Biyosistem Mühendisliği Dergisi
Journal of Biosystems Engineering

Biyosistem Müh Derg 3(2):67-77, 2022
J Biosystems Eng 13(2):66-77, 2022

Araştırma Makalesi/Research Article
ISSN: 2757-8100

Winter Precipitations Values and Possible First Irrigation Time Under Different Planting Patterns in Konya Plain

Ali Fuat TARI[1], Barış BAHÇECİ[2*]

[1]Susuz Mah. 2. İnönü Cad. No:31 D:28 Yenimahalle-Ankara, Türkiye
[2]Adana Çukurova Üniversitesi, Ziraat Fakültesi, Tarımsal Yapılar ve Sulama Bölümü, Adana, Türkiye

Alınış tarihi: 02 Haziran 2022 Düzeltilme tarihi: 15 Ağustos 2022 Kabul tarihi: 26 Kasım 2022

Abstract: In this study, the effects of different rotation systems on the storage of winter precipitation in the soil profile in the Konya plain were investigated. Konya plain is a semi-arid region, and a large part of the agricultural lands are left fallow in the parts where irrigation is not possible so that the winter precipitation remains in the next year. In the experiments, moisture observations were made in the fields cultivated with alfalfa, wheat, sugar beet, wheat, and bean plots processed in rotation. As a result of observations and measurements made over four years, in all trials, soil moisture reached its highest level, at the beginning of March, at a soil depth of 120 cm. The effect of sowing patterns on moisture accumulation is insignificant. While the moisture decreases between March and April were found to be statistically significant, it is understood that the moisture loss is mainly in April. As a matter of fact, due to the moisture loss, a significant difference was not found between the soil moisture contents in April and May. Analyzing long-year climate data showed that the dam gates must be opened in April, and water must be given to the plain to prevent product losses due to drought.

Key words: precipitations, soil moisture, crop rotation, Konya plain

Konya Ovasında Farklı Ekim Nöbetleri Altında Kıştan Kalan Nem Değerleri ve Olası İlk Sulama Zamanı

Received:02 June 2022 Received in revised: 15 August 2022 Accepted: 31 November 2022

Özet: Bu çalışmada, Konya ovasındaki toprak profilinde kış yağışlarının depolanmasına farklı rotasyon sistemlerinin etkileri araştırılmıştır. Konya ovası yarı kurak bir bölge olup, tarım arazilerinin büyük bir kısmı sulamanın mümkün olmadığı kısımlarda nadasa bırakılarak kış yağışları bir sonraki seneye bırakılmaktadır. Denemelerde yonca, buğday, şeker pancarı, buğday ve münavebe ile işlenen fasulye parselleri ile yetiştirilen tarlalarda nem gözlemleri yapılmıştır. Dört yıl boyunca yapılan gözlem ve ölçümler sonucunda tüm denemelerde toprak nemi en yüksek değerine Mart ayı başında 120 cm toprak derinliğinde ulaşmıştır. Ekim desenlerinin nem birikimi üzerindeki etkisi önemsizdir. Mart-Nisan ayları arasındaki nem düşüşleri istatistiksel olarak önemli bulunurken, nem kaybının ağırlıklı olarak Nisan ayında olduğu anlaşılmaktadır. Nitekim Nisan ve Mayıs aylarında toprak nem içerikleri arasında yüksek nem kaybı nedeniyle önemli bir farklılık bulunmamıştır. Uzun yıllara ait iklim verileri incelendiğinde kuraklıktan kaynaklanan ürün kayıplarını önlemek için baraj kapaklarının Nisan ayında açılması ve ovaya su verilmesi gerektiği ortaya çıkmıştır.

Anahtar kelimeler: Yağış , toprak nemi, ekim deseni, Konya ovası
To Cite: Tari A., B.Bahceci, 2022. Winter Precipitations Values and Possible First Irrigation Time Under Different Planting Patterns in Konya Plain. Journal of Biosystems Engineering 3(2):67-77,2022

1. Introduction

Turkey, which is in the semi-arid climate zone, receives less than 400 mm of precipitation per year on 16% of its surface area. The least precipitation falls around Iğdır, Konya Karapınar, Şanlıurfa-Akçakale, and annual precipitation amounts are around 225-250 mm (DMİ, 2018). In addition, the distribution of precipitation over the seasons is also unfavourable for plants.

