Impact estimation of climate change on the irrigation demand for fruit growing in Western Slovenia

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Folgenabschätzung des Klimawandels auf den Bewässerungsbedarf für den Obstbau in West-Slowenien

Zusammenfassung

In einer eingehenden Studie wurden die Auswirkungen des globalen Klimawandels auf den Bewässerungsbedarf für Pfirsiche und Nektarinen im Vipava-Tal im Westen Sloweniens untersucht. Die mit einem globalen Zirkulationsmodell für ganz Slowenien prognostizierten Änderungen der Temperatur und des Niederschlags wurden auf die bestehenden Daten der meteorologischen Station Bilje für den Zeitabschnitt 1991–1990 übertragen. Um eine gewisse Unschärfe zu berücksichtigen, wurden die voraussichtlichen Temperatur- und Niederschlagswerte in Schrittszenarien variiert. Die Simulation wurde für zwei verschiedene Böden mit dem Computermodell SWAP durchgeführt. Der Wassermangel war für Fluvisols niedriger (118 mm/a bis 240 mm/a) als für Cambisols (162 mm/a bis 276 mm/a). Hingegen ist die relative Zunahme des Wassermangels zwischen dem Ausgangszustand und den einzelnen Schrittszenarien für Fluvisols größer (15 %–55 %) als für Cambisols (15 %–55 %).

Schlagworte: Klimawandel, klimatische Wasserbilanz, Bewässerungsbedarf, numerische Simulation, SWAP.

Summary

In-depth study on the influence of global climate change on irrigation demand for peaches and nectarines was conducted for the Vipava Valley in Western Slovenia. Changes of temperature and precipitation, as forecasted with a global circulation model for whole Slovenia, were applied to existing data of the meteorological station Bilje in period 1961–1990. To account for uncertainties, prospective temperature and precipitation values were varied in step scenarios. Simulation was made for two soils with the SWAP computer model. The water shortage in Fluvisols was lower (118–240 mm/year) compared to that of Cambisols (162–276 mm/year). Relative difference between calculated average water shortage for the period 1961–1990 and water shortage determined by the step scenarios is higher on Fluvisols (15–55 %) compared to the Cambisols (15–45 %).

Keywords: Climate change, climatic water balance, irrigation demand, numerical simulation, SWAP.

1 Introduction

Water is a basic element in agriculture, and along with the soil characteristics, it remains the essential for the growth and evolution of plants. Natural water supply for agricultural land comes from precipitation. Precipitation as natural phenomenon is unmanageable of optimal plant production water regime and therefore, when needed, plant water requirements are met via irrigation.

The chaotic nature of climate system (Lorenz, 1967) precludes the deterministic predictability of future climate. However, a long-term systematic change in boundary conditions may influence the climate statistics, and the resulting long-term climatic response to such change may still be estimated (Benestad, 2003). The problem of unpredictability remains in assumptions of boundary conditions change (i.e. change in concentrations of greenhouse gases and aerosols in the future). Different scenarios for future emission of greenhouse gases and sulphate dioxide have been suggested by the Intergovernmental Panel on Climate Change (Nakičenović et al., 2000) to investigate potential future climate changes and their impacts. Such scenarios are used to estimate the global effect of emissions on climate change and can be also used to characterize the spatial pattern of climate change (HOUGHTON et al., 2001). For the latter, emission scenarios are used in simulation of climate system response to the changes in atmospheric composition by using General Circulation Models (GCM). The results of such simulations (HOUGHTON et al., 2001) indicate warming practically on the entire globe in all emission case scenarios. On the other hand, the estimated changes in precipitation are not so uniform in the sign and amplitude as the changes in temperature. Trends in air temperature and precipitation for Slovenia indicate an increase in air temperature and reduction of precipitation during the vegetation period, which will have a substantial impact on rural economy in Slovenia, as shown by BERGANT and KAJFEŽ-BOGATAJ (1999) and ČREPINŠEK et al (2006). The impact of climate change will be substantial for the soil water balance. Distinctive drought periods in past years had great impact on rural plants in light soils (BERGANT and KAJFEŽ-BOGATAJ, 1998, KAJFEŽ-BOGATAJ, 2001). Changes in air temperature and amount of precipitation will most probably also result in drought in soils which otherwise provide optimal water supply for plants (BERGANT and KAJFEŽ-BOGATAJ, 1998). Crop simulation models can reasonably estimate and quantify the impact of specific water stress conditions on crop productivity provided that they are well calibrated and validated in field experiments (GROSSMAN-CLARKE et al., 2001). They permit variation of environmental inputs such as the water regime and temperature and simulate the crop response through several calculated growth parameters such as crop yield. Because of the complexity of the problem, research is continuing and improvements are constantly being added to models, such as for drought impact assessments (EITZINGER et al., 2003).

