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Determination and Assessments the Yield Gap Between the Wheat Yield and Potential Yield in Turkey

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ABSTRACT

Knowing the current and the potential production amount of wheat is essential to meet the growing needs. Yield is determined by many factors. The main factors that limit the potential yield are genetic characteristics, and climatic factors such as rainfall and radiation, and management. Wheat is mostly grown in non-irrigated areas in Turkey. The most significant factors that limit dry agriculture wheat production yield in the Mediterranean climatic type are rainfall and its distribution in the growing season. A steady increase in yield is observed in Turkey in recent years. Average annual wheat production is 20.6 million tons. The potential production in this work is determined as 54 million tons. The gap is about 33 million ton. The actual production is 39% of the potential production. The average yield of the Growing Season Rainfall (GSRF) <500 mm areas is 1.9 t ha^{-1}, and potential yield of 4.7 t ha^{-1}, whereas the average yield of GSRF >500 mm areas is 2.2 t ha^{-1}, and the potential yield is 8.8 t ha^{-1}. The gap between the actual yield and potential yield is quite large. The current yield between the areas (GSRF <500 and >500 mm) is very small. So it is difficult to explain the gap just because of the rainfall.

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Introduction

Wheat, with its direct and indirect use, is one of the most important food sources of our country and the world. Turkey's population, which was 80 million in 2016, is expected to exceed 93 million in 2050 according to 2013-2075 population projections. In recent years, average annual wheat consumption per person is around 213 kg (TURKSTAT, 2017). It is expected that by 2050 per capita grain consumption will be close to and above (160 kg) current values (158 kg) (Alexandratos and Bruinsma, 2012). According to today’s projections, Turkey will need additional 3 tons of wheat to feed extra 13 million people in 2050. Despite being a self-sufficient country in wheat production, this balance has changed in recent years and the sufficiency rate has dropped to 90% (2014-2015) (TURKSTAT, 2017). This gap will continue to grow up in the coming years.

The world population is expected to reach 9.4 or 10.2 billion by 2050 (United Nations, 2017). As it is today, people in 2050 will meet most of their need of daily calories (41%) from grains (Kruse, 2010). Total grain production needs to be increased from 2 million tons (2005-2007) to 3 million tons in 2050 to meet increased biodiesel need and high calorie consumption induced by the increased national income, changing desires, and increased population. Yet the rate of increase in yields of basic field crops (maize, rice, wheat) was 1.95%, 1.1%, 1.08% in the period from 1987-2007, it is estimated to be to 0.56%, 0.61% and 0.74% in 2007-2050, respectively. At this rate, the increase in wheat production will be only 38-40% in 2050 (Tilman et al., 2011; Alexandratos and Bruinsma, 2012). In other words, it seems to be a serious decrease in productivity in the future compared to the past. In order to meet the need, the increase rate should be 2.4%. In this case, it is estimated that there will be 388 million tons of wheat production gap in the world in 2050 (Ray et al., 2013).

Compared to the years 1961-63, wheat yield doubled between the years 2005-2007. This increase has resulted in the development of varieties, which are semi-dwarf, resistant to diseases, drought, warmth and cold, and widespread production and usage of organic nitrogen. In other words, this tremendous increase happened because of the 'Green Revolution'. Although agronomic applications increase the yield in developing countries by a certain amount, it seems difficult to recapture this success in developed countries. Yield increase in developed countries will only be achieved with genetic progress in the upcoming years.

Rainfall is at the head of the limiting factors to reach the potential yield. It has been found that in the case of 450-500 mm water presence in the soil, the yield can be 6000-7000 kg ha^{-1}. Besides excess water than plant need in the soil can cause decrease in the yield (Zhang et al., 2002; Schillinger et al., 2008). Studies have shown that sufficient GSRF to reach maximum yield varies from 400 to 600 mm depending on environmental factors (Patrignani et al., 2014). Passioura and Angus (2010) noted that the radiation is the main factor that limits the yield in the area (rainfall >500 mm).