Almost half of Turkey's surface area receives less than 50 mm of precipitation in summer. Summer drought is an important problem for Turkey. Therefore, in regions where there are no irrigation systems, plants have to meet the water they will use during the summer growing period only with the water accumulated in the soil from winter and spring precipitation (https://cuesa.org/markets).

In many regions where the plant growing season is dry, winters are relatively wet. Where precipitation falls in the form of snow, the soil moisture content is usually higher in the spring. While some of the precipitation, which is the source of soil moisture, is lost due to various reasons, evaporation, runoff, and deep percolation, a part of precipitation accumulates in the soil profile. In this context, the accumulation of winter precipitation in the soil is of agricultural importance.

The accumulation or storage of precipitation in the soil profile is affected by various factors. Although their water holding capacity is dependent on the soil's structure, the water holding capacity of organic matter-rich clay soils is higher than the others. The topographical structure, soil texture, land direction, and the type of precipitation affect the storage of water in the soil at different levels. On sloping lands, some of the precipitation goes away without infiltrating the soil. Likewise, heavy rains increase surface runoff, while hot and windy weather increases evaporation and reduces the storage of precipitation in the soil. Deep percolation in sandy soils, surface flow is more in clay soils. Moisture loss in the soil is higher in south-oriented lands.

Numerous previous studies have revealed that soil moisture content is severely affected by different land uses (Wang et al., 2013), and environmental factors such as topography (Famiglietti et al. 1998, Zhang et al., 2010), soil temperature, solar radiation, vapor pressure differences (Shouqin et al., 2014), precipitation intensity (White et al., 2008) and more (Ivanov et al., 2010). In comparative tests involving various land-use models, the soil moisture content of bare land has always been found to be the highest (Morris et al., 1994).

Various cultural measures are being developed to increase the accumulation of winter precipitation in the soil. However, in practice, all of the methods have shown positive and negative sides. One of these is the widely practiced conservation agriculture (Birkás et al., 2017), which can prevent the loss of arable land while renewing degraded lands. Conservation agriculture envisages farming with an understanding that supports the preservation of a permanent land cover, minimal soil degradation, and the diversification of plant species (Donovan, 2020).

Crop rotation – growing different types of crops every season helps improve soil structure and thus water holding capacity. Examples include rotating deep-rooted and shallow-rooted crops that make use of previously unused soil moisture (Agriinfo, 2015; Namirembe et al., 2015), as plants draw water from different depth levels within the soil. Cultivation of many plant species, reaching different depths of their roots (FAO, 2003,) allows more use of nutrients and water in various layers of the soil profile. Thus, nutrients and water in various layers of the soil profile are taken up by the roots of many different plant species, making more use of the available nutrients and water (Shaozhong, 2002).

Where annual precipitation ranges from 250 to 350 mm and there are snowfalls, it has become common practice to keep crop residues at the surface, increasing water availability for wheat, and promoting greater moisture retention along with the soil profile. With the application, cover crops are 11 to 14 percent more productive than conventional fields during drought years (FAO, 2003). Today, where sustainable agriculture is under threat due to lack of water, the importance of water conservation is increasing day by day. Therefore, in this study, the effects of different rotations and autumn wheat irrigation on the accumulation of winter precipitation were examined by monitoring the soil moisture in the parcels that are widely applied in the closed basin of Konya and where different rotations are applied.

2. Material and Method

2.1. Research site

The research location is Konya Plain. The average altitude from the sea is about 1000 m, and the slope of the plain soils, which topographically shows the characteristics of the bottom land, varies between 0-0.5%.