Climate scenarios made for the estimation of the impact of climate change are based on the GCM (BERGANT, 2000, BERGANT et al, 2007). A study based on a hundred year set of monthly data showed that in Slovenia temperature would increase at least by 2.3 °C, as much as 5.6 °C at maximum and on average by 4.5 °C (MITCHELL and HULME, 2000, NEW et al., 2000, IPCC, 2001, KAJFEŽ-BOGATAJ, 2001).

Ideally the climate simulations from the GCMs could be used directly for hydrologic models, which in turn could be used to evaluate effects of changed meteorological parameters on hydrologic and water resources, such as temperature increase and decrease of annual precipitation. However, the performance of GCMs in the control simulation and the magnitude of the forecast climate change signal are not certain. Different GCMs are still giving different values of climate variable changes and, therefore, do not provide a single reliable estimate that could be advanced as a deterministic forecast for hydrological planning. Results obtained from often-used method of simple alteration of the present conditions should be interpreted simply as a sensitivity analysis to alternative climate rather than as predictions (XU, 1999). Also, GCMs contain many approximations and have horizontal resolutions of about 250 km. This scale is inadequate to describe many small-scale features that are important to land users and farm managers. Therefore, farm scale computer models that simulate water balance, erosion and crop production are needed to evaluate the potential impacts of global increase of CO_2 and temperature change scenarios on water balance (SAVABI and STOCKLE, 2001).

The objective of this study is to determine how anticipated climate changes, manifested as increased air temperatures and decreased and/or varying precipitation, will influence the irrigation demand in Western Slovenia, thus effecting intensive peaches and nectarine production.

2 Material and methods

2.1 Climate change scenarios

A procedure for estimating the impact of climate change applies the model by using a basic set of data for the thirty year period 1961 to 1990, a changed set of climate input parameters, and a comparison of output results of the model (PARRY and CARTER, 1998). Quantitative estimates are necessary in simulation modeling (BOURAOUI and WOLFE, 1990). Water balance simulation models are applied for irrigation scheduling in order to develop optimal irrigation schedules by evaluating alternative water application strategies (VAN DAM et al., 1997, SARWAR et al., 2001). Comparison between two locations with similar climatic conditions but significantly different soil water balance characteristics using the CERES wheat growth model modified for four different climatic scenarios showed that summer crops are more vulnerable and dependent on soil water reserves. The soil water or higher groundwater tables during the winter period cannot be utilized as much by winter crops, and evapotranspiration losses during summer due to higher temperatures could increase significantly (EITZINGER et al., 2001, EITZINGER et al., 2003).

One can state, with some certainty, that higher CO_2 levels will influence water use and as a consequence of the current increase in atmospheric CO_2 concentration, a significant research effort has been devoted to clarifying the response of plants and ecosystems to this specific aspect of global change. The results have often been contradictory, also due to different experimental techniques. It is generally assumed that elevated CO_2 reduces stomatal conductance thus reducing transpiration rates and increasing water use efficiency (TUBA et al., 2003). However conclusions for tree plants/species have been less conclusive. Therefore the elevated CO_2 levels are not included in this study.

The study followed the standard climate change impact assessment methodology according to PARRY and CARTER (1998) whereby a model of the impacted system is run with baseline and altered climate inputs, and the performance of the system are compared (ARNELL, 1999). Although data for the new 30-year period (1971–2000) are already available, the period 1961–1990 was used to define a climate baseline in our study. This is because the synthetic climate change scenarios used in our study are based on regional projections of some available results of GCM, which are driven by the observed greenhouse gas and sulfate aerosol concentrations until the year 1990 and on emission scenarios thereafter. The other reason for using 1961–1990 data is that anthropogenic influence on climate has been greatly dealt with after this period. The deviations from climate in 1961–1990 period better reflect the anthropogenic impact on climate compared to the more recent 1971–2000 period. This standard approach makes two important assumptions: first, that the baseline period represents a stable climate, which would still be appropriate in the future in the absence of climate change, and second, that the scenarios derived from climate model experiments represent just the signal of climate change (ARNELL, 1999).

Air temperature and precipitation measurements show that most years after the 1990 are warmer compared to the long year averages, with precipitation amount relatively lower than average. This is especially evident in warmer part of the year (April–September). Although precipitation trends are insignificant, rough estimate can be made that the most possible climate development in Slovenia goes into warmer and somewhat dryer summers and warmer winters with unchanged precipitation quantity on average (SUŠNIK et al., 2006).

The change of data was initiated with a disparity of 1.5 °C, with the basic set of data for daily air temperature being increased by 1.5 °C, by 3 °C and by 4.5 °C. Precipitation estimate took into consideration anticipated seasonal changes (BERGANT, 2004). Several scenarios were studied, the first one with daily precipitation quantities decreased by 10 % throughout the whole year and the second one, i.e. mixed scenario with precipitation in the period April–September, decreased by 10 %, and in the period October–March increased by 10 % (ARNELL, 1999, IPCC, 2001) (Table 1). Recent studies on precipitation change scenarios for Slovenia show high uncertainty without tangible indication whether precipitation amount will reduce, increase, or remain unchanged (BERGANT and KAJFEŽ-BOGATAJ, 2005). Due to such indefinable results, and to avoid overstating in one direction or the other, the precipitation change used in scenarios shown in Table 1 was chosen. It should be noted however, that the precipitation change, which could exceed values used in simulation, is possible.