All plants need a certain amount of water for vegetative and generative development. There are many factors that regulate the production yield of dry agriculture wheat production, but the most important of them is the amount of rainfall (Tiryakioğlu et al., 2017; Hay and Porter, 2006; Fuentes et al., 2003) and its distribution by month (Nielsen and Halvarson, 1991). Higher-sized wheat requires 101 mm of water for vegetative growth, and it has been reported that the yield for each 1 cm of available water is increased by 149 kg ha^{-1} (Leggett, 1959). It is reported that shorten (semi dwarf) wheat requires 59 mm of water for vegetative growth and is expected 154 kg ha^{-1} for each 1 cm of water (Schillinger et al., 2008). Wheat water stress was more susceptible to stem-elongation and grain-filling than other periods (Zhang and Oweis, 1999) and 70% of this consumption happens in the flowering period (French and Schultz, 1984a). This period in our country, which features Mediterranean climate, is generally arid (Soylu and Sade, 2012).

It is important how much the production will be able to increase to meet the needs that will arise in the upcoming years and to sustain the economic income. In this study it is aimed to determine the gap between yield potential in existing wheat production conditions (dry or irrigated) and actual production amount in Turkey, and to investigate the probable causes of and solutions of it.

Materials and Methods

Winter wheat is usually grown to benefit from winter precipitation. Turkey is under the effect of the Mediterranean climate zone which is characterized with cold and rainy winters, and dry and hot summers. Although the average rainfall is 624.6 mm, it varies from 351 mm (Aksaray province) to 1458 mm (Rize province). Wheat water consumption varies between 360-730 mm according to geographical regions (Kanber, 1982; Anonymous, 2016). Precipitations is not enough for wheat production can in most cultivated areas.

In this study, average wheat cultivation area, production and yield values of the last five years (2012-2016) and monthly rainfall on the basis of cities in Turkey have been used (MGM, 2017; TURKSTAT, 2017). All assessments have been done according to winter bread wheat (*Triticum aestivum* L.) since it constitutes most of the wheat production (79%) in Turkey (TURKSTAT, 2017). The average yield was obtained by taking the average of bread wheat yield and durum wheat yield. Even though there have been little fluctuations (19000-40000 ha) in the gap between cultivated and harvested areas, calculations have been made considering cultivated areas.

Turkey wheat production areas are divided into two main groups as the cities with GSRF (October - June) below 500 mm and 500 mm above. Then these groups were separated into production regions among themselves (Figure 1) based on the classification of agro-climatological (MGM, 2017). The yield potential of these regions is evaluated at the same. Kırklareli was assessed in the second group because of its location. There is no wheat production in Rize and Trabzon provinces. Turkey shows significant climatic changes ranging from temperate climate to terrestrial climate in short distances in terms of its climatic characteristics. The mean precipitation of the regions is shown in Figure 2.

The attainable potential yield must be known to determine the accessibility of the current production. There are different yield definitions (Figure 3) and calculation methods for this. In our study, yield parameters such as current yield (Yc), potential yield (Yp), yield gap (Yg), theoretical yield (Yt) were obtained considering previous studies (Chapagain and Good, 2015; Van Ittersum et al., 2013; Connor, 2004; Fischer et al., 2009). Current yield (Yc); is defined as yield averages of the last few years obtained by farmers producing in a certain region and climatic conditions. Yc in the study was determined by taking the average of the yield and production values of the last 5 years (2012-2016). In our study, the current yield of irrigated areas is shown as Yci and the yield of rainfed areas as Ycr.

Figure 1 Agro-climatological regions of Turkey

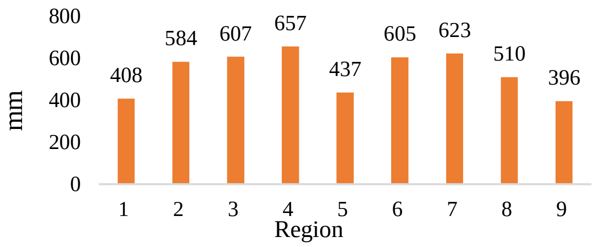

Figure 2 GSRF of the regions

Potential yield is determined by field experiments, yield contests, maximum yield in farmer field and crop simulation methods (Van Ittersum et al., 2013). The methods have advantages and disadvantages compared to each other. Potential yield (same as Attainable yield) for irrigated crop (Ypi) or GSRF >500 mm regions; It is defined as the highest yield, which is well adapted to the region, is not lack of water and nutritional elements, and is obtained in an environment where the agronomic applications (soil processing, sowing time, sowing frequency, weed, disease and harmful struggle, etc.) are done correctly and properly. Water deficiency in these regions does not limit the yield. In this study, the highest yield value has been taken as Ypi obtained in the experiments by the research institutes and universities.

