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Use of the WinTR-55 Hydrologic Model on Determination of Flood Peak Discharge: The Case of Kirklareli Vize Stream and Samsun Minoz Stream Watersheds

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Abstract

Climate change is the main parameter affecting water resources. This parameter will exacerbate hydrologic extreme events like drought and flood. Determination of possible peak flow in the agricultural watershed is important in terms of preventing crop losses. The materials and the methods suitable for agricultural watersheds (hydrology) were used in this study. The general aim of this study is to determine the success of estimation power of the Windows Technical Release-55 (WinTR-55) Model. In this study, the peak flows estimated by the WinTR-55 model using the data of the Kirklareli Vize and Samsun Minoz Stream watersheds were compared with the observed peak flows. The most successful estimation was for the 100-year return period with error 25% in the Vize stream watershed and was for the 10-year return period with error 2% in the Minoz Stream watershed. With the aid of the WinTR-55, which tends to predict larger peak flow rates, greater peak flow rates were estimated compared with observed peak flow for each return period. So, it was understood that WinTR-55 can be used for the prevention of flood damage in the Vize and Minoz Stream watersheds confidently. As a result, it is recommended that calculated peak flow in public institutions such as State Hydraulics Works (SHW) should made with the help of the WinTR-55 model.

Keywords
Flood Peak Discharge, Vize and Minoz Stream Watersheds, Wintr-55, Hydrologic Model

Taşkın Pik Debisinin Belirlenmesinde WinTR-55 Hidrolojik Modelinin Kullanımı: Kırklareli Vize Deresi ve Samsun Minöz Deresi Havzaları Örneği

Özet

İklim değişikliği, su kaynaklarını etkileyen başlıca parametredir. Bu parametre, kuraklık ve sel gibi ekstrem hidrolojik olayları şiddetlendirecektir. Tarımsal havzalarda muhtemel pik debilerin belirlenmesi, ürün kayıplarının önlenmesi açısından önemlidir. Tarımsal havzalara (hidrolojiye) uygun materyal ve yöntemin kullanıldığı, bu çalışmanın genel amacı; Windows Technical Release-55 (WinTR-55) modelinin tahmin gücünün başarısını belirlemektir. Bu çalışmada, Kırklareli Vize Deresi ve Samsun Minöz Deresi havzalarının verileri kullanılarak WinTR-55 modeliyle tahmin edilen pik debiler, gözlenen pik debilerle karşılaştırılmıştır. En başarılı tahmin; Vize Çayı havzasında %25 hata ile 100 yıllık tekerrür için, Minöz Çayı havzasında %2 hata ile 10 yıllık tekerrür için gerçekleşmiştir. Daha büyük pik debiler tahminlemeye eğilimli olan WinTR-55 yardımıyla, her bir tekerrür periyodunda gözlenen pik debilere kıyasla, daha büyük pik debiler tahmin edilmiştir. Böylece WinTR-55'in; Vize deresi ve Minöz deresi havzasında taşkın zararlarının önlenmesinde güvenle kullanılabileceği anlaşılmıştır. Sonuç olarak; Devlet Su İşleri (DSİ) gibi kamu kurumlarında hesaplanan pik debinin, WinTR-55 modeli yardımıyla yapılması önerilmektedir.

Anahtar Sözcükler
Taşkın Pik Debisi, Vize ve Minöz Dereleri Havzası, Wintr-55, Hidrolojik Model

1. Introduction

It would be expected that climate change, which will be one of the remarkable events soon, will stimulate hydrologic extreme events like drought and flood. The agriculture sector is very sensitive to the climatic disasters. So, it is thought that usage of hydrologic models as a decision support element helps to prevent from flood damage of farming land simply. In addition, the true prediction of flood peak flow, which is a component of runoff in the hydrologic cycle, is one of the most important factors to affecting construction cost on the dimensioning of the agricultural drainage channels.

The need for easy to use and reliable methods (like the WinTR-55 model) is increasing in institutions dealing with this issue for agricultural watersheds of our country (like Vize and Minoz Stream watersheds). Hydrologic models make it possible to reach different outputs with a series of inputs related to the use of equations, and facilitate the determination of the effect of the change in the peak flow in response to the land-use change (Alkan 2016).

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Various classifications and names of hydrologic models can be summarized as follows:

Event-based hydrologic models simulate individual precipitation-runoff events by focusing on leakage and runoff. Continuous models explicitly consider all flow components and consider the re-change of soil moisture that changes with different storm events (Daniel et al. 2011).

Compared to distributed models, the results of lumped models are easier to interpret due to their simple nature. Lumped models consider the entire basin as a homogeneous system and estimate the flow at the outlet, rather than calculating specific flows in the basin (Poovakka and Eldho 2019).

Some hydrologic models are Gridded Surface/Subsurface Hydrologic Analysis (GSSHA), Precipitation-Runoff Modeling System (PRMS) (Swathi et al. 2020), Xinanjiang precipitation-runoff model, Areal Non-Point Source Watershed Environmental Simulation (ANSWERS), Agricultural Non-Point Source Pollution Model (AGNPS), Kinematic Runoff and Erosion (KINEROS), Water Erosion Prediction Project (WEPP) and Penn State Runoff Model (PSRM) (Daniel et al. 2011). Popular and actual hydrologic models are Hydrologic Engineering Center-Hydrologic Modeling System (HEC-HMS), Soil & Water Assessment Tool (SWAT), MIKE-SHE, Hydrological Simulation Program-Fortran (HSPF), Storm Water Management Model (SWMM) and Watershed Modeling System (WMS) (Alkan 2016).

