# ASSESSMENT OF IRRIGATION WATER REQUIREMENTS FOR APPLES, PEARS, AND PLUMS IN THE KOLUBARA AND MORAVA DISTRICTS UNDER CHANGING CLIMATE CONDITIONS

**Marija ĆOSIĆ, Aleksa LIPOVAC, Ružica STRIČEVIĆ, Dunja SOTONICA, Ana VUKOVIĆ VIMIĆ**

*University of Belgrade, Faculty of Agriculture, 6 Nemanjina street, Belgrade, Serbia*
*Author(s) email: c.marija@agrif.bg.ac.rs, sruzica@agrif.bg.ac.rs, alipovac@agrif.bg.ac.rs, sotonica.dunja94@gmail.com, pazisadana@gmail.com*
**Corresponding author email:** c.marija@agrif.bg.ac.rs

**Abstract**

*Climate change, which manifests through shifts in temperature, rainfall patterns, and the frequency of extreme events like droughts and floods, has a substantial impact on agricultural production and food security.*

*This study investigates the influence of climate change on the irrigation needs of apple, pear, and plum crops in two fruit-growing districts in western Serbia, specifically in the Kolubara and Morava districts. This research aims to provide valuable insights for farmers to plan and adapt their production strategies in response to evolving climate conditions.*

*To estimate the water requirements, crop evapotranspiration (ETc), effective rainfall (Pe), and water deficit (In) were determined using historical climate data from meteorological stations in Valjevo (Kolubara district) and Požega (Morava district) for the observed period (1961 - 2021). For projecting future water requirements (2021 - 2040), we employed data from eight regional climate models within the EURO – CORDEX project. The analysis of water requirements for apple, pear, and plum was conducted for both grassed and non-grassed orchards.*

*In the Kolubara district, the average seasonal water deficit during the observed period was 356 mm in grassed orchards and 191 mm in non-grassed orchards, with the most significant irrigation requirements occurring in July and August, representing 60 - 70% of the seasonal water requirement. Looking ahead to the future period (2021 - 2040), the average water deficit increases to 401 mm in grassed orchards and 202 mm in non-grassed orchards, marking a 13% and 6% rise, respectively, compared to the observed period. This signifies a need for 1 to 2 additional irrigation sessions.*

*In the Morava district, the average seasonal water deficit during the observed period was 403 mm in grassed orchards and 236 mm in non-grassed orchards, with the highest irrigation requirements in June, July, and August, accounting for 80 - 90% of the seasonal water requirement. Due to an anticipated increase in total precipitation in the future period (2021 - 2040) in the Morava district, there is a decrease in the seasonal water deficit by 3% in grassed orchards and 16% in non-grassed orchards. However, even with reduced water requirements in the future, there remains a significant requirement for irrigation in May, June, July, and August when rainfall is limited.*

***Key words**: water deficit, irrigation, climate change*

## INTRODUCTION

Worldwide fruit production, especially in arid and semi-arid climates, carries significant risks without the incorporation of irrigation. A universal challenge for fruit growers revolves around the establishment of an optimal irrigation regimen, considering both the frequency and volume of watering, aimed at achieving high-quality yields while also safeguarding the environment. Estimating irrigation needs for herbaceous plants is relatively precise, in contrast to the variability encountered when estimating irrigation requirement for fruit crops, mainly due to the differing anatomical and morphological structures of fruit trees and their adaptability to soil water fluctuations. The water potential in fruit orchards is closely linked to the soil's moisture content (Yahyai, 2012).

Elevated daily temperatures, coupled with water deficits, can adversely affect fruit growth and yield (Calderon-Zavala et al., 2004; Jackson, 2011). To prevent reductions in yield and fruit quality in the following season, the soil moisture content should be maintained at a level that avoids substantial water deficits in fruit orchards during and post-harvest (Johnson and Phene, 2008; Abriskueta et al., 2010; Marsal et al., 2010).