Figure 1. Geographic location of the trial site, (Berke et al., 2014)

2.2. Soil properties

The experimental site soils are composed of alluvial soils formed on the clay deposits carried by the Meram creek and alluvial soils formed on the Neogene age lacustrine-derived lake deposits. The soils are in the ground state and are clay, clay loam and silty loam textured, very calcareous in fine granular structure, and poor in organic matter. There is no salinity problem in soils with a slightly alkaline reaction. Considering the soil properties related to irrigation; For 120 cm depth, field capacity is 435 mm and available water is 198 mm (Table 1) (Atalay and Secerli, 1971).

Table 1. Soil properties of the experimental site

Depth cm	Sandy %	Clay %	Silty %	Texture	Lime %	FC %	PWP %	BD gr cm^{-3}
0-15	13.05	70.52	16.43	C	23.7	32.32	17.56	1.27
15-30	13.52	67.5	18.98	C	22.8	28.57	15.53	1.26
30-60	11.43	69.59	18.88	C	36	31.4	17.06	1.27
60-90	9.11	73.89	16.91	C	27.9	28.94	15.73	1.24
90-120	8.52	74.47	17.01	C	36.7	25.39	13.8	1.23

FC; field capacity, PWP, permanent wilting point, BD; bulk density

2.3. Climatology

Konya plain, located in a semi-arid region, has typical continental climate characteristics. Hot and dry summers, cold and snowy winters. Considering the long years in the Konya closed basin, which has semi-arid climate characteristics, it can be said that there has been a decrease of 10-25 mm in precipitation in the last 30 years. This situation shows that the climate character of the region has shifted from semi-arid climate type to arid climate type. Especially throughout the Basin, precipitation decreases towards the end of spring, and decreases to almost non-existent levels in summer. Since 70% of the precipitation falls outside the plant growing period, the Basin is among the second-degree arid areas of Turkey (https://www.wwf.org.tr/, 2014).

Table 2. Climatic data for the experiment years

		Months												
Years		10	11	12	1	2	3	4	5	6	7	8	9	Sum/av
1.	Precipitation (mm)	0.3	85.0	46.4	50.4	22.1	56.0	19.1	8.1	29.1	24.1	.	.	340.6
	Aver. temp. (ºC)	10.7	2.2	-0.5	1.2	3.1	-0.8	8.8	15.6	19.1	22.3	20.7	16.9	9.9
	Evaporation (mm)	107.6	10.8	.	.	.	.	114.4	169.1	195.4	260.0	227.3	171.0	1252.6
	Rel Humidity (%)	57.0	75.0	72.0	73.0	71.0	72.0	59.0	52.0	53.0	48.0	46.0	45.0	60.0
	Wind Speed (m s^{-1})	1.5	2.0	2.4	2.4	2.0	2.8	3.4	2.8	2.8	3.2	2.4	1.5	2.5
2.	Precipitation (mm)	24.7	56.6	55.2	6.4	35.0	24.7	44.8	48.5	24.9	19.1	0.3	1.0	341.2
	Aver. temp. (ºC)	10.5	4.4	2.0	0.6	2.2	3.8	10.6	15.6	19.3	22.6	21.5	17.0	10.8
	Evaporation (mm)	84.1	6.1	.	.	.	.	93.6	155.7	180.6	255.6	239.8	166.0	1181.5
	Rel Humidity (%)	63.0	75.0	78.0	79.0	70.0	66.0	65.0	56.0	54.0	49.0	45.0	50.0	62.0
	Wind Speed (m s^{-1})	2.5	1.8	2.3	1.6	2.7	3.5	2.2	2.3	2.3	3.2	2.8	2.0	2.4
3.	Precipitation (mm)	60.1	72.6	14.5	32.3	2.6	24.9	1.2	43.0	2.2	.	.	2.2	255.6
	Aver. temp. (ºC)	10.4	1.5	2.7	-7.8	-3.9	7.3	15.1	16.0	19.9	23.0	23.0	17.7	10.4
	Evaporation (mm)	70.6	14.8	.	.	.	.	158.8	179.6	202.6	263.8	244.0	168.2	1303.3
	Rel Humidity (%)	73.0	76.0	78.0	75.0	74.0	60.0	45.0	52.0	47.0	44.0	42.0	52.0	60.0
	Wind Speed (m s^{-1})	1.5	1.9	2.0	1.7	2.4	2.3	2.2	2.3	1.8	2.9	2.0	1.7	2.0
4	Precipitation (mm)	43.5	57.6	11.9	17.8	24.9	4.2	16.5	46.4	8.5	1.1	.	37.0	269.4
	Aver. temp. (ºC)	9.8	6.2	-0.5	-0.5	0.2	5.4	10.4	13.9	19.0	23.2	20.3	164.1	9.9
	Evaporation (mm)	79.1	27.2	.	.	.	.	101.9	139.8	204.7	261.2	1229.7	141.7	1185.3
	Rel Humidity (%)	71.0	72.0	83.0	73.0	76.0	57.0	56.0	61.0	50.0	48.0	49.0	57.0	63.0
	Wind Speed (m s^{-1})	1.8	2.3	1.7	1.4	2.9	3.0	3.0	2.3	2.7	3.0	2.6	1.6	2.4
	*****Monthly precipatation, (mm)**	**29.8**	**32.5**	**43.6**	**37.8**	**28.5**	**29.1**	**32.1**	**43.4**	**25.7**	**7.0**	**6.3**	**13.4**	**329.2**