The WMS, developed by Environmental Modeling Systems at Brigham Young University, is a comprehensive graphical modeling environment for all phases of watershed hydrology and hydraulics. WMS includes information about the watershed description, geometric parameter calculations, Curve Number (CN), precipitation, and roughness coefficients. WMS provides an interface for various Geographic Information Systems (GIS)-based (compatible) hydrology and hydraulics models. Hydrologic modeling components packaged in the system are HEC-HMS, TR-20, TR-55, National Flood Frequency Model (NFF), SWMM, Modified Rational Method Model (MODRAT) and HSPF. Hydrologic Engineering Center-River Analysis System (HEC-RAS), Quantum GIS and CE-QUAL-W2 in the WMS perform hydraulics modeling (Daniel et al. 2011; Gulbaz 2019).

HSPF and SWMM can be used to simulate flow and water quality (point and non-point source pollution). The United States Environmental Protection Agency (USEPA) SWMM is a hydrodynamic, one-dimensional, comprehensive mathematical model that simulates water flow and quality in urban areas. SWMM (hydrologic-hydraulics) model is a lumped parameter and continuous simulation model (Lee et al. 2010). HSPF is a semi-distributed and continuous model that simulates hydrologic and water quality processes. HEC-1, which is developed to simulate hydrologic processes (precipitation, leakage, base flow, flow conversion and translation) in watersheds with an area of 1-100 000 km^2, produces flow hydrographs. MIKE-SHE is a distributed and physically based watershed model that simulates the main processes in the hydrologic cycle (Daniel et al. 2011). Krishna Rao et al. (2018) used to train the artificial neural networks (ANN) using climate parameters. They developed six ANN models. Their results showed that the developed ANN models outperform the empirical models.

The calibration and validation parameters of the models can be summarized as follows:

After the flow simulations (the performance differences of the groups), the statistical significance of the differences at the model performance statistics (eg at the 0.05 significance level), evaluation can be made by using tests such as Mann-Whitney U (M-W) test, t-test and f variance equality test (one-way analysis of variance-ANOVA).

As evaluation criteria in model simulations (in calibration-validation stages), root mean square error (RMSE)-observation standard deviation ratio, percent bias (PBIAS), efficiency index (EI), coefficient of determination (R^2), correlation coefficient (R), absolute error (AE), percent difference (%), relative error (RE) and Nash-Sutcliffe Efficiency (NSE) coefficient can be used (to compare the performance of the models) to evaluate the results of hydrologic modeling (Lee et al. 2010; Yaghoubi et al. 2019; Poovakka and Eldho 2019).

Pearson correlation coefficient, also known as linear correlation coefficient (R), indicates the linear relationship between observations and simulations. R is expected to be greater than 0.5 for successful estimation. During the calibration and validation phase, R is expected to be greater than 0.7 (Poovakka and Eldho 2019). The coefficient of determination (R^2) value is an indication of the strength of the correlation between the measured and estimated values. R^2 ranges from 0 to 1. R^2 and efficiency index (EI) values close to 1 represent a more accurate estimation (Lee et al. 2010).

Many studies have been conducted on hydrologic models in the World. Bauer (2005) combined the TR-55 model with a Genetic Algorithm (GA) and integrated it in AutoCAD Civil 3D 2008. For this process, Visual Basic for Applications (VBA) is used. The study aimed to develop an optimization application for a new retention pool design. Henning (2009) made stormwater modeling of campus of the University of Nevada Reno. The researcher determined peak discharge for the return period by using the WinTR-55 model. Results showed that the south of the campus was durable against the stormwater in terms of hydrologic modeling. Sutjiningsih et al. (2015) aimed to test the feasibility of a modified Schaffernak approach for annual sediment yield estimation in Sugutamu, a small sub-basin in the Ciliwung River. The results showed that it is possible to quantify the sediment yield by using the modified Schaffernak approach with the WinTR-55 application.

Mesta et al. (2019) made the watershed modeling with HEC-HMS. The established model was calibrated using daily data between 1997-2002 and verified using data between 2003-2005. The Nash-Sutcliffe Efficiency (NSE) coefficient for the Yenicegoruce station of the model was calculated as 0.8 and 0.75 for the calibration and validation stages, respectively. Gulbaz (2019) created the hydrologic model of the Sazlıdere Basin in Istanbul and the hydraulics model of the Turkkose Stream. He modeled the physical characteristics of the watershed in his study with WMS.

He used HEC-HMS for the hydrologic model and HEC-RAS for the hydraulics model. As a result, he obtained the flood spread maps of 03–05 July 2005. He modeled that the water depth in the residential area is 5 m and wide of the flood spread is 250 m. Thus, he made the flood analysis of Turkkose Stream with the model and determined the areas that could be affected by the flood in the residential area. Sorman et al. (2020) compared the HEC-HMS and HBV model between 2008-2015 in Aras Basin in Turkey. The performance of both models was evaluated with Nash-Sutcliffe. As a result, the models have a calibration success greater than 0.8 and a validation greater than 0.7 according to discharge values. So, they state that this modeling in the Aras Basin was successful. Gholami and Khaleghi (2021) optimized the initial loss (IL) values in the HEC-HMS model. IL reflects vegetation, infiltration, and antecedent moisture condition (AMC). To simulate the discharge values, they entered the IL values as input into the ANN. After all, forests can increase IL values and reduce discharge. They state that the ANN predictions are more successful than the HMS model.

