	0.00	0.00	0.41	0.00	0.00	0.21	0.35	0.09	0.61	0.36	0.00
26-07	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.36	0.19	0.10	0.00	0.33	0.00
27-07	0.00	0.00	0.82	0.00	0.00	0.00	0.42	0.00	0.00	0.00	0.00	0.00	0.00
28-07	0.00	0.00	0.00	0.00	3.25	0.03	0.00	0.36	0.00	0.00	0.00	0.19	0.62
29-07	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.27	0.00	0.00	0.29	0.36	0.53
30-07	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.98	0.00	0.00	0.50	0.00

31-07	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	2.47	0.00	0.00	0.00	0.00
01-08	0.00	0.00	0.00	8.70	0.35	0.00	0.00	0.25	0.30	0.00	0.00	0.14	0.00
02-08	0.00	0.00	0.00	0.00	0.51	0.00	0.00	0.00	0.61	0.00	0.00	0.12	0.00
03-08	0.00	0.00	0.00	0.00	0.51	0.00	0.00	0.20	0.23	0.13	0.00	0.23	0.26
04-08	0.00	0.00	0.00	0.00	0.64	0.00	0.00	0.81	0.41	0.03	0.00	0.30	0.62
05-08	0.00	0.00	0.36	0.00	0.22	0.03	0.37	0.00	0.36	0.10	0.00	0.14	0.40
06-08	0.00	0.00	0.00	1.69	0.28	0.04	0.30	0.00	0.18	0.00	0.33	0.00	0.00
07-08	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.24	0.13	0.07	0.00	0.00	0.00
08-08	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
09-08	0.00	1.57	0.00	0.00	0.00	0.07	0.00	0.00	0.36	0.00	0.00	0.07	0.00
10-08	0.00	0.93	0.00	0.00	0.00	0.36	0.00	0.00	0.49	0.00	0.00	0.14	0.00
11-08	0.00	0.00	0.00	0.00	0.00	1.62	0.10	0.00	0.13	0.04	0.00	0.26	0.00
12-08	0.00	0.00	0.00	0.00	1.89	0.10	0.19	0.72	0.00	0.08	0.00	0.00	0.19
13-08	0.00	0.00	0.00	0.00	0.00	0.56	0.38	0.85	0.18	0.06	0.00	0.21	0.39
14-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.64	0.33	0.00	0.00	0.00	0.40
15-08	0.00	0.00	0.00	0.00	0.00	0.11	0.23	0.00	0.31	0.03	0.00	0.00	0.00
16-08	0.00	0.00	2.02	0.36	0.00	0.54	0.00	0.00	0.45	0.05	0.00	0.00	0.00
17-08	0.00	0.00	2.78	0.00	0.00	0.33	0.37	0.00	0.00	0.04	0.14	1.60	0.00
18-08	0.00	0.00	0.00	0.00	0.00	0.08	0.93	0.40	0.00	0.00	0.14	0.09	0.00
19-08	0.00	0.00	0.00	0.21	0.00	0.06	0.45	0.00	0.22	0.00	0.00	0.25	0.00
20-08	0.00	0.00	0.00	0.00	0.00	0.06	0.37	0.00	1.85	0.00	0.00	0.00	0.00
21-08	0.00	1.62	0.00	0.00	0.00	0.06	0.28	0.00	0.27	0.00	0.00	0.00	0.18
22-08	0.00	0.00	0.00	0.00	0.00	0.06	1.85	0.00	0.44	0.07	4.67	0.39	0.86
23-08	0.00	0.00	0.00	0.00	0.00	0.05	0.37	0.28	0.00	0.04	0.00	0.00	0.00
24-08	0.00	12.43	0.00	0.00	0.77	0.18	0.14	0.00	0.00	0.00	0.00	0.00	0.00
25-08	0.00	0.00	0.00	0.00	0.00	0.00	0.68	0.00	0.45	0.10	0.00	0.07	0.00
26-08	0.00	0.00	0.84	0.00	0.00	0.00	0.37	10.55	0.34	0.05	0.00	0.00	0.00
27-08	0.00	0.00	0.00	0.24	0.00	0.45	0.49	7.75	0.09	1.06	1.08	0.26	0.00