****Observation period 1919-2020 ; https://www.mgm.gov.tr/*

2.4. Crops and crop rotations

A: Alfalfa. Alfalfa plots during the whole experiment

B: Wheat + Sugarbeet + Wheat + Beans.

Wheat planted in October was irrigated to bring the soil depth of 30 cm to the field capacity, and after the harvest, the soil was processed and left for the winter. In the second year, sugar beet was planted and the same procedures were continued throughout the experiment.

C: Wheat + Sugarbeet + Wheat – Beans

Wheat planted in October was irrigated to bring the soil depth of 30 cm to the field capacity, and after the harvest, the soil was not processed and left for the winter. In the second year, sugar beet was planted and the same procedures were continued throughout the experiment

D : Wheat + Sugarbeet + Wheat + Beans

Wheat crop planted in October was irrigated to bring the soil depth of 30 cm to the field capacity, and after the harvest, the soil was left for the winter without being cultivated. In the second year, sugar beet was planted and the same procedures were continued throughout the experiment.

E : Wheat + Sugarbeet + Wheat + Beans

Wheat planted in October was irrigated to bring the soil depth of 60 cm to the field capacity, and after the harvest, the soil was not processed and left for the winter. In the second year, sugar beet was planted and the same procedures were continued throughout the experiment.

3. Result and discussion

In the first and third years of the experiment, wheat was planted, and was irrigated to bring the soil depth of 30 cm and 60 cm to field capacity and after the harvest, the soil was left for the winter without being cultivated. Sugar beet in the second year, beans were planted in the fourth year, and the treatments had no effect statistically on crops yields ($p>0.05$).

Table 3. Winter precipitation for the trial years and average precipitation for many years

Yıllar	10	11	12	1	2	3	4	5	10-4
1	0.3	85.0	46.4	50.4	22.1	56.0	19.1	8.1	279.3
2	24.7	56.6	55.2	6.4	35.0	24.7	44.8	48.5	247.4
3	**60.1**	**72.6**	**14.5**	**32.8**	**2.6**	**24.9**	**1.2**	**4.3**	208.7
4	43.5	57.6	11.9	17.8	24.8	1.2	16.5	46.4	173.3

In all experiment years, soil moisture reached its highest level in March at a soil depth of 120 cm. It was observed that the soil moisture contents in the spring months were significantly different from the soil moisture contents at the beginning of November (p=0.000**). There is a significant moisture loss between March-April and March-May periods, and there is a statistically significant difference between the moisture contents of the soils according to the results of the t_{test} (p=0.00). While the moisture decreases between March and April were found to be statistically significant (p=0.00**), it is understood that the moisture loss is mainly in April. As a matter of fact, due to the high moisture loss, a significant difference (p=0.614) was not found between the soil moisture contents in April and May (Table 4).