Lane et al. (2019) used four hydrologic models in 1000 basins in the United Kingdom (UK). The results showed successful simulations in most of the UK. Besides, each model produced simulations over 0.5 Nash-Sutcliffe efficiency for at least 80% of watersheds. All four models produced better simulations in wetter basins in the West and produced unsuccessful results in central Scotland and southeast England. Fidal and Kjeldsen (2020) aimed to investigate the effect of associating soil moisture and urban runoff on precipitation-runoff. They tested their two new conceptual models in 28 urban watersheds in the United Kingdom. Besides, they used the SWMM and MIKE models. Swathi et al. (2020) used different methods for discharge and discharge translation estimation. For discharge translation, the SWMM model uses kinematic wave (KW) and dynamic wave (DW) methods. The SWMM was tested with four precipitation events and was calibrated with six precipitation events. Discharge translation methods KW, DW and Muskingum-Cunge (M-C) have been found to have minor effects on the discharge. Poovakka and Eldho (2019) used the GR4J, Australian Water Balance Model (AWBM) and Sacramento model for flow simulation. These models were calibrated by using the NSE coefficient. During the calibration of the GR4J, AWBM and Sacramento models, four, eight and twenty-two parameters were used, respectively. After all, all models were found to give satisfactory results. However, researchers determined that the GR4J model predicted more successfully than the AWBM and Sacramento models. Citakoglu et al. (2017) did a regional frequency analysis of peak discharge for the Black sea region by using the L-Moments method. The generalized normal distribution was determined to be the best probability distribution in half of the region. Lastly, regional peak discharge maps covering a range of return periods from 2 to 1000 years were produced. Demir and Keskin (2020) aimed to determine Manning roughness coefficient and flood by using remote sensing. They used the HEC-RAS 2D and FLO-2D programs to flood modeling in Samsun-Turkey. Their results showed that the overall classification accuracy was 93% and the kappa coefficient was 91%. Demir and Keskin (2022) aimed to obtain discharge rates by using an unit hydrograph in Mert River-Samsun. For this purpose, they also used the Synder, DSI Synthetic and Mockus methods. The most appropriate statistical distribution was determined by the Kolmogorov-Smirnov (K-S) test. Lastly, the discharge rates were modeled by using the FLO-2D.

Demir and Kisi (2016) prepared the flood risk maps of the Mert Stream watershed, Samsun, by using HEC-RAS and ArcGIS for the 10-year, 25-year, 50-year and 100-year return period. Demir and Keskin (2019) aimed determine the roughness coefficient of Manning by using remote sensing and Cowan method in Mert Stream watershed, Samsun. As a result, the researchers obtained the accuracy and kappa coefficient over the 90% in the classification. Ulke et al. (2017) made numerical modeling of Mert Stream discharges in Samsun by using MIKE model for the 100-year and 500-year return period. Gulbahar (2016) evaluated performance of the conventional flood methods in Istanbul. Some of the methods were unit hydrograph, Rational, Mockus, Snyder and Natural Resources Conservation Service (NRCS). As a result, the researcher found that NRCS method gave minimum discharge while Snyder method gave maximum discharge. Besides, results of unit hydrograph method were closest the actual discharges. In addition, Rational method were more suitable for small watershed (<25 km^2). Lastly, Mockus method gave results closer to the observed discharges compared to Snyder method. Sonmez et al. (2012) aimed to determine discharge values of eight streams in Istanbul. For this, the researchers used NRCS, Mockus, Snyder and Kirpich methods. Ozturk et al. (2003) used Rational, Mockus and DSI synthetic methods to determine peak flow in five streams in Konya and Malatya, Turkey. As a result, Mockus method produced larger peak flow compared to the other methods.

Compared to such hydrologic models in the literature, the WinTR-55 model requires fewer input data and is easy to use to determine peak flow. Besides, the model is more suitable for use in agricultural watersheds (Roberts et al. 2009). Determination of possible peak flow in agricultural watersheds is important in terms of preventing crop losses. In this study, Vize and Minoz Stream watersheds are important because they are agricultural watersheds where cereal production is intense. Besides, these watersheds were investigated because they are located in areas suitable for flash floods (Erel 2010; Bakanogullari and Gunay 2010). Therefore, the importance of the study is that an alternative method (WinTR-55) against the traditional methods (such as Mockus method) were proposed in flood-sensitive agricultural watershed. Flood peak flows are determined by traditional methods (such as Mockus and Rational methods) in institutions of Turkey (such as DSI-State Hydraulics Works and municipalities). This study, which proposes an alternative method for these institutions, also contributes to the literature in this respect.

The general aim of this study is to determine the success of estimation power of the WinTR-55 model in two selected sample agricultural watersheds and to investigate the success of the model against traditional methods (such as Mockus method).

In this study, the peak flows estimated by the WinTR-55 model using the data of the Kırklareli Vize and Samsun Minoz Stream watersheds were compared with the results of the Mockus method and the observed peak flows. The materials and the methods suitable for agricultural watersheds (hydrology) were used.

As a result, in institutions of Turkey, it was recommended to use the reliable and actual method (WinTR-55 model) in agricultural watershed. These situations show the originality side of this study.