28-08	0.00	0.00	0.00	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13
29-08	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.00	0.36	0.00	0.00	0.00	0.22
30-08	0.00	0.00	0.44	0.00	0.00	0.00	0.59	0.00	0.85	0.00	0.00	0.55	0.22
31-08	0.00	0.00	0.00	0.00	6.42	0.00	0.37	0.72	0.22	0.04	0.00	0.23	0.00
01-09	0.00	0.00	0.00	2.07	0.82	1.33	0.11	1.08	0.00	0.00	0.00	0.77	0.00
02-09	0.00	1.62	0.00	1.38	0.00	0.00	0.00	0.76	0.70	0.00	1.66	2.35	0.00
03-09	0.00	1.23	0.00	0.00	0.00	0.00	0.11	0.60	0.80	0.00	0.00	1.50	0.65
04-09	0.00	0.00	0.00	0.69	1.86	0.00	0.00	2.09	0.91	0.00	0.00	2.54	0.00
05-09	0.00	0.00	0.00	1.43	0.00	0.00	0.19	1.73	0.81	0.16	0.00	0.77	0.00
06-09	0.00	2.57	0.00	8.21	0.14	1.49	0.00	0.00	1.41	0.00	0.62	1.26	0.00
07-09	0.00	0.00	0.00	0.00	0.23	1.49	0.20	0.60	1.84	0.46	0.00	0.00	0.46
08-09	0.00	0.00	0.00	0.00	0.14	1.17	0.00	0.00	2.00	0.00	0.00	24.85	1.00
09-09	0.00	0.00	0.00	0.00	1.41	0.00	0.00	0.52	0.00	0.38	0.62	0.00	1.41
10-09	6.02	0.00	0.00	0.00	0.53	0.00	0.00	0.52	1.67	1.38	0.00	0.00	0.00
11-09	0.65	0.00	0.00	0.00	0.48	2.88	0.99	0.63	0.51	0.00	0.00	6.75	0.00
12-09	0.00	0.00	0.00	0.00	2.35	0.00	0.92	2.59	0.55	0.00	0.52	10.20	1.23
13-09	0.00	0.00	0.00	0.00	0.23	0.00	1.17	1.01	0.25	0.83	0.00	0.00	0.00
14-09	0.00	0.60	0.00	0.00	2.83	0.00	0.00	0.56	0.00	0.31	0.00	0.00	0.00
15-09	0.00	0.00	0.00	0.00	13.99	0.00	0.29	0.39	1.03	0.46	0.00	9.48	0.00
16-09	1.25	0.00	0.00	0.00	51.03	0.00	0.33	0.76	0.00	0.00	0.00	0.00	0.00
17-09	0.00	0.00	0.00	0.00	0.00	3.20	0.00	0.63	0.26	1.54	0.00	0.00	0.00
18-09	0.00	0.00	0.00	0.00	0.00	0.89	0.35	0.50	0.30	1.22	0.00	0.77	0.00
19-09	10.73	1.62	0.00	0.00	0.76	1.97	0.00	0.00	0.00	1.99	0.00	0.66	0.56
20-09	4.03	0.00	0.00	0.00	0.42	0.00	0.00	0.00	0.30	0.38	1.00	1.55	0.97
21-09	0.00	0.00	0.00	0.00	0.16	1.33	0.63	0.00	0.39	0.23	2.18	1.88	0.00
22-09	0.00	0.00	0.00	0.00	0.29	1.75	0.00	0.00	0.00	0.00	1.35	1.14	0.65

23-09	0.00	0.00	0.00	0.00	0.42	1.69	0.31	0.00	0.00	12.97	1.29	1.44	1.44
24-09	0.00	0.00	0.00	0.00	4.86	1.11	0.00	0.00	19.85	0.00	0.00	0.00	0.00
25-09	0.00	0.00	0.00	0.00	0.00	1.17	0.00	0.26	0.00	0.00	0.00	0.00	4.10
26-09	0.00	0.00	0.00	0.00	0.00	0.66	0.00	0.00	0.00	0.89	7.27	1.05	1.84
27-09	0.00	0.00	0.00	0.00	0.00	0.66	0.26	0.00	0.00	0.00	0.00	0.00	0.00
28-09	2.28	0.00	0.00	0.00	9.05	0.66	0.37	0.00	12.25	0.00	2.70	1.23	1.20
29-09	9.11	2.41	0.00	0.00	0.00	1.33	0.17	0.00	21.32	0.25	13.82	0.56	1.98
30-09	4.95	0.00	0.00	0.00	0.00	0.82	0.44	0.63	0.00	0.16	0.00	0.99	0.97