The previous plant is sugar beet, and since it is irrigated, the moisture content of the soil is high at the time of harvest, In early November, that is, before the winter rains begin. In addition, as a requirement of the trial, 30 and 60 cm depths were irrigated to the field capacity. Therefore, the moisture content of the soils is high at the beginning of November. On the other hand, as seen from the climate table, the amount of evaporation in the monitoring period is higher than in other years. As a matter of fact, the moisture accumulation rate in alfalfa plots was negative in the mentioned year. Therefore, the level of moisture accumulation in the 3rd year of the experiment is insignificant or negative (Table 4).

Table 4. Change of soil moisture content

Treatment	Year	Soil moisture, mm /120 cm							Rate of change%	
		1.11	1.12	1.1	1.2	1.3	1.4	1.5	1.4	1.5
	1	304.0	272.7	319.1	372.2	372.5	363.3	326.2	22.5	19,5
	2	304.6	307.1	378.3	376.3	377	359.6	341.7	23.8	18,1
A	**3**	394.8	440	381.8	392.8	**390.2**	**377.5**	**325.7**	-1.2	-4,4
	4	259.8	295.2	326.9	313.9	343.5	326.8	373	32.2	25,8
	1	323.9	349.3	373.7	403.1	388.6	363.2	355	20.0	12,1
	2	299.8	292.7	361.2	366	385.7	359.8	393.3	28.7	20,0
B	**3**	398	442	397.5	403.8	**415.7**	**378.2**	**309.7**	4.4	-5,0
	4	267.3	377.2	363	302.4	323.4	304.4	363	21.0	13,9
	1	329.3	349.3	372.7	403.1	388.6	363.2	355	18.0	10,3
	2	282.9	288.2	391.4	366	367.6	358.1	379.7	29.9	26,6
C	**3**	397.8	465.2	376.1	409.3	**397.2**	**362.2**	**318**	-0.2	-8,9
	4	262.4	270.1	313.8	297.3	326.9	296.2	351.3	24.6	12,9
	1	329.3	340.7	392.3	397.5	395.2	374.1	354.3	20.0	13,6
	2	272.4	276.8	292.1	398.5	336.4	369.4	370.4	23.5	35,6
D	**3**	397	403.7	405.2	412	401.1	372.4	309.1	1.0	-6,2
	4	257.3	283.3	310.1	288	306.7	288.8	328.4	19.2	12,2
	1	329.3	340.7	392.3	397.5	395.9	374.2	354.3	20.2	13,6
E	2	333.5	353.5	407.6	387.6	395.1	371.0	388.6	18.5	11,2
	3	379.2	403.9	402.6	410.5	393.5	362.4	315.2	3.8	-4,4
	4	253.5	316	301.6	296	314.8	318.8	340.2	24.2	25,8
Period	01.11-01.03	01.11-01.04	01.11-01.05		01.3-01.4	01.3-01.5	1.4-1.5	1.04-1.05		

p	0.000***	0.001***	0.001**	0.000**	0.036*	0.614***	0.000**

The effects of tillage and planting patterns, ie the treatments, on the accumulation of winter rains were found to be insignificant.

The results of the four-year trial are summarized in Figure 2. In the first and third years of the experiment, soil moisture decreased continuously in all treatments after March, followed a parallel course in the other two years, and even in the fourth year, in May, there was an increase in soil moisture. The reason for this is the rains in April and May and the field is not cultivated.

Various cultural measures are being developed to increase the accumulation of winter precipitation in the soil. One of these is the widely practiced conservation agriculture (Birkás et al., 2017). Conservation agriculture envisages farming with an understanding that supports the preservation of a permanent land cover, minimal soil degradation, and the diversification of plant species (Donovan, 2020).