Table 1: Modification of basic data set for daily air temperatures and precipitation data
Tabelle 1: Variation der Tageslufttemperaturen und Niederschläge gegenüber den Ausgangsdaten

Scenario	Air temperature change	Precipitation change
Scenario 1	+ 1.5 °C	Decreased by 10 %
Scenario 2	+ 1.5 °C	April – September decreased by 10%, October – March increased by 10%.
Scenario 3	+ 3 °C	Decreased by 10 %
Scenario 4	+ 3 °C	April – September decreased by 10%, October – March increased by 10%.
Scenario 5	+ 4.5 °C	Decreased by 10 %
Scenario 6	+ 4.5 °C	April – September decreased by 10%, October – March increased by 10%.

2.2 Computer models

Dynamics of soil water balance was calculated by using the mathematical model SWAP (VAN DAM et al., 1997). SWAP (Soil-Water-Atmosphere-Plant) is a computer model that simulates vertical transport of water, solutes and thermal energy (heat flow) in unsaturated and saturated soils (KROES et al., 2000). KROES et al. (2000) described an application of SWAP for integrated modeling of the soil-water-atmosphere-plant system. DROOGERS et al. (2000) used SWAP in a distributed manner in order to analyze all the water balance terms of a composite irrigated area in the

Gediz basin of Western Turkey. KITE and DROOGERS (2000) estimated actual evapo-transpiration and transpiration. SWAP was used for examining the response of three water delivery schedules, representing various levels of flexibility on crop production, water saving soil salinisation drainage volumes and water table behavior (SARWAR et al., 2001).

The SWAP model is based on the calculation of 1-D Richard equation for the calculation of water current in the soil matrix. Due to its physical basis, the Richard equation enables the use of hydraulic functions database. SWAP has built in a sub-model for the soil hydraulic characteristics calculation with a lock-up table (WOESTEN et al., 1994), or Hypres series (WOESTEN et al., 1999), and analytical pedotransfer functions (VAN DAM et al., 1997). Hypres series give the mean hydraulic properties for rather broadly defined soil texture classes. As a consequence, these functions are more general applicable, but they give limited site specific information (WOESTEN et al., 1999). Analytical pedotransfer functions are soil hydraulic functions which explain the water potential h versus soil water content θ as described by VAN GENUCHTEN (1980) and MUALEM (1976).

Calibration and sensitivity analysis of the model for the soil hydraulic characteristics and soil water content simulation was made for apple trees in Ljubljana (1994–1995) (ZUPANC, 2003). Independent data set of soil hydraulic characteristics, soil water content and meteorological data for peaches grown in Experimental Station in Bilje (described in section 2.5) for the period between 19.6.2002 and 17.10.2002 was used for model validation. For calibration, parameter sensitivity and validation soil functions calculations were calibrated and validated against four measured pF values. Potential Force or pF value is defined as log of cm of water column, describing soil water suction (HILLEL, 1998). Soil water content was measured with gravimetric method.

Model simulations were done with and without the irrigation. In SWAP, irrigations may be prescribed at fixed times or scheduled according to a number of criteria (VAN DAM et al., 1997). In this study, simulation for irrigation demand was made for a vegetation period (from beginning in April to the end of September) for sprinkler irrigation with allowable depletion of 50 % field capacity. For the simulated irrigation management options each water application is directly linked to soil water content in the root zone.

2.3 Description of the study area climate

Vipava valley is intensive fruit production area, located in Western Slovenia. Average air temperature for many years is between 11 °C and 12.7 °C and, the yearly average precipitation is 1453 mm. The coldest month is January, with temperature from –0.4 °C to 6 °C, and the warmest month is July with temperature values from 20 °C to 23 °C. Daily meteorological data for the conventional meteorological station Bilje (115 m a.m.s.l.) in the period 1961–1990 served as model input. For model validation daily meteorological data for the year 2002 from the same station Bilje were used. Precipitation during the vegetation period in the considered period 1961–1990 indicated two maximums during 1965–1968 and another one, slightly smaller during 1974–1978. Past decade with considered basic data set is marked by droughty period in 1986 and 1988 (EAS, 2003).

In the model average daily values for min and max air temperature (°C), daily precipitation (mm), average air humidity (%), sum of daily sunshine hours (h) and average wind speed (m/s) were used. Input for reference evapotranspiration ET calculation with Penman – Monteith generator incorporated in SWAP model was also latitude and a.m.s.l.