01-10	0.00	0.00	0.00	0.00	0.00	0.96	1.00	0.00	0.00	0.64	0.00	0.00	1.12
02-10	0.00	0.00	0.00	0.00	0.00	0.78	0.91	20.32	0.00	0.00	0.00	0.80	1.12
03-10	0.00	0.00	0.00	0.00	0.00	0.84	0.40	0.00	0.00	0.00	40.92	0.00	1.47
04-10	0.00	0.00	0.00	0.00	0.00	0.78	0.46	0.00	1.39	0.00	0.00	0.00	2.05
05-10	0.00	0.00	0.00	0.00	0.00	0.00	7.38	1.54	0.71	0.00	0.00	0.50	1.83
06-10	0.00	0.00	0.00	0.22	0.00	0.90	0.88	2.04	1.22	0.00	0.00	0.60	0.98
07-10	0.00	0.00	0.00	0.00	50.64	0.42	3.43	2.81	0.00	0.52	0.00	0.00	0.00
08-10	0.00	0.00	5.72	0.00	9.02	0.00	0.34	2.28	0.00	0.73	0.00	0.00	0.85
09-10	0.00	0.00	20.06	3.09	0.00	0.00	0.00	0.00	3.49	0.00	0.00	0.00	0.98
10-10	0.00	0.00	11.33	0.00	0.00	0.00	0.55	0.00	0.00	0.73	0.00	0.00	0.00
11-10	0.00	0.00	0.00	0.51	1.19	0.00	0.27	0.00	1.52	0.73	0.00	0.70	0.00
12-10	1.82	0.00	0.00	0.15	1.48	0.00	0.00	0.00	0.00	0.00	0.95	0.70	0.00
13-10	1.82	0.00	0.00	0.12	10.88	0.00	0.62	0.00	0.00	4.59	0.00	7.61	3.25
14-10	9.91	0.00	0.00	0.20	0.00	1.86	1.01	4.00	0.00	0.00	2.56	0.00	12.12
15-10	0.00	0.00	0.00	0.00	0.00	0.00	0.55	0.00	0.00	0.00	2.38	0.60	0.00
16-10	0.00	0.00	0.00	0.00	0.00	0.00	0.44	0.00	0.00	0.52	0.00	1.51	6.69
17-10	0.00	0.00	0.00	0.15	0.00	0.00	1.10	0.77	41.58	0.73	0.66	13.82	0.00
18-10	0.00	0.00	0.00	0.15	0.00	0.00	0.77	4.24	12.79	3.02	0.00	3.05	27.73
19-10	0.00	0.00	0.00	0.00	0.00	3.78	0.00	5.25	0.00	0.00	0.00	0.00	24.49
20-10	0.00	0.00	0.00	0.00	23.34	4.38	0.00	1.89	0.00	1.25	0.00	0.00	19.65
21-10	0.00	0.00	0.00	1.30	0.00	0.00	0.00	1.25	0.00	41.96	0.00	0.60	0.00
22-10	0.00	0.00	0.00	0.00	0.52	0.00	0.00	1.78	0.00	32.61	0.00	0.00	0.00
23-10	0.00	15.01	0.00	1.91	1.06	11.10	0.00	1.05	1.72	7.20	0.00	1.72	0.00
24-10	0.00	0.00	0.00	0.00	0.00	9.12	0.55	0.00	0.00	7.58	0.00	1.14	0.55
25-10	0.00	0.00	0.00	0.00	1.44	7.62	0.00	0.66	0.00	0.00	0.00	0.00	0.68
26-10	32.17	0.00	0.00	0.00	0.52	0.00	1.10	3.38	0.00	0.00	0.00	10.09	1.86
27-10	0.00	16.99	0.00	0.00	0.00	0.00	0.00	1.21	0.00	0.00	0.00	0.00	17.44
28-10	0.00	0.00	0.00	0.00	1.06	19.50	0.00	0.00	1.22	0.00	0.00	0.00	35.51
29-10	0.00	0.00	0.00	0.00	1.06	0.00	0.00	1.78	0.00	0.00	0.00	0.00	0.00
30-10	0.00	0.00	0.00	0.00	1.19	30.78	0.22	0.00	15.88	6.65	0.00	0.60	0.00
31-10	12.77	0.00	0.00	0.00	1.06	2.16	0.00	1.78	18.27	0.00	0.00	0.85	0.98
01-11	0.00	0.00	0.00	0.00	1.93	0.00	2.58	1.95	0.00	7.02	0.00	3.31	0.00
02-11	0.00	0.00	0.00	0.00	2.43	0.00	0.00	0.00	0.00	3.28	0.00	0.00	0.86
03-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.25	15.00	0.00	0.00	45.22	0.00
04-11	0.00	0.00	0.00	61.08	1.25	0.00	0.00	0.00	0.00	30.28	0.00	0.00	0.00