In the context of climate change, there is an increasing frequency of dry periods during the summer months and reduced and uneven distribution of rainfall during the growing season. Therefore, irrigation becomes an essential measure in plant production. Irrigation consumes around 70% of renewable water resources and depends on the availability of freshwater from rivers, lakes, and reservoirs (FAO, 2020). Many authors emphasize that in future climate conditions, risks in fruit production are increasing (due to increased irrigation requirements, drought, heatwaves, floods, frost, hail), and it is necessary to implement adaptation measures through the use and construction of irrigation systems, reservoirs, drainage systems, anti-hail nets, anti-frost systems, the selection of varieties resistant to dry climate conditions (Trbic et al., 2022; Ahmadyan et al., 2019; Vujadinović Mandić et al., 2022; Ćosić et al., 2021; Lipovac et al., 2018; Makar et al., 2022; Stričević et al., 2019). This study has examined the irrigation requirements for apple, pear, and plum in grassed and non-grassed orchards in two fruit-growing regions of western Serbia under changing climatic conditions with the aim of assisting producers in making decisions and implementing suitable agrotechnical adaptations to achieve high yields of good quality.

## MATERIALS AND METHODS

The analysis in these studies was carried out using meteorological data collected from the Valjevo (Kolubarski district) and Požega (Moravički district) meteorological stations. Table 1 presents the coordinates and altitudes of the meteorological stations employed in this research.

Table 1 Meteorological Stations Used in the Research

| District | Station | Latitude | Altitude m a.s.l. |
|---|---|---|---|
| Kolubarski | Valjevo | 44° 17’ N | 174 |
| Moravički | Požega | 43° 51’ N | 311 |

A set of daily meteorological records encompassing air temperature and precipitation for the past four decades (1961-2021) was subjected to analysis. Using the FAO IDP (Irrigation and Drainage Paper) No. 56 methodology (Allen et al., 1998), the research involved the computation of reference evapotranspiration (ETo), effective rainfall (Pe), crop evapotranspiration (ETc), and water deficit (In). The Hargreaves method was employed to calculate the reference evapotranspiration:

$$ETo = 0.0023 \cdot 0{,}408 \cdot Ra \cdot (Tmax - Tmin)^{0.5} \cdot (Tavg + 17.8)$$

Where: ETo – reference evapotranspiration ($mm \cdot dan^{-1}$); Ra – extraterrestrial radiation (mm·dan-

[1]); Tmax – maximum air temperature (°C); Tmin – minimum air temperature (°C); Tavg – average daily temperature (°C).

Effective rainfall was determined by considering daily rainfall with a 90% probability of occurrence.

$$Pe_{day} = P_{day} \cdot 0.9$$

Gde je: $Pe_{day}$ – daily effective rainfall (mm); $P_{day}$ – daily rainfall obtained from the meteorological station (mm)

Crop evapotranspiration was calculated as the product of reference evapotranspiration and the crop coefficient:

$$ETc = ETo \cdot kc$$

Where: ETc – crop evapotranspiration ($mm \cdot dan^{-1}$); ETo – reference evapotranspiration ($mm \cdot dan^{-1}$); kc – crop coefficient.

The crop coefficient values for apple, pear, and plum, along with the duration of vegetation and various phenophases, were extracted from FAO 56 publication (FAO Irrigation and Drainage Paper No. 56) for both grassed and non-grassed orchards. According to the FAO methodology, these three fruit types fall into the same category due to their similar vegetation duration, phenophases, and water needs. Table 2 displays the crop coefficient values for apple, pear, and plum during different phenophases in both grassed and non-grassed orchards.