2. Material and Methods

2.1. Kirklareli-Vize Stream Watershed

The Vize Stream watershed is located in the Topcu village of Vize County allied with Kirklareli Province. The Vize Stream flows into the Meric River. The research area is in the Thrace Region of Turkey. The average elevation of the watershed is 215 meters (Figure 1). The location of the watershed output is between (North) Latitude 41.3053 and (East) Longitude 27.4120. It is 185 meters above from the sea level. The watershed consists of heathland 2.74 km^2 (58.6%), cereals 1.88 km^2 (40.5%) and vegetables 0.02 km^2 (8%) (Bakanogullari and Gunay 2010).

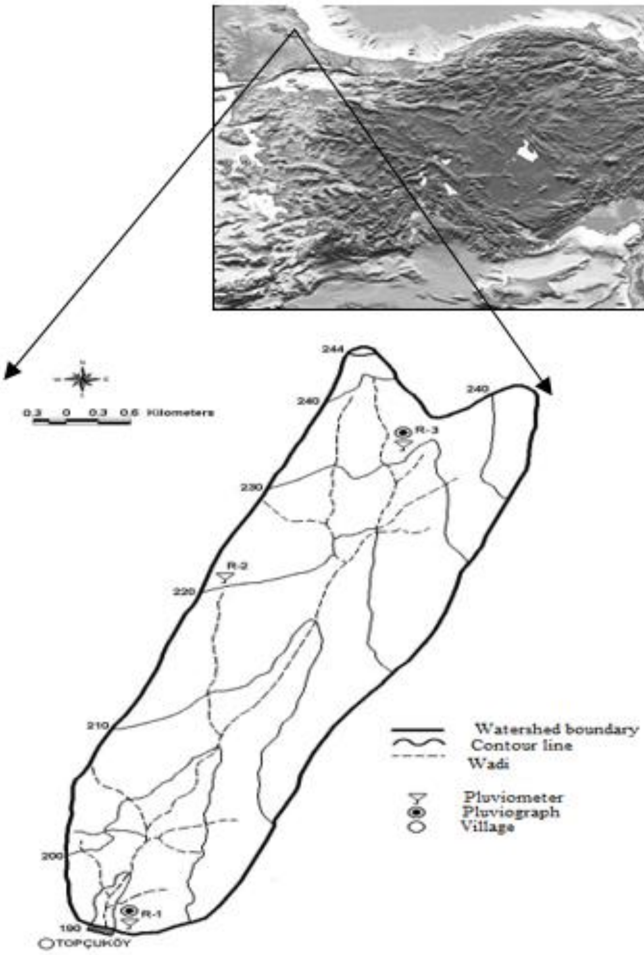

Figure 1: Topographic map and location of the Vize Stream watershed (Bakanogullari and Gunay 2010)

Watershed characteristic, one of the inputs data of the WinTR-55 model, is in Table 1. Circadian (24-hours) rainfall amount, the other inputs data of the WinTR-55 model, is in Table 2. According to the result of the K-S test, the best distribution in terms of rainfall values was Gama-2 for Vize Stream watershed in Table 2.

Table 1: Used watershed characteristics of the Vize Stream watershed in the WinTR-55 model (Bakanogullari and Gunay 2010)

Watershed characteristics	Value
Watershed area	4.64 km^2
Main waterline length	4.5 km
Watershed average slope	3%
Watershed curve number	70.6
Time of concentration	3.45 hours

Table 2: Used circadian rainfall amount of the Vize Stream watershed in the WinTR-55 model (Bakanogullari and Gunay 2010)

Return period (year)	Circadian rainfall amount (mm)
2	53.3
5	61.5
10	64.6
25	67.2
50	68.3
100	69.4

2.2. Samsun-Minoz Stream Watershed

The Minoz Stream watershed is located in Cakalli village of Kavak County allied with Samsun Province. The watershed has an area of 7.89 km^2 and the watershed outlet is 430 m above sea level. The research watershed is located within the F-36-d1 sheet on the 1/25000 scale topographic map and between the coordinates 253500-257500 m E and 4559500-4557500 m N (UTM). The research area is in the Black Sea Region of Turkey. The average elevation of the watershed is 664 meters (Figure 2).