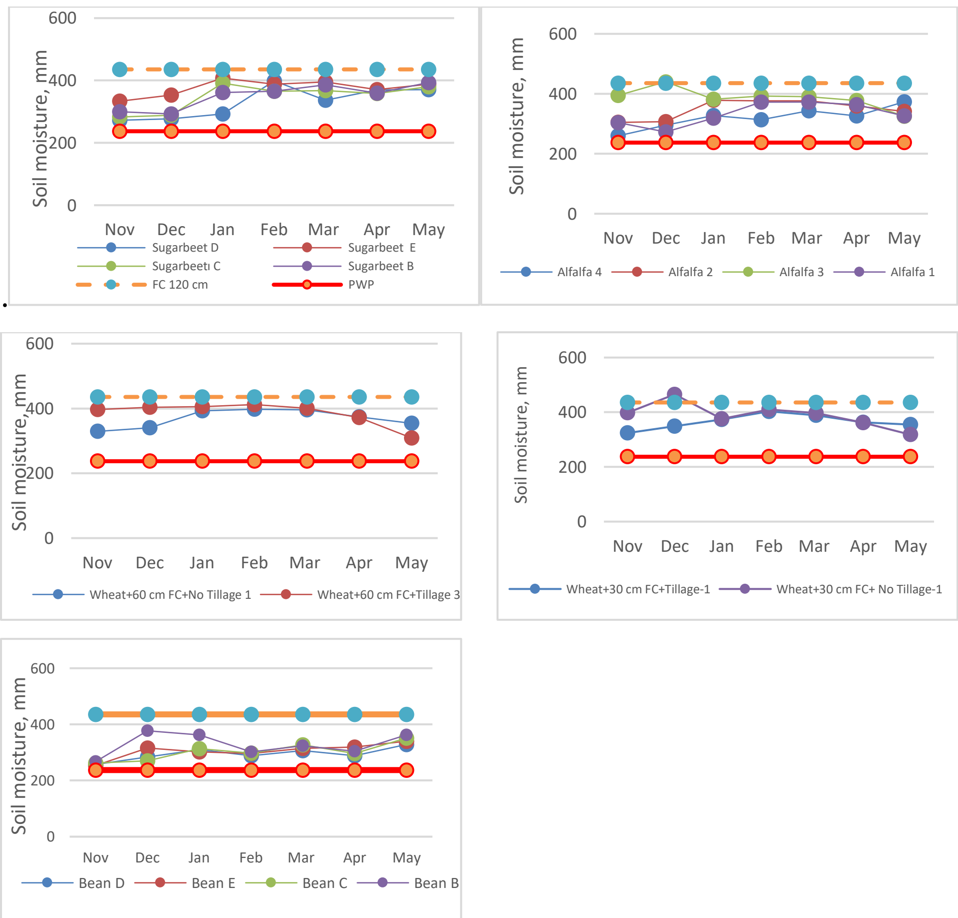

Figure 2. Monthly changes in soil moisture contents according to treatments

Since wheat is widely grown in the Konya plain, the correct determination of the water requirement of wheat in the spring months is of vital importance in terms of water management. If irrigation water is not supplied the plain at the appropriate time, farmers use groundwater to avoid yield losses. On the other hand, if the dams are put into operation in the early spring, water losses and drainage problems increase in the rainy spring months.

Table 5. Irrigation requirement at the beginning of April in the existing soil conditions of the plants included in the experiment, mm

Crop	Day of year	Soil moisture,	FC	PWP	AWC	AW	ET	SMD*
Wheat	1.04.	277.1	342.9	186.3	156.6	90.8	160	65.8
	1.05.	242.4	342.9	186.3	156.6	56.1	145	100.5
Alfalfa	1.04.	356.7	435.6	237.2	198.4	119.5		78.9
	1.05.	341.7	435.6	237.2	198.4	104.5		93.9
Sugarbeet	1.04.	364.4	435.6	237.2	198.4	127.2		71.2
Bean	1.04.	277.1	342.9	186.0	156.9	91.1		65.8

FC, field capacity, PWP, permanent wilting point, AWC, available water capacity, AW, available water, ET, evapotranspiration, SMD, soil moisture deficit, calculated from average values.*

In the wheat plots, the RAW value at the beginning of April is 90.8 mm, and the plant water consumption is 160 mm. During the experiment, April precipitation varied between 1.2 and 44.8 mm. The long-term precipitation average is 32.1 mm, and it would not be wrong to say that in this case, a dry April month may be in question every 4 years. In the years with average precipitation (160-90 = 70 mm), the moisture deficit is 70 mm, and even if some of this is met by precipitation, 35-40 mm of irrigation water is still needed. Therefore, in the Konya plain, the moisture remaining from the winter in mid-April will not be sufficient for the plants planted.