Potential yield for rainfed crop (Ypw); It is used instead of Ypi when wheat is grown without irrigating and the rainfall cannot meet the plant water need (GSRF <500 mm). The yield in these areas is limited by water deficiency (Connor et al., 2011). There is a significant relationship between GSRF and yield in these regions (French and Schultz, 1984a). Ypw is calculated by yield simulation models, transpiration efficiency, GSRF and linear models using yield values (French and Schultz, 1984b). In the study Ypw in the provinces where GSRF below 500 mm in Mediterranean Climatic characteristics has been determined using Equation 1 (Schillinger et al., 2008) obtained as a result of multiple regression analysis taking the seasonal distribution of rainfall for years to some extent.

$$\mathrm{Ypw} = 150 \times \mathrm{OWR} + 174\mathrm{SR} - 1986 \qquad (1)$$

Ypw : Yield (kg ha^{-1})
OWR : Over winter rainfall, cm (October - March)
SR : Spring rainfall, cm (April-June)

The yield gap (Yg) has been determined as the difference between current yield and potential yield (Yp-Yc). In the study done, the values found in the provinces have been collected and the Yg value for the country has been calculated. Theoretical yield is determined by genetic and environmental factors and can be estimated by models such as APSIM, CERES, CropSyst or SUCROS (FAO and DWFI., 2015). Sinclair et al. (2013) reported the theoretical yield as 12.9 t ha^{-1} (Lollato et al., 2017), but this value is not taken into consideration in the study since it might be higher in value depending on genetic and agronomic developments.

Results and Discussion

Considering the last 30 years in Turkey, there has been a decrease in agricultural areas with a total of 2.6 million hectares, largely because of urbanization pressure and this decline has become a significant trend starting from 2000s. As in developed countries (Fischer et al., 2009), 1.7 million hectares (18%) of this decline happened in wheat production areas. Despite the decrease in cultivated areas, there is a slight increase in total wheat production. The wheat yield, which followed a fluctuating trend until mid-1990s, has entered a trend of about 2% annual increase after this date. Despite the decline in cultivation areas, the high rate of yield growth has also led to an increase in production (Figure 4). This increasing trend shows similar characteristics with the increasing trend in the Midland American Region in the years 1960-1980 (Patrignani et al., 2014). It is thought that this is related to fertilizer use and the application of information in some agronomic practices.

The rainfed area is 5.9 million hectares in 7.7 million wheat production areas in total. GSRF is below 500 mm in 3.3 million hectares of rainfed area and GSRF is above 500 mm in 2.6 million hectares of it. Cultivation area, production, yield and potential yield values for provinces are given in Tables 1 and 2. While the current yield (Ycr) of rainfed areas is 2 t ha^{-1}, the current yield (Yci) of irrigated areas is 3.5 t ha^{-1} in across Turkey. While the current yield is1.9 t ha-1 in rainfed areas, it is 3.4 t ha-1 in irrigated areas of the provinces where GSRF<500 mm (Table 1). The current yield is 2.2 t ha-1 in the rainfed areas and 3.7 t ha-1 in irrigated areas of the provinces where GSRF>500 mm (Table 2).