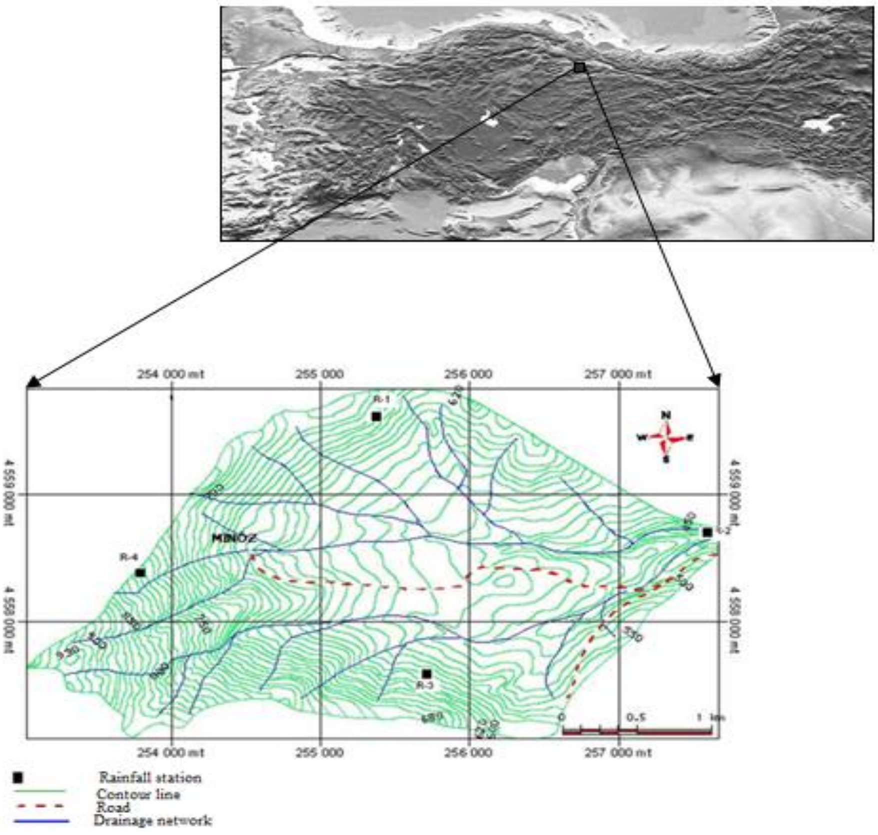

Figure 2: Topographic map and location of the Minoz Stream watershed (Erel 2010)

Watershed characteristic, one of inputs data of the WinTR-55 model, is in Table 3. Circadian rainfall amount, the other inputs data of the WinTR-55 model, is in Table 4. According to the result of the K-S test, the best distribution in terms of rainfall values was Pearson type-3 for Minoz Stream watershed in Table 4 (Erel 2010).

Table 3: Used watershed characteristics of the Minoz Stream watershed in the WinTR-55 model (Erel 2010)

Watershed area	**7.89 km^2**
Main waterline length	4.93 km
Watershed average slope	15%
Watershed curve number	74
Time of concentration	1.51 hours

The land-use and vegetation status of the watershed are as follows: Dry farming is carried out in the watershed. Wheat, corn and tobacco are the main crops in the watershed. The watershed consists of hoe crops (4%), cereals (15.57%), pasture (5.76%), village settlement (5.76%), degraded forest (25.4%) and empty land (43.52%) (Erel 2010).

Table 4: Used circadian rainfall amount of the Minoz Stream watershed in the WinTR-55 model (Erel 2010)

Return period (year)	**Circadian rainfall amount (mm)**
2	38.60
5	48.05
10	52.75
25	57.59
50	60.62
100	63.28

2.3. WinTR-55 Model

NRCS-TR 55 method, uses for determining flood peak flow in small watersheds, needs circadian rainfall amount data. The WinTR-55 computer simulation model, which uses the NRCS-TR 55 method, calculates flood peak flows with the following equation (Huffman et al. 2013; Alkan 2016).

$$q_p = q_u \text{ A Q } F_p \quad (1)$$

where q_p= Peak runoff flow (m^3/s), q_u= Unit peak runoff flow (km^2/cm) A= Watershed area (km^2), Q= Runoff depth, which consists of a circadian rainfall of the desired return period (mm)
F_p= Swamp and pond adjustment factor (From Table 5)

Table 5: Adjustment factor, F_p (Huffman et al. 2013)

Percentage of swamp and pond area in watersheds	$\boldsymbol{F_p}$
0.0	1
0.2	0.97
1	0.87
3	0.75
5	0.72

q_u can be determined from various schedules depending on the concentration duration (Equation 1). If the user wants to manually calculate the time of concentration, it is recommended to use the following equation.

$$T_c = L^{0.8}\left[\frac{\left(\frac{1000}{CN}-9\right)^{0.7}}{4407(S_g)^{0.5}}\right] \quad (2)$$

where *Tc*: Concentration duration (hour), *L*: Length of the longest waterway, which is from the farthest point of the watershed to the watershed outlet (meter), *CN*: Runoff curve number, S_g: Average watershed slope (m/m).

The limitations in Table 6 must be considered for the WinTR-55 model to operate without error.

Table 6: Limitations and capabilities of the WinTR-55 model (Roberts et al. 2009)

Variables	Limitations
Minimum area	0.4047 hectare
Maximum area	6500 hectare
Concentration duration for any sub-area (hour)	$0.1 \leq Tc \leq 10$
Reach routing (Translation method)	Muskingum-Cunge
Rainfall duration	24 hours
Antecedent Moisture Condition	2
CN	40-98

The Win TR-55 model can determine peak flow rates for 2, 5, 10, 25, 50 and 100-years recurrent rainfall using Type II rainfall distribution and 24-hours rainfall time. The Win TR-55 model is based on the NRCS-CN method. This is the most widely used rainfall-runoff model in the United States of America (USA). TR-55 can calculate flow volume, hydrographs, peak flow and required storage volume for floodwater reservoirs. CN is based on hydrologic soil group, land cover type and antecedent moisture condition (Bauer 2005).

In the WinTR-55, a hydrograph can be created for each sub-basin. The hydrograph translation method used in this model is the Muskingum-Cunge method. Muskingum-Cunge (M-C) method is used as a delay method in drainage channels. This method is widely used in basins where there is no observed flow data. M-C model parameters such as storage coefficient and weight factor are determined according to the channel properties. The use of the M-C method is very popular due to the scarcity of calibration data and the availability of channel size data (Swathi et al. 2020).