05-11	0.00	0.00	0.00	35.98	0.00	0.00	3.90	0.00	0.00	4.92	0.00	12.15	0.00
06-11	0.00	0.00	0.00	0.00	49.83	41.52	3.47	0.00	0.00	0.00	0.00	0.00	1.71
07-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.16	0.00	0.00	0.67	0.00
08-11	0.00	0.00	0.00	9.20	7.80	0.00	6.84	0.00	1.98	0.00	0.00	0.00	0.00
09-11	0.00	0.00	0.00	0.00	0.00	0.00	1.21	0.00	0.00	0.00	0.00	0.00	3.72
10-11	0.00	0.00	0.00	0.00	0.00	0.00	4.50	0.00	0.00	0.00	0.00	0.00	0.92
11-11	0.00	0.00	0.00	0.00	23.44	0.00	0.00	0.00	0.00	0.00	0.00	52.96	3.09
12-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.02	4.75
13-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	17.64	0.00	0.00	0.00	1.47
14-11	13.01	0.00	0.00	52.75	0.00	0.00	7.22	0.00	0.00	32.91	0.00	0.00	0.00
15-11	0.00	0.00	0.00	0.00	0.00	0.00	27.15	0.00	0.00	0.00	0.00	0.00	4.81

16-11	11.92	0.00	0.00	0.00	0.00	1.44	5.78	0.00	0.00	0.00	0.00	0.00	3.72
17-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	111.16	0.00	0.00	17.06	0.00	0.00
18-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	25.24	15.73	0.00	1.03
19-11	0.00	0.00	0.00	0.00	0.00	0.78	2.41	0.00	0.00	6.62	45.70	0.00	0.00
20-11	0.00	0.82	11.04	28.13	0.00	0.00	35.23	0.00	0.00	0.00	0.00	0.00	0.00
21-11	76.85	0.00	0.00	0.00	5.27	1.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22-11	0.00	37.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.08	0.67	1.89
23-11	10.43	11.99	0.00	10.77	36.28	0.90	0.00	6.29	0.00	0.00	0.00	0.00	1.71
24-11	0.00	0.00	0.00	27.54	0.00	0.00	0.00	11.58	0.00	0.00	0.00	0.00	0.00
25-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	56.05	0.00	0.00	0.00	0.00	0.00
26-11	6.78	0.00	8.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
27-11	14.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28-11	14.61	0.00	4.44	9.20	0.00	0.00	0.00	0.00	0.00	6.96	0.00	0.00	1.90
29-11	14.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.90	0.00	7.98
30-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	17.85	0.00	0.00	1.89
01-12	0.00	0.00	0.00	0.00	0.00	9.43	1.05	0.00	0.00	0.00	0.00	0.00	0.00
02-12	0.00	0.00	0.00	0.00	4.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.33
03-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.82	51.15
04-12	9.78	0.00	0.00	0.00	6.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.92
05-12	44.75	0.00	0.00	10.74	0.00	0.00	17.53	0.00	0.00	62.21	0.00	0.00	0.00
06-12	12.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
07-12	0.00	0.00	0.00	0.00	35.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