2.4 Soil

From pedologic map of Slovenia in scale 1:25000 (CSES, 2002), six soil profiles (SP) were mapped on the Vipava valley area. The model input for soil characteristics calculations were depth of each layer, soil texture (% of Sand, Clay and Loam), organic matter % and soil bulk density (g/cm^3). For Cambisols the selection encompassed Eutric Cambisol on glacial gravel and sand deposits and Ari Eutric Cambisol on flysh. Though Distric Cambisol on flysh is not typical for the Vipava valley, the sand clay texture classification could be found and as such, it was grouped among the selected and studied profiles. From the division of Fluvisols soil, Eutri Endogleyic Fluvisols were chosen (Table 2). Points determining plant available water (Field Capacity FC and Wilting Point WP), expressed as a ratio of volumetric water content at a pertaining water potential (2.3 pF or 200 cm WC for FC, 4.2 pF or 15000 cm WC for WP) were calculated with Van Genuchten-Mualem model for simulation of h–θ curves (Table 2).

Table 2: Basic soil physical parameters of the chosen soil profile used as model inputs in our study (CSES, 2002)
Tabelle 2: Charakterisierung der wichtigsten bodenphysikalischen Parameter der für die Studie ausgewählten Böden (CSES, 2002)

Soil type	Layer depth (cm)	Sand	Silt	Loam	Texture	Organic matter (%)	FC	WP	Bulk density (g/cm^3)
Eutric Cambisol on glacial gravel and sand deposits	0–18	45	38	17	Loam	2.9	0.25	0.11	1.44
	18–42	45	40	16	Loam	3.1	0.24	0.11	1.45
	42–52	21	44	36	Clay Loam	1.9	0.36	0.20	1.28
	52–70	39	31	29	Clay Loam	1.7	0.29	0.16	1.35
	70–90	47	31	22	Loam	0.9	0.25	0.11	1.48
Ari Eutric Cambisol on flysh	0–32	35	41	25	Clay Loam	4.3	0.29	0.14	1.37
	32–68	45	33	22	Clay Loam	1.2	0.26	0.13	1.40
	68–100	45	33	22	Clay Loam	1.2	0.26	0.13	1.41
Distric Cambisol on flysh	0–9	59	26	15	Sandy Loam	2.1	0.23	0.12	1.50
	9–40	57	26	18	Sandy Loam	1.4	0.23	0.11	1.46
	40–65	54	26	20	Sandy Loam	1.2	0.24	0.13	1.44
Eutri Endogleyic Fluvisols	0–17	36	43	21	Loam	3.4	0.27	0.13	1.39
	17–37	38	44	18	Loam	4.2	0.26	0.12	1.42
	37–70	43	35	22	Loam	3.4	0.26	0.12	1.42
	70–95	22	51	26	Loam	2.2	0.31	0.15	1.33
	95–120	25	53	22	Silt Loam	1.6	0.30	0.14	1.33
Eutri Endogleyic Fluvisols	0–26	22	58	20	Silt Loam	2.3	0.29	0.12	1.37
	26–60	17	64	19	Silt Loam	1.1	0.30	0.12	1.37
	60–90	25	56	19	Silt Loam	0.6	0.29	0.12	1.38
	90–110	25	56	19	Silt Loam	0.6	0.38	0.10	1.38
Eutri Endogleyic Fluvisols	0–9	15	66	18	Silt Loam	7.8	0.30	0.12	1.37
	9–25	13	63	23	Silt Loam	2.7	0.31	0.13	1.33
	25–45	12	60	27	Silt Clay Loam	2.6	0.33	0.15	1.31
	45–65	11	60	29	Silt Clay Loam	1.3	0.30	0.15	1.30
	65–87	10	61	29	Silt Clay Loam	1.3	0.34	0.16	1.29
	87–100	10	63	28	Silt Clay Loam	1.7	0.33	0.15	1.30

2.5 Peaches and nectarines

Bilje Experimental Station is situated in the plains southwest of the Vipava valley, i.e. in the Western Slovenia (latitude 45°52'N, longitude 13°38'E, altitude 115 m a.s.l). Peaches (*Prunus persica*) and nectarines (*Prunus persica* var. *nuciperica* (Schneid)) differ in no aspect, except that nectarines lack pubescence and are considered a botanical variety of peach (FRECON, 1988). Description of growth of peaches and nectarines relates to spindle bush, the most commonly cultivated type of peaches and nectarines in Slovenia (ŠTAMPAR, 2003) and vegetatively reproduced bases with shallow roots (50 cm deep). Peach and nectarine orchards have a grass cover between tree lines, with a 20 cm narrow stripe of bare soil in the actual tree line. Descriptive parameters used as input for the SWAP model were soil cover factor *SC*, leaf area index *LAI* (FAUST, 1989), soil depth and root depth and density in soil profile (NATALIE et al., 1984, NATALIE et al., 1985) (Table 3). Calculation of the actual *ET* of peaches was made using the coefficient of water efficiency use k_c (ALLEN et al., 1998) for the period April–August.

3 Results and discussion

3.1 Computer model validation

SWAP was validated for two most important parameters regarding irrigation management – soil hydraulic function, which calculates the h–θ curves and soil water content. Soil characteristic curve simulation showed Van Genuchten-Mualem function to be the best fit for the measured data for the soil profile at the experimental station in Bilje, Slovenia.