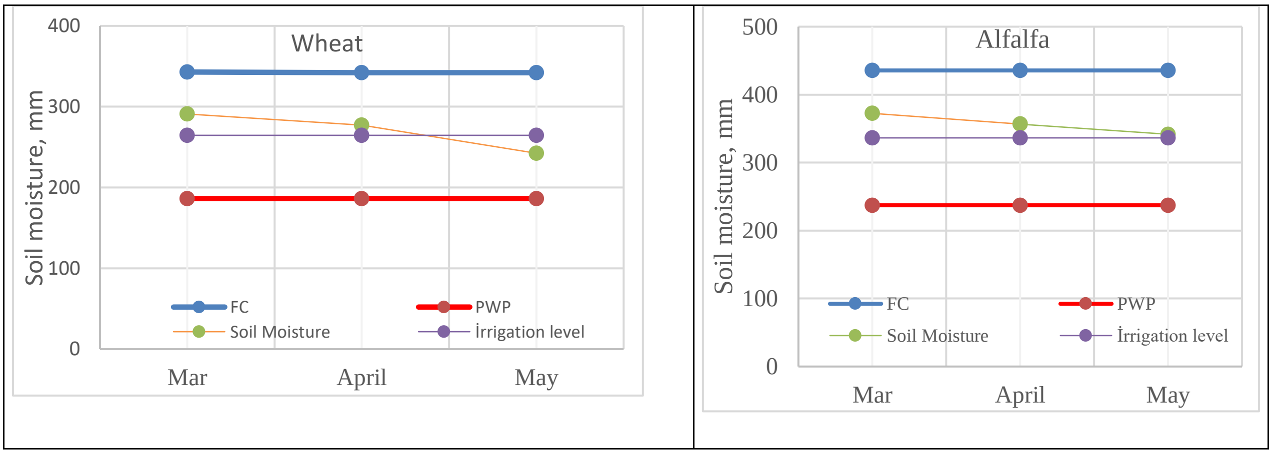

Figure 3. Moisture changes in the soil profile in spring

Considering the moisture content of the soil profile, as seen in Figure 3, the soil moisture content decreases to the irrigation moisture level towards the end of the second half of April in the wheat plots, and at the beginning of May in the alfalfa plots.

Analyzing long-year climate data showed that the probability of March or April being dry every three to four years was found to be quite high. For example, the probability of 20 mm or less precipitation is around 25-30%. This means that in the Konya plain, which is a wheat warehouse, the dam gates must be opened in April, and water is given to the plain to prevent product losses due to drought.

4. Conclusions

The conservation every drop of water in the Konya Basin, which has a water deficit of 2 billion m^3 every year is of vital importance in terms of the sustainable agriculture. Therefore, the planting pattern and tillage technique should be planned in such a way as to preserve and use the available moisture in the soil at the maximum level (Berke et al. 2014). For plants whose growth period is spring, the sum of winter precipitation and early spring precipitation accumulated in the soil is insufficient and irrigation water is needed in the spring months in Konya plain.

It should be considered to encourage agricultural policies that will encourage the planting of crops whose growing period is spring, and techniques such as mulch farming and ploughing the soil from below.

The fact that moisture loss is at significant levels during the spring months shows how important early planting is. Therefore, both the development of planting equipment and the introduction of early cultivars into rotation are gaining importance. Thus, winter precipitation will be utilized to the maximum level and more stored water will remain in dams and ponds for plants to be grown in summer.