2.4. Mockus Method

Mockus method is easy to use and to draw hydrograph (as triangular). The method can be applied to watershed areas with a time of concentration (Tc) of up to 30 hours. In larger areas, the watershed area is divided into subbasin parts and the hydrograph to be drawn for each part are superposed according to the lag times (Ozturk et al. 2003; Sonmez et al. 2012; Gulbahar 2016). The formulas of the method are as follows (Gulbahar 2016),

$$Tc = 0.00032\ ({L_h}^{0.77}/S^{0.385}) \quad (3)$$
$$D = 2\sqrt{Tc} \quad (4)$$
$$\Delta D = Tc/S \quad (5)$$
$$Tp = 0.5\Delta D + 0.6\ Tc \quad (6)$$
$$q_p = K.A/Tp \quad (7)$$
$$Q_p = q_p h_a \quad (8)$$

Where Tc: Time of concentration (hour), L_h: The length of watershed area (meter), S: Average slope of watershed area (%), D: Time of duration of precipitation (hour), ΔD: Time of heavy precipitation (hour), Tp: Time of duration for peak flow (hour), h_a: Annual precipitation depth (cm), K: Coefficient of watershed (between 0.2 and 1.6), q_p: Flow generated by 1 mm precipitation, Q_p: Flow generated by (2, 5, 10, 25, 50, 100 years) precipitation (m^3/sec)

2.5. Kolmogorov-Smirnov Test (Frequency Analysis)

Kolmogorov-Smirnov (K-S) test is based on the examination of two cumulative distributions function. The first function is cumulative distributions in H_0 hypothesis. The second function is the observed cumulative distributions from the sample in H_1 hypothesis (Demir and Keskin 2022). The hypothesis of K-S test (o: observed, e: estimated):

H_0: $O_v = E_v$ (The observed frequencies match the estimated frequencies.)
H_1: $O_v \neq E_v$ (The observed frequencies do not match the estimated frequencies. The difference is important.)

$$\Delta = \max \left| F_0 - F_e \right| \quad (9)$$

Δ: The test statistic, which is the largest of the absolute difference between the cumulative relative frequencies of the observed and estimated values.
F_0: Observed cumulative relative frequencies, F_e: Estimated cumulative relative frequencies.
If $\Delta_c < \Delta_t$, H_0 is accepted (H_1 is rejected)
Δ_t: Obtained critical value from the K-S test table for the Δ statistic
Δ_c: Calculated critical value from the sample for the Δ statistic

2.6. Calibration and Validation of the Model

Nash-Sutcliffe (NSE) is used to test the predictive power of hydrologic models. NSE takes values between $-\infty$ and 1. When NSE is equal to 1, it means that the observed and estimated flow are in perfect agreement, that is, the modeling is successful. NSE values between 0.50-0.65 are reported to be acceptable and NSE values between 0.65-0.75 are reported to be good. R^2 values greater than 0.6 are acceptable (Mesta et al. 2019; Poovakka and Eldho 2019).

The coefficient of determination (R^2), Nash-Sutcliffe (NSE) and absolute percent error (%) calculation equations are shown below (Abdi and Ayenew 2021). In equations, G: Observed, T: Estimated values.

$$R^2 = \frac{(\sum(G_i-\bar{G})(T_i-\bar{T}))^2}{\sum(G_i-\bar{G})^2\sum(T_i-\bar{T})^2} \quad (10)$$

$$\text{NSE} = 1 - \frac{\sum(G_i-T_i)^2}{\sum(G_i-\bar{G})^2} \quad (11)$$

$$\text{Absolute percent error (\%)} = \text{I} \frac{T-G}{G} \text{I X } 100 \quad (12)$$

3. Results

The Vize and Minoz Stream watersheds had a peak value of observed flow. The distribution that best matches the peak flow in return periods was determined using statistical distributions. For this purpose, the most appropriate distribution was determined by the K-S test (by using observed flow). According to the result of the K-S test, the best distribution was Gama-2 in Vize Stream watershed and was Pearson type-3 in Minoz Stream watershed. So, the flow results of Gama-2 were accepted as an observed flow for Vize Stream watershed and the flow results of Pearson type-3 were accepted as an observed flow for Minoz Stream watershed. In general, the estimations in the Minoz Stream watershed were more successful than the estimations in the Vize Stream watershed (R^2:0.99>0.91).

3.1. Results Related to the Kirklareli-Vize Stream Watershed

The WinTR-55 flows were compared with the observation flows, because WinTR-55 model was more successful in estimation phase compared to Mockus method. The observed values (frequency analysis results of the observed flows in the Vize stream watershed) and estimated values of the model were shown in Table 7. The graphic representation of Table 7 is presented in Figure 3. As the return period increases, the estimated and observed flows converge to each other (Figure 3). According to literature (Mesta et al. 2019; Poovakka and Eldho 2019), NSE and R^2 values greater than 0.6 are acceptable. In the Vize stream watershed, considering the R^2 value (0.9), NSE (0.7) value and the absolute percent error (%) of the observed and predicted flow rates, it can be said that the estimation is successful. The most successful estimation was for the 100-year return period with error 25% in Table 7.