08-12	0.00	0.00	0.00	0.00	6.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
09-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.62	0.00	2.88	0.00
10-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.81	24.65
11-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.16	0.00
12-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	42.24	11.82	14.87	0.00
13-12	0.00	0.00	0.00	0.00	0.00	34.52	0.00	0.00	0.00	2.70	0.00	0.00	17.80
14-12	0.00	0.00	0.00	0.00	0.00	0.00	2.10	18.36	0.00	0.00	0.00	0.00	0.00
15-12	12.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.15	0.00
16-12	0.00	0.00	0.00	25.92	40.71	6.76	0.00	0.00	0.00	0.00	0.00	0.00	10.11
17-12	0.00	0.00	0.00	75.60	2.95	41.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18-12	12.13	0.00	0.00	0.00	0.00	0.00	5.49	18.48	2.04	0.00	3.27	22.74	0.00
19-12	5.30	0.00	0.00	0.00	15.74	0.00	0.00	0.00	0.00	0.00	0.00	3.83	0.00
20-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.05	0.00	23.75	15.14	0.00
21-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22-12	12.95	0.00	3.30	4.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23-12	8.70	0.00	15.38	0.00	0.00	0.00	0.00	0.00	1.71	0.00	0.00	0.00	0.00
24-12	0.00	0.00	3.23	0.00	0.00	9.17	0.00	0.00	1.27	0.00	0.00	0.00	0.00
25-12	0.00	0.00	0.00	32.70	0.00	19.69	0.00	0.00	1.10	0.00	0.00	0.00	0.00
26-12	0.00	0.00	1.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.27
27-12	0.00	52.86	2.06	5.04	0.00	0.00	0.00	0.00	0.00	0.00	2.40	15.20	20.79
28-12	0.00	0.00	0.00	0.00	0.00	0.00	4.09	22.98	0.00	0.00	27.73	6.32	2.72
29-12	0.00	0.00	11.32	0.00	4.62	0.00	21.19	0.00	0.00	0.00	0.00	0.00	0.00
30-12	0.00	0.00	0.00	0.00	7.47	0.00	0.00	0.00	1.90	0.00	0.00	0.00	0.00
31-12	0.00	0.00	19.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

**Annex 4: Tables with precipitation data used for validation (Source: Menemen
Metrological Station, Turkey)**

Day	Daily precipitation per month (mm)									
	10-09	11-09	12-09	01-10	02-10	03-10	04-10	05-10	06-10	07-10
1	0.0	0.2	0.0	0.0	9.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	11.8	0.0	22.4	0.0	0.0	0.0	0.8	0.0
3	0.0	8.0	20.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	8.2	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	1.8	0.0
6	0.0	0.0	0.0	0.0	0.4	0.0	9.8	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	45.0	8.6	0.0	0.0	0.0	0.0
8	0.0	10.4	0.0	0.0	13.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.2	0.0	0.0	2.0	2.4	0.0	0.0	2.0	0.0