Acknowledgments: The authors extend their thanks and respect to all employees, technical staff, and workers of the Konya Regional TOPRAKSU Research Institute, where the tests used in this study were conducted.

Financial support: Field trials of this study were carried out on the territory of Konya Regional TOPRAKSU Research Institute and with their support.

Author Contribution: The literature review study carried out during the writing process of the article was carried out by the corresponding author. All transactions were carried out under the responsibility of a both authors.

Conflict of interest statement: The authors declare that there is no conflict of interest regarding the study.

Ethics Committee: The article is not a study that requires ethics committee approval.

References

Agriinfo, 2015. Soil And Water Conservation Methods - Management Practices, http://www.agriinfo.in/?page=topic&superid=1&topicid=436 FAO, 2003: Conservation Agriculture for Soil Moisture, Briefing N

Atalay, M., Secerli, L., 1971. Konya arazi tasnif raporu, TOPRAKSU Bölge Müdürlüğü, Konya

Berke, M.Ö., Dıvrak, B.B., Sarısoy, H.D. 2014. Konya'da Suyun Bugünü Raporu, (https://www.wwf.org.tr/, 20; https://wwftr.awsassets.panda.org/downloads/konya_

Birkás, M., Dekemati, I., Kende, Z., Pósa P.,2017. Review of soil tillage history and new challenges in Hungary, Hungarian Geographical Bulletin DOI:https://doi.org/10.15201/hungeobull.66.1.6

DMİ, 2018. Devlet Meteoroloji İşleri Genel Müdürlüğü, http.mgm.gov.tr

Donovan, M. 2020. What is conservation agriculture? https://www.cimmyt.org/news/what-is-conservation-agriculture/

FAO, 2003. Conservation Agriculture for Soil Moisture, Briefing Notes - Production Systems Management, http://www.fao.org/ag/ca/doc/BN_soil_moisture_LR.pdf

Famiglietti, J.S., Rudnicki, J.W., Rodell, M. 1998**.** Variability in surface moisture content along a hillslope transect: Rattlesnake Hill, Texas. J. Hydrol., 210, 259–281. (CrossRef)

Ivanov, V.Y., Fatichi, S., Jenerette, G.D., Espeleta, J.F., Troch, P.A., Huxman, T.E. 2010**.** Hysteresis of soil moisture spatial heterogeneity and the homogenizing" effect of vegetation. Water Resour. Res. 46. [CrossRef]

Morris, R.C., Fraley Jr, L. 1994. Soil permeability as a function of vegetation type and soil water content. Health Phys., 66, 691. [CrossRef]

Namirembe, S., Nzyoka J.M., Gathenya, J.M. 2015. A guide for selecting the right soil and water conservation practices for small holder farming in Africa. ICRAF Technical manual No.24. Nairobi, Kenya: World Agroforestry Centre (ICRAF)

Shouqin, Z., Weihua, Z., Jiake, L., Chaofu, W. 2014**.** Temporal variation of soil water and its influencing factors in hilly area of Chongqing, China. Int. J. Agric. Biol. Eng., 7, 47–59.

Shaozhong, K. 2002. New Agricultural Sci Technological Revolution and Development of

Chinese Water Saving Agriculture in 21st Century, Climate Change Adaptation Technologies for Water A practitioner's guide to adaptation technologies for increased water sector resilience.

Wang, S., Fu, B., Gao, G., Liu, Y., Zhou, J. 2013. Responses of soil moisture in different land cover types to rainfall events in a re-vegetation catchment area of the Loess Plateau, China. Catena, 101, 122–128. (**CrossRef)**

White, J.L., Knapp, A.K., Kelly, E.F. 2008**.** Increasing precipitation event size increases aboveground net primary productivity in a semi-arid grassland. Oecologia, 158, 129–140. [CrossRef]

Zhang, Y., Liu, J., Xu, X., Tian, Y., Li, Y., Gao, Q. 2010**.** The response of soil moisture content to rainfall events in semi-arid area of Inner, Mongolia. Procedia Environ. Sci., 2, 1970–1978. [CrossRef]