Table 7: The analysis of estimated and observed peak flow values with WinTR-55 model in Kirklareli-Vize Stream watershed

Return period (year)	Estimated flow with Mockus method (m^3/sec)	Estimated flow with WinTR-55 model (m^3/sec)	Observed flow (Gama-2) (m^3/sec)	Difference between estimated and measured flow (m^3/sec)	Difference between estimated and measured flow, absolute percent error (%)
2	0.83	0.59	0.15	0.44	293
5	3.53	0.84	0.34	0.5	147
10	7.39	0.94	0.47	0.47	100
25	15.87	1.03	0.63	0.4	63
50	25.71	1.06	0.75	0.31	41
100	39.3	1.1	0.88	0.22	25

In the Vize Stream watershed, the WinTR-55 method found results farther from the measured flow rates at low return periods, while it found closer results as the return periods got larger. Estimated flow rates followed a nearly curvilinear line. In terms of logarithmic distribution, the observed flows fitted the logarithmic distribution more than the estimated flows (R^2:0.99>0.89) (Figure 3).

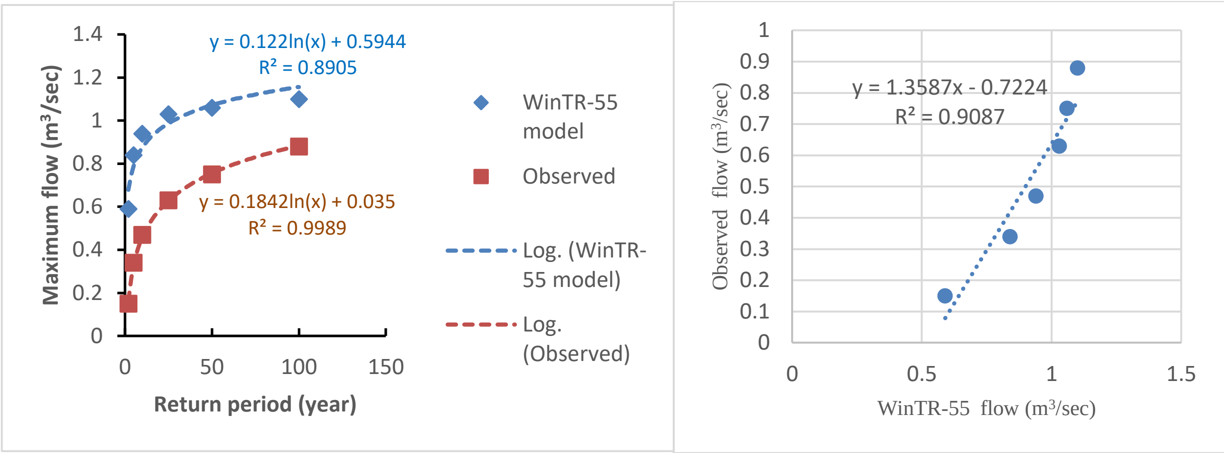

Figure 3: A comparison chart of flow values observed with peak flow values modeled by WinTR-55 in Kırklareli-Vize Stream watershed and the scatter diagram (Bakanogullari and Gunay 2010)

3.2. Results Related to the Samsun-Minoz Stream Watershed

The WinTR-55 flows were compared with the observation flows, because WinTR-55 model was more successful in estimation phase compared to Mockus method. The observed values (frequency analysis results of the observed flows in the Minoz stream watershed) and estimated values of the model were shown in Table 8. The graphic representation of Table 8 is presented in Figure 4. It was seen that the estimated with WinTR-55 and observed flows rates are very compatible with each other in various return periods and follow a curvilinear line (Figure 4). According to literature (Mesta et al. 2019; Poovakka and Eldho 2019), NSE and R^2 values greater than 0.6 are acceptable. In the Minoz Stream watershed, considering the R^2 value (0.98), NSE (0.88) value and the absolute percent error (%) of the observed and predicted flow rates, it can be said that the estimation is successful. The most successful estimation was for the 10-year return period with error 2% in Table 8.

Table 8: The analysis of estimated and observed peak flow values with WinTR-55 model in Samsun-Minoz Stream watershed

Return period (year)	Estimated flow with Mockus method (m^3/sec)	Estimated flow with WinTR-55 model (m^3/sec)	Observed flow (Pearson type-3) (m^3/sec)	Difference between estimated and measured flow (m^3/sec)	Difference between estimated and measured flow, absolute percent error (%)
2	0.29	1.26	1	0.26	26
5	0.4	3	2.8	0.2	7
10	0.47	4.11	4.2	0.09	2
25	0.54	5.37	6	0.63	11
50	0.58	6.22	7.4	1.18	16
100	0.63	7.02	8.8	1.78	20

In the Minoz Stream watershed, the WinTR-55 method found results closer to the measured flow rates at low return periods, while it found farther results as the return periods got larger. Compared to the observed flow rates, the WinTR-55 model estimated greater flow at low return periods and it estimated lower flow at large return periods In terms of logarithmic distribution, the observed flows fitted the logarithmic distribution more than the estimated flows (R^2: 1 > 0.99) (Figure 4).