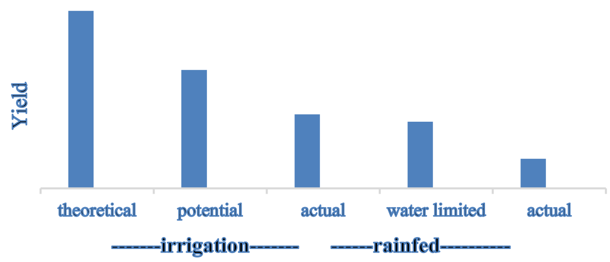

Figure 3 Wheat yield definitions (FAO and DWFI, 2015)

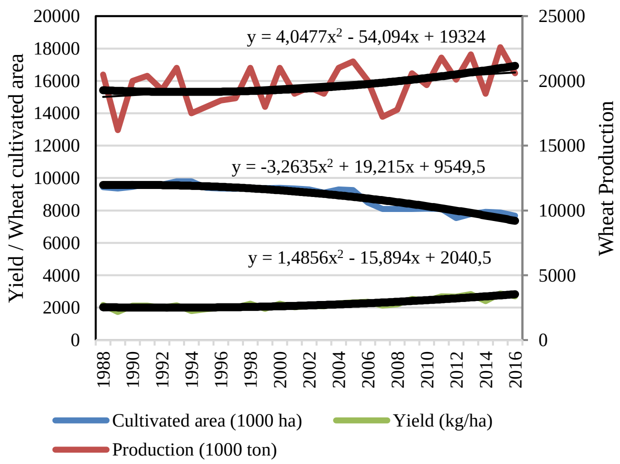

Figure 4 The wheat cultivated area, production and yield in Turkey

Yield values and average regional values of the regions comprised of provinces with GSRF<500 mm are given in Figure 5. There are significant differences between regions comprised of the provinces where GSRF<500 mm (Figure 5a). The Ycr (1.3 t ha^{-1}) in non-irrigated areas of the provinces located in the region 5 and 6 is quite low compared to the other regions. The Ycr (1.9-2.2 t ha^{-1}) of the provinces in the regions 1, 8 and 9 are partially similar. Among them, region 9 (396 mm) and region 1 (408 mm) are the areas where GSRF is the lowest. It is difficult to say that the difference in Ycr among regions is influenced by the amount of precipitation. A similar thing is valid for Yci too. In these regions, the Ypw due to GSRF varied between 4.3 t ha^{-1} and 5.4 t ha^{-1} (Figure 5a), whereas the average Ypw of the provinces where GSRF is <500 mm has been determined as 4.7 t ha^{-1} (Figure 5b).

Table 1 The cultivated area, production and yields of provinces with GSRF <500 mm