Table 2. Crop coefficient values (grassed and non – grassed apple, pear, plum orchards)

| Culture | Phenophases | | | Duration of vegetation (days) |
|---|---|---|---|---|
| | Start (I) | Intensive growth (II) Flowering and fruiting (III) | Maturity (IV) | |
| apple, pear and plum (frost, non-grassed orchard) | 0.45 | 0.95 | 0.70 | 245 |
| apple, pear and plum (frost, grassed orchard) | 0.50 | 1.2 | 0.95 | 245 |

The water deficit was determined by calculating the diference between crop evapotranspiration and effective rainfall.

$$In = ETc - Pe$$

Where: In – net water deficit (mm); ETc – crop evapotranspiration ($mm \cdot dan^{-1}$); Pe – effective rainfall (mm).

The analysis of future climate changes has to include current and relevant results of climate projections, which implies the appropriate selection of one or more scenarios related to greenhouse gases and appropriate integrations of climate models with the greatest spatial resolution possible. The scenario RCP8.5 (Relative Concentration Pathway) from the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2014) was selected for the analysis. This scenario does not envisage the application of mitigation measures and therefore it can be regarded as “the worst option“. However, Serbia has already reached the values of temperature change envisaged for the following 20 years, so the selection of more moderate scenarios would be inappropriate in this case.

The selected integrations of climate models were taken from the project “Development of the internet application and platform for assessing vulnerability to climate change and adaptation” realized within the UNDP project “Advancing medium and long-term adaptation planning in the Republic of Serbia (Djurdjevic et al., 2021) and they include a set of 8 regional climate models with a 0.1° (about 12 km) spatial resolution from the EURO-CORDEX project dataset (Table 3). In accordance with the mentioned project, this study included the analysis of the twenty-year future period 2021-2040.

Table 3. Selected combinations of global and regional climate models

| Regional climate model | Global climate model |
|---|---|
| CCLM4-8-17 | ICHEC-EC-EARTH |
| CCLM4-8-17 | MOHC-HadGEM2-ES.rcp85 |
| CCLM4-8-17 | MPI-M-MPI-ESM-LR |
| HIRHAM5 | ICHEC-EC-EARTH |
| RACMO22E | ICHEC-EC-EARTH |
| RACMO22E | MOHC-HadGEM2-ES |
| REMO2009 | MPI-M-MPI-ESM-LR |
| REMO2009 | MPI-M-MPI-ESM-LR |

## RESULTS AND DISCUSSIONS

Table 4 presents the data for crop evapotranspiration (ETc), effective rainfall (Pe), and water deficit (In) during the growing season of apple, pear, and plum in both grassed and non-grasseded orchards for the observed period (1961 – 2021) in the Kolubara District. It also includes the median values from eight regional climate models for ETc, Pe, and In for the future period (2021 – 2040).

During the observed period, the average seasonal water deficit was 356 mm in grassed orchards and 191 mm in non-grassed orchards, with the highest deficits occurring in July and August, accounting for 60 to 70% of the seasonal water requirements. It's essential to emphasize the importance of monitoring water deficits throughout all growth phases. Sometimes, despite adequate seasonal rainfall, significant deficits and irrigation requirements arise in specific months during the growth phase when rainfall is limited (as shown in Table 4).

Looking ahead to the period from 2021 to 2040, the average seasonal water deficit increases to 401 mm in grassed orchards and 202 mm in non-grassed orchards. This represents a 13% and 6% increase, respectively, compared to the observed period. Notably, the most significant water deficits occur in May, June, July, and August, constituting over 90% of the seasonal deficit, indicating a substantial need for irrigation and comprehensive water management throughout all growth phases. On the other hand, increased rainfall in the early spring and autumn months contributes to a surplus in water balance. These findings underscore the impact of climate change and underscore the importance of conducting comprehensive analyses to recommend and implement appropriate adaptation measures.

While grassed orchards exhibit higher evapotranspiration and water deficits, the practice of grassing orchards in regions with sufficient rainfall creates favorable microclimatic conditions that positively impact fruit quality and soil erosion protection. Stričević et al. (2017) also stress that although grassing orchards increases water requirements, it is preferable, especially on sloped terrain, to protect against erosion.