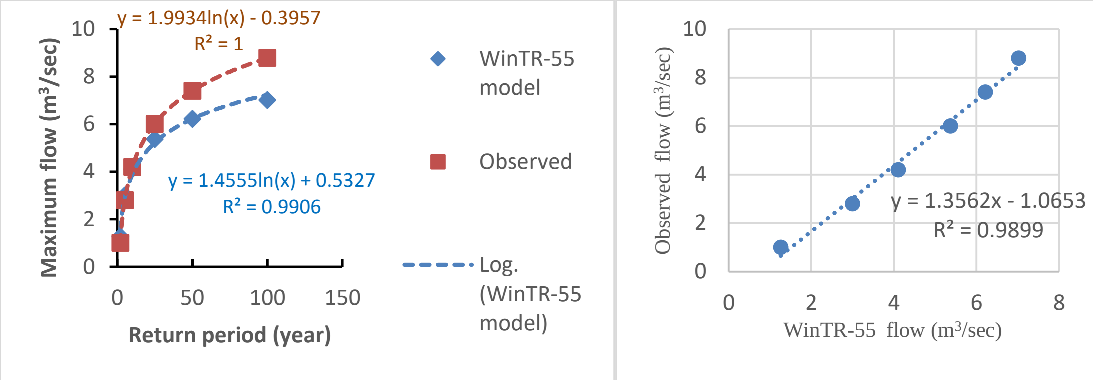

Figure 4: A comparison chart of flow values observed with peak flow values modeled by WinTR-55 in Samsun-Minoz Stream watershed and the scatter diagram (Erel 2010)

4. Discussion and Conclusion

According to Alkan (2016), the WinTR-55 model tends to determine a larger peak flow value than other determination methods of synthetic peak flow. According to Roberts et al. (2009) and Sutjiningsih et al. (2015) the WinTR-55 model requires fewer input data and is easy to use to determine peak flow and sediment yield. On the other hand, the model produces more reliable results in small watersheds. According to Gulbahar (2016) NRCS method tends to give minimum discharge and unit hydrograph method tends to be close to actual discharges. Besides, Rational method are more suitable for small watershed. According to Sonmez et al. (2012) NRCS method is simple, physical and successful. Besides, Snyder method tends to predict larger peak flow while Mockus and NRCS methods tends to predict smaller peak flow. To choose the right method, area and slope of the watershed should be take into account. According to Ozturk et al. (2003) Mockus method tends to produce larger peak flow compared to Rational and DSI synthetic method. Besides, Mockus method is more reliable because it takes into account efficient watershed parameters compared to the other methods.

Watershed characteristics (such as area and slope) are effective in choosing the right method. Like the Rational method, the WinTR-55 model is suitable for small watershed. The results of the Mockus method are more variable and sensitive depending on the watershed characteristics. Therefore, the WinTR-55 model, which uses less and more effective input data, is more advantageous compared to the other methods.

By using the WinTR-55 model, larger peak flows than the actual peak flows were estimated in this study. The WinTR-55 model, which tends to predict larger peak flow rates, shows that the model can be safely used in the Vize Stream watershed to be protected from flood damage.

Materials and methods suitable for agricultural watersheds (hydrology) were used in this study. Moreover, in institutions of Turkey, it was recommended to use the reliable and actual method (WinTR-55 model) in agricultural watershed. This situation shows the originality of the study.

Compared to the hydrologic models in the literature, the WinTR-55 model requires fewer input data and is easy to use to determine peak flow. Besides, the model is more suitable for use in agricultural watersheds. Determination of possible peak flow in agricultural watersheds is important in terms of preventing crop losses. In this study, Vize and Minoz Stream watersheds are important because they are agricultural watersheds where cereal production is intense. Besides, these watersheds were investigated because they had areas suitable for flash floods.

The distribution that best matches the rainfall-flow in return periods is determined using statistical distributions. For this purpose, the most appropriate distribution can be determined by the K-S test (by using observed rainfall and flow). According to the result of the K-S test in terms of rainfall and flow, the best distribution was Gama-2 in Vize Stream watershed and was Pearson type-3 in Minoz Stream watershed.

In the Kirklareli Vize Stream watershed, corresponding to 2, 5, 10, 25, 50 and 100 year return periods, estimated peak flows by using WinTR-55 were determined 1.40 m^3/sec, 2.29 m^3/sec, 2.67 m^3/sec, 3.00 m^3/sec, 3.15 m^3/sec and 3.30 m^3/sec, respectively. In the Samsun Minoz Stream watershed, corresponding to 2, 5, 10, 25, 50 and 100 year return periods, estimated peak flows by using WinTR-55 were determined 2.66 m^3/sec, 6.86 m^3/sec, 9.55 m^3/sec, 12.66 m^3/sec, 14.76 m^3/sec and 16.68 m^3/sec, respectively. The most successful estimation was for the 100-year return period with error 25% in the Vize stream watershed and was for the 10-year return period with error 2% in the Minoz Stream watershed.

The estimation of the peak flow was more successful in the Minoz watershed compared to the Vize watershed because the estimated values were much closer to observed values in the Minoz watershed. Even so, the WinTR-55 model can be safely used in the Vize Stream watershed to be protected from flood damage because the estimated values were higher than observed values in the Vize watershed.

There are serious problems in reaching the correctly measured data of flood peak flows in watersheds. The number of basins with measured peak flow values is few. It is thought that it will be useful to compare the peak flow rates of these basins with the WinTR-55 model results.

It is recommended that institutions of Turkey (such as State Hydraulics Works and municipalities) should determine peak flows in agricultural watersheds with hydrologic models (such as WinTR-55) instead of traditional methods (such as Mockus and Rational methods). The zoning plans of important areas should be made by using the hydrologic models in basins. Endangered places can be determined with the help of flood spread maps. As a result, the regions to be opened for settlement can be created according to these findings.

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