Table 3: Parameters for growth and development for peaches and nectarines (ALLEN et al., 1998, FAUST, 1989, NATALIE et al., 1984 and NATALIE et al., 1985)

Tabelle 3: Parameterwerte für Wachstum und Entwicklung für Pfirsiche und Nektarinen (ALLEN et al., 1998, FAUST, 1989, NATALIE et al., 1984 und NATALIE et al., 1985)

Month	k_c	Development stage	*SC*	*LAI*	Rooth depth [cm]	Relative rooting depth	Relative rooting density
Apr	0.66	0	0.60	4	50	0	0.3
May	0.74	1	0.69	7	50	0.1	0.6
Jun	0.98	2	1	6	50	0.2	0.9
Jul	1.07	3	1.26	6	50	0.3	1.0
Aug	1.26	4	1.24	6	50	0.6	0.8
						0.8	0.5
						1	0.1

Figure 1 shows the simulated curves versus the measured pF values per each soil layer for Fluvisol soil profile where soil water status validation measurements were made. Simulated curves were compared to measurements of 2.3 pF, 2.6 pF, 3.5 pF and 4.2 pF.

Validation results for soil water content calculations in observed period for SWAP in peaches and nectarines orchard on Eutri Endogleyic Fluvisol in year 2002 (19.6.–17.10.) are presented in Figure 2. In the observed period peach orchard received no irrigation treatment, as well as no irriga-

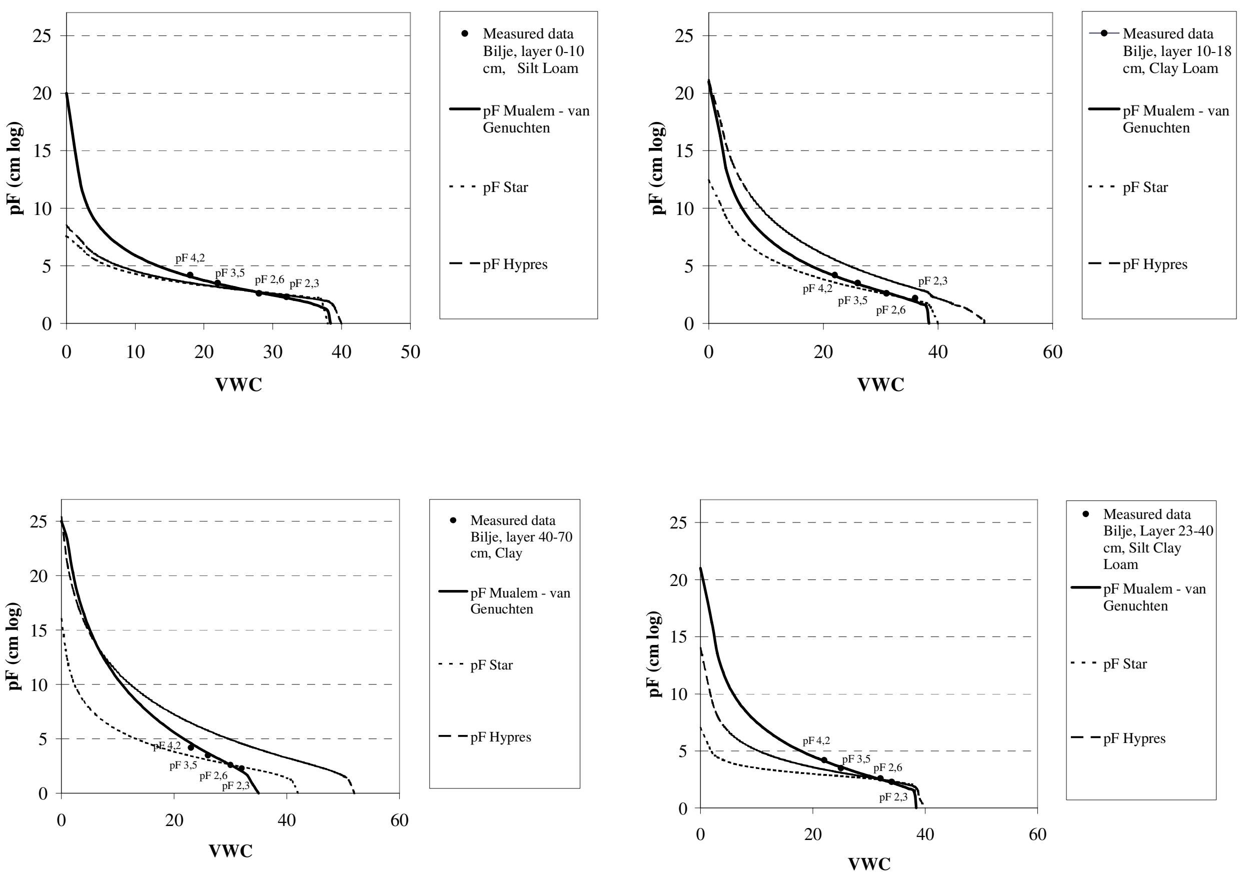

Figure 1: Result comparison between simulated h–θ curves obtained with Mualem-Van Genuchten functions, Star and Hypres series with measured pF values over individual layers for soil profile in experimental site Bilje