In Table 5, you'll find data on crop evapotranspiration (ETc), effective rainfall (Pe), and net water deficit (In) during the growing season of apple, pear, and plum for both grassed and non-grassed orchards during the observed period (1961 – 2021) in the Moravički District. It also includes the median values from eight regional climate models for ETc, Pe, and In for the future period (2021 – 2040).

In the observed period, grassed orchards in the Moravički District had an average seasonal water deficit of 400 mm, while non-grassed orchards had a deficit of 235 mm, with the highest irrigation requirements occurring in June, July, and August, representing 80 – 90% of the seasonal water requirement. Looking into the future period (2021 – 2040), due to an increase in overall precipitation, there is a decrease in the seasonal water deficit by 3% in grassed orchards and 16% in non-grassed orchards. However, it's important to note that, despite a projected decrease in water requirements, substantial water deficits and the irrigation requirement remain significant in May, June, July, and August, when effective rainfall is limited. On the other hand, significant rainfall during the early spring and autumn months contributes to the overall seasonal water balance, highlighting the necessity of conducting detailed assessments during each growth phase (as shown in Table 5).

Table 4. Crop evapotranspiration (ETc), effective precipitation (Pe), water deficit (In) during the vegetation season per fruit group for the observed 1961-2021 period and future period of 2021-2040 (Kolubara district)

| Culture | | apple, pear and plum (frost, grassed orchard) | | | | | | | | | apple, pear and plum (frost, non-grassed) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Period** | Month | March | April | May | June | July | August | September | October | Seasonal sum | March | April | May | June | July | August | September | October | Seasonal sum |
| **2061 - 2021** | ETc (mm) | 31 | 64 | 120 | 178 | 188 | 168 | 103 | 59 | 880 | 28 | 59 | 111 | 141 | 149 | 133 | 78 | 44 | 715 |
| | Pe (mm) | 45 | 58 | 85 | 95 | 78 | 63 | 57 | 43 | 524 | 45 | 58 | 85 | 95 | 78 | 63 | 57 | 43 | 524 |
| | **In (mm)** | -15 | 6 | 36 | **83** | **110** | **105** | 45 | 17 | **356** | -17 | 1 | 26 | **46** | **71** | **70** | 21 | 1 | **191** |
| **2021 - 2040** | ETc (mm) | 33 | 73 | 147 | 183 | 192 | 170 | 98 | 56 | 945 | 29 | 60 | 116 | 145 | 152 | 135 | 75 | 41 | 749 |
| | Pe (mm) | 57 | 75 | 63 | 97 | 63 | 58 | 69 | 64 | 556 | 57 | 75 | 63 | 97 | 63 | 58 | 69 | 64 | 556 |
| | **In (mm)** | -15 | 4 | **80** | **83** | **127** | **103** | 19 | -17 | **401** | -20 | -9 | **49** | **46** | **87** | **67** | -4 | -29 | **202** |
| **Difference** | ETc (mm) | 2 | 9 | 26 | 6 | 4 | 3 | -5 | -4 | 65 | 2 | 1 | 5 | 4 | 3 | 2 | -4 | -3 | 34 |
| | Pe (mm) | 12 | 16 | -21 | 2 | -16 | -5 | 12 | 21 | 32 | 12 | 16 | -21 | 2 | -16 | -5 | 12 | 21 | 32 |
| | **In (mm)** | -1 | -1 | **44** | 1 | **16** | -2 | -27 | -33 | **46** | -2 | -10 | **22** | 0 | **16** | -3 | -25 | -30 | **12** |