R	Province	Rainfall (mm)				Current yield						Potential yield				RF
						Rainfed			İrrigated			Rainfed (Ypw)		İrrigated (Ypi)		
		T	GSRF	OWR	SR	CA	PR	Y	CA	PR	Y	PR	Y	PR	M	
1	Ankara	410	364	237	127	417.5	952.4	2399	30.8	118.4	3762	1573.3	3769	209.4	6800	R1
	Bilecik	546	483	355	134	27.7	61.2	2220	2.4	8.1	3410	157.3	5671	16.2	6800	
	Bolu	589	497	349	141	42.8	94.2	2202	5.4	23.1	4294	243.7	5698	36.6	6800	
	Çankırı	451	384	235	153	80.4	196.4	2399	10.3	36.1	3510	338.3	4211	69.9	6800	
	Çorum	441	382	231	155	182.4	397.1	2133	31.7	126.7	3827	760.9	4172	215.4	6800	
	Eskişehir	403	359	243	118	113.8	232.5	2083	64.5	252.4	3893	422.7	3714	438.8	6800	
	Kırıkkale	405	365	227	137	107.0	234.6	2315	7.3	27.6	3481	406.5	3799	49.9	6800	
	Kırşehir	404	370	239	130	95.8	226.8	2314	6.5	24.0	3782	369.8	3861	43.9	6800	
	Uşak	538	496	373	119	66.4	135.9	2095	3.7	11.7	3274	377.8	5687	25.1	6800	
	Yozgat	416	379	234	145	289.5	627.0	2197	38.8	122.4	3213	1173.8	4055	263.5	6800	
5	Ağrı	466	415	242	172	73.2	102.4	1406	32.7	68.4	2130	339.6	4638	226.1	6910	R2
	Ardahan	639	478	272	221	5.4	6.4	1188	0.0	0.0	0.0	31.8	5939	0.0	0.0	
	Erzincan	529	496	332	162	17.8	23.1	1242	24.6	66.8	2806	103.3	5819	170.1	6910	
	Erzurum	580	490	311	185	74.6	98.4	1314	42.0	99.8	2394	440.6	5909	290.2	6910	
	Iğdır	392	335	179	157	5.6	8.4	1502	12.7	37.5	2952	19.2	3439	87.8	6910	
	Kars	513	410	208	199	56.5	80.0	1420	0.4	0.8	2085	259.5	4592	2.7	6910	
6	Şanlıurfa	460	455	369	85	122.5	187.8	1513	199.3	854.0	4300	616.3	5030	1662.4	8340	R3
	Van	528	496	333	161	48.0	49.1	1046	35.0	58.1	1684	279.5	5823	291.6	8340	
8	Amasya	498	436	278	156	74.8	171.7	2095	33.6	132.5	3972	367.3	4910	288.2	8580	R4
	Tokat	559	491	323	165	88.3	172.1	1927	39.1	138.7	3429	506.4	5737	335.3	8580	
	Sivas	480	443	285	158	274.1	584.6	2131	10.3	33.9	3285	1381.6	5041	88.1	8580	
	Malatya	492	477	348	130	43.9	60.9	1449	18.2	39.5	2218	240.8	5487	156.1	8580	
9	Afyonk.	466	419	292	131	112.0	228.4	2060	54.9	187.0	3419	523.1	4670	373.1	6800	R5
	Konya	431	401	293	111	475.5	1033.8	2204	225.7	1039.7	4559	2069.3	4351	1535.0	6800	
	Aksaray	351	328	214	115	52.3	106.6	2089	30.2	141.9	4636	168.4	3218	205.4	6800	
	Karaman	444	427	345	88	78.8	147.0	1964	14.9	54.0	3633	371.1	4709	101.2	6800	
	Niğde	411	387	260	128	39.1	61.4	1578	31.9	123.5	3877	161.5	4134	217.2	6800	
	Nevşehir	421	390	249	137	105.1	221.1	2172	10.0	34.4	3531	434.6	4137	68.0	6800	
	Kayseri	450	420	280	143	132.5	278.0	2241	19.2	79.2	3886	621.9	4693	130.8	6800	

R: Region; T: Total; CA: Cul. Area (1000 ha); PR: Production (1000 ton) ; Y : Yield (kg/ha); M: Max. Yield (kg/ha); RF: References; R1: Kale and Tarı, 2012; R2: Equation 1; R3: Sezen and Yazar, 2006; R4: Aydın et al., 2009; R5: Şahin et al., 2016