Abbildung 1: Vergleich von simulierten h-θ-Kurven aus der Mualem-van-Genuchten-Funktion, aus der Star- und der Hypres-Datenbank und von gemessenen pF-Werten für die einzelnen Horizonte im Bodenprofil der Versuchsstation Bilje tion simulation was done for validation of soil water content calculation with SWAP. Measured soil water content values vs. simulated are shown in Figure 2. There is some discrepancy between measured and simulated soil water content for 20 cm depth (overestimated SWC for < 5 %) and 40 cm depth for SWC measurements taken on 227, 239 and 250 JD, however Figure 2 indicates good agreement between simulated and measured soil water content dynamics throughout the observed period. This implies that simulations can be used to assess the soil water status dynamics.

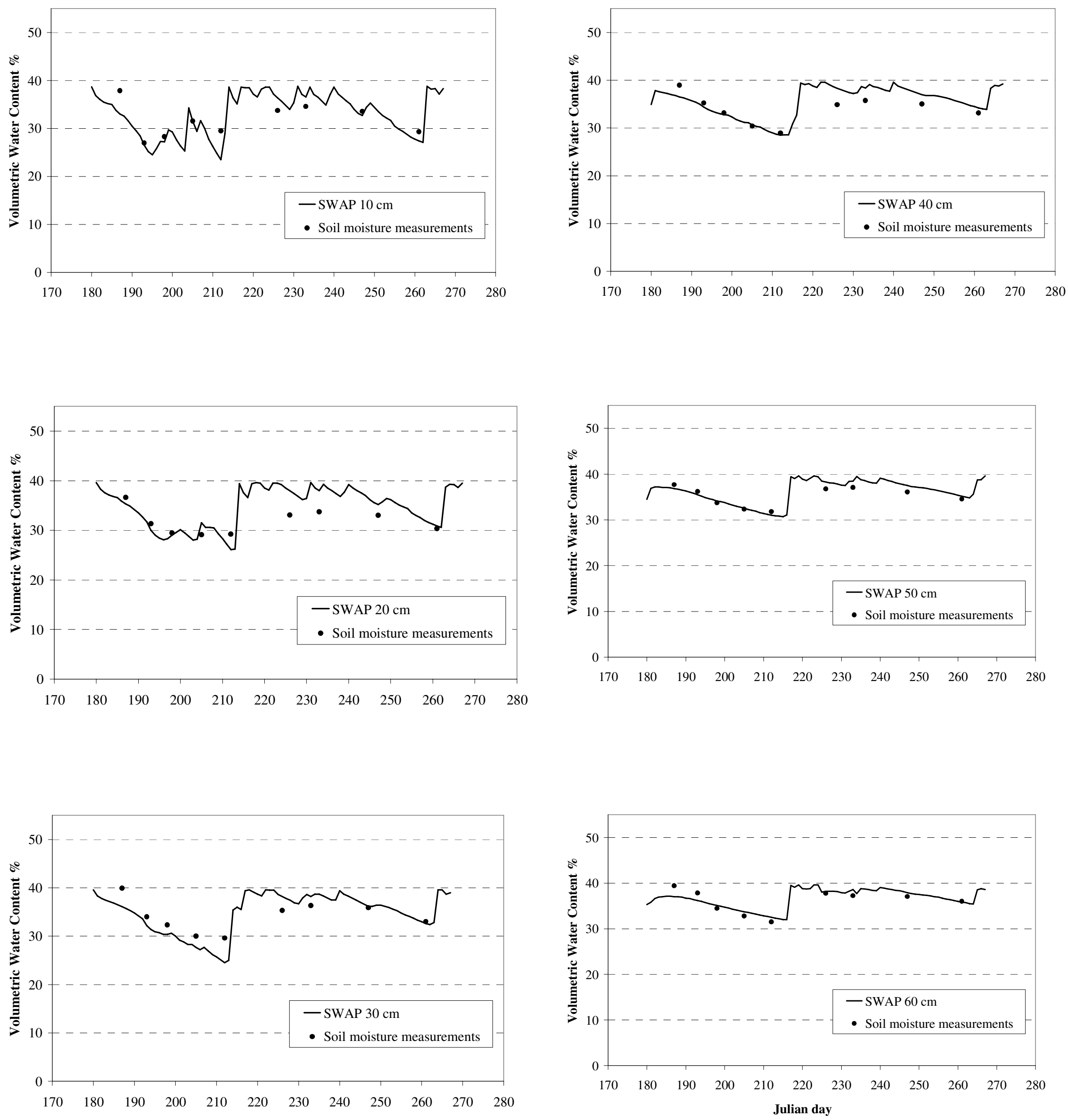

Figure 2: Validation of SWAP calculations of soil moisture content in soil profile in depth increment of 10 cm for Peaches in the Vipava valley during the observed period 19.6.2002–17.10.2002