Table 5. Crop evapotranspiration (ETc), effective precipitation (Pe), water deficit (In) during the vegetation season per fruit group for the observed 1961-2021 period and future period of 2021-2040 (Moravica district)

| Culture | | apple, pear and plum (frost, grassed orchard) | | | | | | | | | apple, pear and plum (frost, non-grassed) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Period** | Month | March | April | May | June | July | August | September | October | Seasonal sum | March | April | May | June | July | August | September | October | Seasonal sum |
| **2061 - 2021** | ETc (mm) | 31 | 65 | 122 | 180 | 192 | 171 | 103 | 59 | 892 | 28 | 60 | 113 | 142 | 152 | 136 | 78 | 43 | 725 |
| | Pe (mm) | 47 | 54 | 77 | 76 | 77 | 59 | 52 | 45 | 489 | 47 | 54 | 77 | 76 | 77 | 59 | 52 | 45 | 489 |
| | **In (mm)** | -16 | 11 | **45** | **104** | **115** | **112** | **50** | 13 | **403** | -19 | 6 | 36 | 66 | 75 | 76 | 26 | -2 | **236** |
| **2021 - 2040** | ETc (mm) | 32 | 71 | 144 | 183 | 190 | 170 | 97 | 53 | 929 | 29 | 59 | 114 | 145 | 150 | 134 | 74 | 39 | 736 |
| | Pe (mm) | 58 | 70 | 62 | 82 | 66 | 55 | 73 | 64 | 536 | 58 | 70 | 62 | 82 | 66 | 55 | 73 | 64 | 536 |
| | **In (mm)** | -19 | 9 | **85** | **101** | **125** | **107** | 17 | -18 | **394** | -23 | -4 | **55** | **63** | **85** | **72** | -6 | -30 | **199** |
| **Difference** | ETc (mm) | 2 | 6 | 22 | 3 | -3 | -1 | -6 | -5 | 37 | 1 | -1 | 1 | 2 | -2 | -1 | -4 | -4 | 11 |
| | Pe (mm) | 12 | 15 | -15 | 5 | -12 | -4 | 21 | 18 | 47 | 12 | 15 | -15 | 5 | -12 | -4 | 21 | 18 | 47 |
| | **In (mm)** | -3 | -2 | **40** | -2 | **10** | -5 | -34 | -31 | **-10** | -4 | -10 | **19** | -3 | **10** | -4 | -32 | -28 | **-37** |

## CONCLUSIONS

The results of this research indicate the water requirements of apple, pear, and plum in the Kolubara and Moravički Districts for the observed period (1961 – 2021) and the future period (2021 - 2040). It can be observed that there is no significant increase in water requirements in the future period compared to the observed period. What is essential to emphasize is the need to analyze the water requirements of fruit orchards during all stages of development because it often happens that the seasonal water deficit does not provide an accurate picture of the actual water needs. During early spring and autumn months, higher rainfall levels reduce the water deficit, while during the summer months (June, July, and August), significant deficits and the need for irrigation arise. The obtained results can assist producers in assessing the risks of water deficit during the fruit growing season and, accordingly, implementing suitable agronomic practices to achieve high-quality and stable yields.

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**REFERENCES**

Abrisqueta, I., Tapia, L., Conejero, W., Sanchez-Toribio, M., Abrisqueta, J., Vera, J., Ruiz-Sánchez, M.C. (2010). Response of early-peach [Prunus persica (L.)] trees to deficit irrigation. Spanish Journal of Agricultural Research. 8.10.5424/sjar/2010. 08S2-1345.

Ahmadyan, M., Sobhani, B., Jahanbakhsh Asl, S. (2019). The effects of climate change on water requirement of apple tree during the growth period. A case study of Orumiyeh and Semirom stations. Journal of Natural Environmental Hazards, Volume 8, Issue 21 - Serial Number 3, September 2019 Pages147-162. http://dx.doi.org/10.22111/JNEH.2019.25340.1410

Allen, R. G., Pereira, L. S., Raes, D., Smith, M. (1998). Crop Evapotranspiration. Guidelins for computing crop water requirements. *Irrigation and drainage paper*, No. 56, FAO Rome.

Calderón-Zavala, G., Lakso, A.N., Piccioni, R.M., (2004). Temperature effects on fruit and shoot growth in the apple (Malus domestica) early in the season. Acta Hortic.636, 447-453.