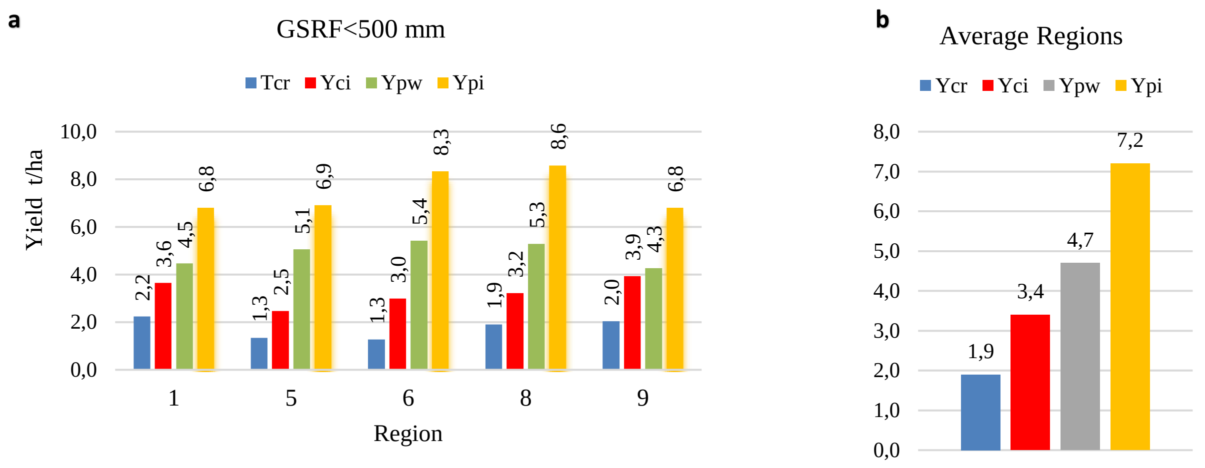

Figure 5 Wheat yield of regions (a) and average regions (b) of GSRF <500 mm

A multiple linear regression model was constructed for the effect of winter and spring precipitation amounts on estimates of Ypw. The model was highly significant ($P<0.001$) and descriptive ($R^2 = 0.998$). While the model was not sufficiently affected by winter precipitation, it was observed that the spring precipitation value contributed significantly. Ypi is seen 20-25% higher the regions 6 and 8 compared to other regions. In general evaluation of the areas where GSRF<500 mm, Yp's are more than twice than Yc's (Figure 5b). It is expected that there is little difference between actual Ycr and Ypw in dry farming areas and this also means that this gap might close if irrigation can be done (Van Ittersum et al., 2013). The fact that the average Yci is 1.3 t ha^{-1} lower than Ypw in these provinces indicates that the difference between Yp and Yc is not only water related.

The yield values and average regional values of the regions where GSRF>500 mm are given in Figure 6. Ycr value varies in a wide range from 1.6 to 3.2 t ha^{-1} in these regions (Figure 6a). The highest Ypr value is in region 3, the lowest is in region 7. Other regions show similarities among themselves. Yci values are similar in the regions 2, 3 and 4 and they are about 33% higher in the regions 6, 7 and 8. The Ypi is the lowest (5.0 t ha^{-1}) in the region 8, and it is followed by the regions 7, 2, 3, 6 respectively (Figure 6a). The average Ypi is 4 times higher than Ycr and 2.4 times higher than Ycr in the regions comprised of the provinces where GSRF>500 mm (Figure 6b). It is remarkable that the mean Yc value is 50% higher than the Ycr value of the regions where GSRF>500 mm.

Potential yield is defined in different forms and is calculated by different methods. However, significant differences (50%) can be found between the values calculated according to the used method (Lobell et al., 2009). The main reason for this is the fact that the soil characteristics at the local level are not known precisely and that the distribution of climate characteristics such as temperature and humidity is changing over the year. Since the Yp varies according to the methods, the Yg will change as well. Nevertheless, the information obtained knowledge about Yg will be quite valuable, no matter which method is used.

Table 2 The cultivated area, production and yields of provinces with GSRF >500 mm