Abbildung 2: Evaluierung der mit SWAP berechneten Bodenwassergehalte in verschiedenen Tiefen des Bodenprofils für Pfirsiche im Vipavatal für den Zeitraum vom 19.6.2002–17.10.2002

3.2 Simulated irrigation demand in the 1961–1990

The results show irrigation demand for base line data in the considered period 1961–1990 for studied soil profiles in the Vipava valley for peaches and nectarines calculated with the SWAP model. Figure 3 shows box-and-whisker plot of irrigation demand of the studied soil profiles described in Table 2. Calculated values represent only assessment of the profile cross-section, which is covered with peaches and nectarine trees (corresponding plant descriptive parameters used as model input). For the estimation of the whole orchard water balance, profile cross-section with grass cover should be considered.

The water shortage in Fluvisols was lower (118–240 mm/year) compared to that of Cambisols (162–276 mm/year). The simulated irrigation demand of Eutri Endogleyic Fluvisol (Loam/Silt Loam) soil profile was 118 mm/year in average (0–278 mm/year) and 148 mm in average (75–382 mm/year) in Eutri Endogleyic Fluvisols (Silt Loam/Silt) soil profile. Eutri Endogleyic Fluvisol (Silt Loam) soil profile had higher water shortage 243 mm/year in average (95–395 mm/year).

Of the Cambisols, Distric Cambisol on flysh (Sandy Loam) soil profile had the highest annual average irrigation demand 276 mm/year (75–450 mm/year). The Eutric Cambisol on glacial gravel and sand deposits (Loam/Clay Loam) soil profile had 161 mm/year (0–343 mm/year), whereas the Ari Eutric Cambisol on flysh (Clay Loam) soil profile had 244 mm/year in average (73–447 mm/year) (Figure 3).

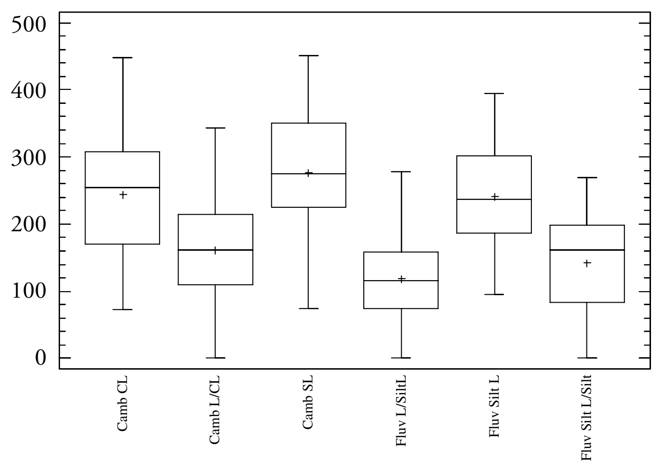

Figure 3: Irrigation demand (mm) for base set 1961–1990 for Bilje, the Vipava valley for studied soil profiles. The box-plots give median ± 25 % quartiles and ranges. The outliers are indicated by squares

Abbildung 3: Bewässerungsbedarf (mm) für den Ausgangsdatensatz 1961–1990 für Bilje, Vipavatal für die untersuchten Böden. Die Boxplots geben den Median ± 25 %-Quartile und die Varianzen wider. Ausreißer sind durch Quadrate kenntlich gemacht

3.3 Step scenarios simulation results

For the studied soil profiles (Table 2) the irrigation demand using the step scenarios (Table 1) was calculated. The effect of increased daily maximum and minimum temperature and changed precipitation amount on the simulated irrigation demand of the peaches orchard is presented in Figure 4.

The strongest irrigation demand increase (%) showed Distric Cambisol on flysh (Sandy Loam) soil profile. This is an expected result considering the shallow depth of the profile and high percentage % of sand fraction, which has the lowest water retention abilities. The greatest response to the first 1.5 °C temperature increment was in Distric Cambisol on flysh (responded to the first 1.5 °C temperature increment the most), amounting up to additional 80 mm/year in average (65–115 mm/year) or 29 % ± 1 % increase. The least sensitive in step scenario simulations, of both Cambisols and Fluvisols, showed to be Ari Eutric Cambisol on flysh (Clay Silt Loam) soil profile with 10 % water shortage increase for the first increment scenario, 23 % increase for the second increment scenario and the lowest, 30 % increase in water shortage, for the most severe scenario. Ari Eutric Cambisol on flysh is also the deepest of the used profiles (100 cm). However, irrigation demand on the third from this soil profile group, Eutric Cambisol on glacial gravel and sand deposits (90 cm deep), was by 20 % higher in the first temperature increment, by 35 % in the second and by 45 % in the third temperature increment.