10	0.0	19.6	33.8	4.8	0.6	0.0	0.0	0.0	0.0	0.0
11	0.0	19.0	1.0	0.4	17.6	0.0	0.0	0.0	0.0	0.0
12	0.0	3.8	4.2	5.6	3.4	0.2	0.0	0.0	0.0	0.0
13	0.0	0.4	3.2	6.2	18.6	0.4	0.0	0.0	0.0	0.0
14	0.2	0.0	0.0	0.6	0.0	0.4	0.0	0.0	0.0	0.0
15	3.2	0.0	0.2	0.2	0.2	0.0	0.0	2.2	0.0	0.0
16	8.4	0.0	36.6	1.6	0.0	0.0	0.0	0.0	0.0	0.0
17	1.4	0.0	4.2	3.8	0.0	0.0	0.0	0.0	0.0	0.0
18	3.6	0.0	7.0	0.4	0.0	0.0	0.0	12.8	0.0	0.0
19	0.0	0.0	3.4	0.0	0.0	0.0	1.0	0.0	0.0	6.4
20	0.2	0.0	32.6	0.0	0.8	0.0	15.6	0.0	0.0	0.0
21	0.0	0.0	0.6	0.0	1.2	0.0	24.6	8.2	0.0	0.0
22	0.0	0.0	0.0	24.2	0.0	0.0	0.0	0.2	2.8	0.0
23	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	9.2	0.0
24	0.0	0.0	0.0	0.0	13.0	0.0	0.0	0.0	0.0	0.0
25	0.0	0.0	2.0	0.0	22.8	0.0	0.0	0.0	0.0	0.0
26	0.0	0.0	0.2	0.0	0.2	0.0	0.0	0.0	0.0	0.0
27	0.0	0.0	0.0	19.0	28.8	0.0	0.0	0.0	0.0	0.6
28	0.0		4.6	0.8	0.2	8.0	0.0	0.0	0.0	0.0
29	0.0	0.0	0.2	26.2		0.2	0.0	0.0	0.0	0.0
30	0.0	0.0	0.0	3.2		0.0	0.0	0.0	0.0	0.0
31	0.0		0.0	11.6		0.0		0.0		0.0

Day	Daily precipitation per month (mm)									
	08-10	09-10	10-10	11-10	12-10	01-11	02-11	03-11	04-11	05-11
1	0.0	14.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.4
2	0.0	0.0	0.0	0.0	0.2	14.2	0.0	0.0	9.4	0.0
3	0.0	0.0	0.0	0.0	0.0	8.8	5.6	1.6	0.2	0.6
4	0.0	0.0	0.0	0.0	0.0	0.0	6.2	0.0	0.0	4.8
5	0.0	0.0	0.0	0.0	15.2	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.0	0.2
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	7.4	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.6	0.0	0.4	0.0	0.0	0.0	0.0	3.4
12	0.0	0.0	6.6	11.6	0.0	0.0	0.0	0.0	0.0	0.2
13	0.0	0.0	0.4	0.0	11.6	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	87.8	0.0	0.8	0.0	10.4	0.0	12.2	0.0
15	0.0	0.0	0.0	0.0	0.2	0.0	1.0	0.0	0.0	0.0
16	0.0	0.0	0.8	0.0	35.8	0.6	0.0	0.0	0.4	0.0
17	0.0	0.0	0.0	0.0	6.8	0.0	0.0	3.2	13.2	0.0
18	0.0	0.0	75.6	5.6	1.0	0.0	0.0	9.6	4.8	0.0
19	0.0	0.0	25.2	0.2	14.2	0.0	22.0	0.2	0.2	20.6
20	0.0	0.0	2.4	0.2	4.6	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.2	0.0	0.2	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.2	0.0	11.2	15.6	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	3.4	32.4	0.0	0.0	0.0
24	0.0	0.0	0.0	0.8	0.0	9.0	13.4	0.0	0.0	0.0
25	0.0	0.0	0.2	0.8	4.4	15.2	0.0	0.0	0.0	0.0
26	0.0	11.6	5.2	0.0	19.8	0.0	0.0	0.0	0.6	4.8
27	0.0	0.0	11.0	0.0	13.6	0.0	0.0	0.0	6.4	16.8
28	0.0	0.0	72.2	0.0	8.8	0.0	0.0	0.0	7.0	0.2
29	0.0	0.0	0.0	0.0	0.0	5.2		0.2	0.0	0.0
30	0.0	2.4	0.0	0.0	0.0	0.0		0.0	0.0	0.0
31	0.0		0.0		0.0	0.0		5.8		0.0

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