Ćosić, M., Lipovac, A., Vujadinović Mandić, M., Stričević, R., Đurović, N., Ranković Vasić, Z., Životić, Lj. (2021). Water requirements of fruit and vine plantations in the area of the Kolubara district in present and future conditions. Book of Proceedings. 3rd International and 15th National Congress Serbian Society of Soil Science and University of Belgrade, Faculty of Agriculture „Soils for future under global challenges“ 21-24 September 2021, Sokobanja, Serbia.

Djurdjevic et al. (2021). Data collected and database prepared for the country, region and local level, Project: Development of web-based application and platform for Climate Change Vulnerability Assessments and Adaptation, within the project “Advancing medium and long-term adaptation planning in the Republic of Serbia” (RPF 668), 2021.

FAO (2020). The State of Food and Agriculture. Overcoming Water Challenges in Agriculture; FAO: Rome, Italy, 2020.

IPCC, (2014). *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

Johnson, R. S., Phene, B.C. (2008). Fruit quality disorders in an early maturing peach cultivar caused by postharvest water stress. Acta Hortic.792, 385-390.

Jackson, D. I. (2011). Climate and Fruit Plants. In Temperate and subtropical Fruit production.DI Jackson,D.I., Looney, N.F., Morley-Bunker, M. (Eds.).3rdEdition. CAB International. pp. 11-17.

Marsal, J., Lopez-Gerardo, V., Campo, J., Mata, M., Arbones, A.,Girona, J. (2010). Postharvest regulated deficit irrigation in ‘Summit’ sweet cherry: Fruit yield and quality in the following season. Irrigation Science. 28, 181-189.

Stričević, R., Srđević, Z., Vujadinović-Mandić, M., Sređević B., 2017. Sustainable water respurces and water footprint concept: Application in fruit growing. VODOPRIVREDA 0350-0519, Vol. 49 (2017) No. 288-290 p.

Stričević, R., Trbić, G., Vujadinović Mandić, M., Vuković, A., Lipovac, A., Bogdan, I., Cupać, R. (2019). Assessment of Climate

Change Impact on Water Requirements of Orchards in Bosnia and Herzegovina. In: Climate Change Adaptation in Eastern Europe pp 199-211.

Trbic, G., Popov, T., Djurdjevic, V., Milunovic, I., Dejanovic, T., Gnjato, S., Ivanisevic, M. (2022). Climate Change in Bosnia and Herzegovina According to Climate Scenario RCP8.5 and Possible Impact on Fruit Production. Atmosphere 2022, 13, 1. https://doi.org/10.3390/atmos13010001

Makar, R. S., Shahin, S. A., El-Nazer, M., Wheida, A., Abd El-Hady, M. (2022). Evaluating the Impacts of Climate Change on Irrigation Water Requirements. *Sustainability*, *14* (22), 14833. https://doi.org/10.3390/su142214833

Lipovac, A., Vujadinović Mandić, M., Vuković, A., Stričević, R., Ćosić, M. (2018). Assessment of AquaCrop model on potato water requirements in climate change conditions. Conference proceedings, The 10th Eastern European Young Water Professionals Conference, New Technologies in Water Sector7-12 May 2018 Zagreb – Croatia. p. 70-78.

Vujadinović Mandić, M., Vuković Vimić, A., Ranković-Vasić, Z., Djurović, D., Ćosić, M., Sotonica, D., Nikolić, D., Djurdjević, V. (2022). Observed Changes in Climate Conditions and Weather-Related Risks in Fruit and Grape Production in Serbia. *Atmosphere*, *13*(6), 948. https://doi.org/10.3390/atmos13060948.

Yahyai, R. A. (2012). Managing irrigation of fruit trees using plant water status. Agricultural Sciences, Vol.3, No.1, 35-43 http://dx.doi.org/10.4236/as.2012.31006.