Eutri Endogleyic Fluvisol (Loam/Silt Loam) soil profile, the deepest from the Fluvisol soil profile group (120 cm), increased 27 % for the first temperature increment, 40 % for the second and up to 57 % for the third temperature increment of 4.5° C. This is higher irrigation demand than that of the Distric Cambisol on flysh, the shallowest of the Cambisols used in this study. The other Eutri Endogleyic Fluvisols applied in the simulation were less sensitive

Temperature had stronger effect on change of irrigation demand than precipitation decrease or seasonal alteration of precipitation demand. Difference of precipitation decrease or seasonal alteration effect on water shortage was insignificant. In most cases the water shortage reduced with seasonal alteration, except in combination with +4.5° C for

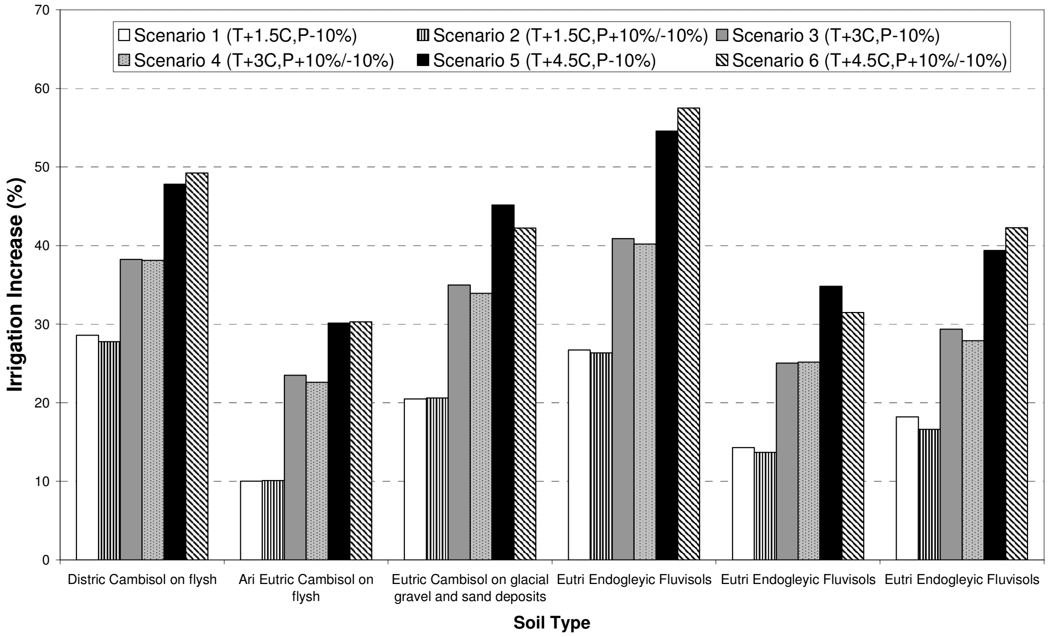

Figure 4: Comparison of Water shortage increase (%) between Soil types calculated with model SWAP for individual Scenarios in Table 1
Abbildung 4: Vergleich der mit dem Modell SWAP berechneten Zunahmen des Wassermangels (%) für verschiedene Bodentypen und für die einzelnen Szenarien lt. Tabelle 1

Distric Cambisol on flysh (Sandy Loam), Eutri Endogleyic Fluvisols (Loam/Silt Loam) and Eutri Endogleyic Fluvisols l (Silt Loam/Silt) soil profiles.

For the chosen soil profiles of Fluvisols of the Vipava valley, the applied scenarios of climate change indicate larger increase of irrigation needs for peaches and nectarines (15–57 %) than those of soil profiles of Cambisols (10–49 %) as shown in Figure 4.

4 Conclusions and discussion

Model SWAP was used to study the increase of temperature and varying precipitation regime impact on irrigation demand in Western Slovenia for peaches and nectarines. In the study step scenarios were applied to alter the 1961–1990 meteorological data set. Model was calibrated and validated for simulation of soil hydraulic characteristic and soil water content. For soil hydraulic characteristic calculations Van Genuchten-Mualem function was chosen as the best fit. It has been shown that due to the different water retention capacities, water shortage on some soil types will be more expressed than on the others.

The water shortage in Fluvisols was lower (118–240 mm/year) compared to that of Cambisols (162–276 mm/year). In Cambisols Distric Cambisol on flysh (Sandy Loam) soil profile showed the strongest irrigation demand increase. In step scenario simulations, of both Cambisols and Fluvisols, Ari Eutric Cambisol on flysh (Clay Silt Loam) showed to be the least sensitive one. The highest response to changed temperatures and changed precipitation amount showed Eutri Endogleyic Fluvisol (Loam/Silt Loam) soil profile, which was also the deepest soil profile used in the computer simulation.

Calculation with SWAP indicated that the increase of air temperature had a greater impact on the calculation of irrigation needs than the reduction of precipitation.

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