R	Province	Rainfall (mm)		Rainfed			İrrigated			Potential yield Ypi			RF
		T	GSRF	CA	PR	Y	CA	PR	Y	CA	PR	M	
2	Aydın	647	625	7.8	18.3	2362	13.5	59.7	4694	21.3	198.7	9320	R1
	Balıkesir	616	575	108.6	269.4	2478	11.0	42.7	3906	119.5	1114.1	9320	
	Burdur	540	503	37.6	78.9	2093	20.3	68.9	3398	57.8	539.1	9320	
	Çanakkale	616	574	74.2	235.2	3168	4.1	18.7	4574	78.3	730.0	9320	
	Denizli	584	547	42.4	108.9	2573	35.8	152.2	4180	78.3	729.5	9320	
	Isparta	614	573	44.3	88.5	2006	4.5	14.5	3080	48.8	455.1	9320	
	İzmir	612	590	16.2	44.0	2538	16.7	71.0	4065	33.0	307.3	9320	
	Kütahya	560	509	125.8	224.8	1829	15.0	49.3	3294	140.8	1312.0	9320	
	Manisa	577	548	80.5	169.6	2248	24.1	112.9	4513	104.6	974.6	9320	
	Muğla	817	796	25.8	58.1	2117	14.2	42.3	3015	40.0	372.6	9320	
3	Bursa	748	670	65.0	154.3	2079	12.0	56.3	4821	76.9	730.6	9500	R2
	Edirne	607	534	125.6	478.9	3816	14.2	69.0	4896	139.7	1327.4	9500	
	İstanbul	749	636	33.2	138.0	4160	0.0	0.0	2816	33.2	315.6	9500	
	Kocaeli	812	674	22.2	58.8	2648	0.1	0.2	4065	22.3	211.9	9500	
	Kırklareli	579	496	116.6	445.4	3820	1.7	7.6	4460	118.3	1124.2	9500	
	Sakarya	754	623	13.9	29.7	2274	2.9	10.1	3444	16.8	159.5	9500	
	Tekirdağ	608	531	175.4	743.6	4266	0.0	0.0	0	175.4	1665.9	9500	
	Yalova	801	696	1.3	3.3	2612	0.0	0.0	0	1.3	12.4	9500	
4	Adana	688	644	104.5	301.8	2203	86.8	383.4	3482	191.3	1913.0	10000	R3
	Antalya	785	761	73.7	141.7	1939	28.8	103.6	3488	102.4	1024.1	10000	
	Gaziantep	568	556	39.2	80.1	2067	39.2	174.7	4431	78.3	783.3	10000	
	Hatay	860	805	29.3	76.7	2696	42.2	195.7	4567	71.6	715.8	10000	
	Kahramanm.	574	555	68.6	157.3	2369	57.0	260.7	4644	125.5	1255.3	10000	
	Mersin	559	542	88.6	156.9	1866	28.0	122.1	4111	116.5	1165.3	10000	
	Osmaniye	782	737	31.5	86.6	2756	22.8	96.0	4208	54.4	543.6	10000	
6	Batman	641	631	68.1	179.6	2676	7.2	33.3	4685	75.3	724.9	9630	R4
	Bingöl	700	673	2.7	4.0	1652	10.5	25.2	2626	13.2	127.2	9630	
	Bitlis	695	670	31.5	41.2	1324	3.8	7.9	2136	35.3	340.2	9630	
	Diyarbakır	631	620	308.5	866.2	2813	61.6	276.1	4439	370.1	3564.3	9630	
	Hakkari	683	663	2.5	2.5	994	6.2	9.4	1544	8.7	83.6	9630	
	Kilis	594	579	21.8	41.4	1855	2.5	9.5	3823	24.3	234.2	9630	
	Mardin	530	525	64.3	147.2	2329	121.5	578.4	4772	185.8	1788.9	9630	
	Muş	663	632	70.4	90.4	1288	47.3	113.6	2474	117.7	1133.1	9630	
	Siirt	699	685	35.7	95.5	2739	2.9	12.0	4186	38.6	371.8	9630	
	Şırnak	645	634	58.5	144.4	2504	11.2	44.7	3727	69.7	671.0	9630	
7	Artvin	1008	776	0.3	0.5	1538	0.0	0.0	0	0.3	2.1	7390	R5
	Bartın	916	707	15.0	23.9	1728	0.0	0.0	0	15.0	110.9	7390	
	Bayburt	648	542	8.0	11.1	1408	17.4	40.6	2338	25.4	187.9	7390	
	Düzce	802	646	1.1	2.8	2482	0.0	0.0	0	1.1	8.1	7390	
	Giresun	787	658	13.6	18.1	1479	0.0	0.0	0	13.6	100.5	7390	
	Gümüşhane	605	523	13.5	20.2	1280	5.2	13.8	2638	18.7	138.4	7390	
	Karabük	683	549	14.2	25.1	1774	0.0	0.0	0	14.2	104.8	7390	
	Kastamonu	695	559	53.0	79.1	1494	9.0	21.9	2436	62.0	458.0	7390	
	Ordu	853	695	5.4	4.8	866	0.0	0.0	0	5.4	39.6	7390	
	Samsun	658	550	87.8	219.8	2311	18.5	74.4	4036	106.3	785.4	7390	
	Sinop	669	544	16.8	32.1	1967	2.6	9.4	3699	19.4	143.2	7390	
	Zonguldak	944	727	10.7	15.5	1388	0.0	0.0	0	10.7	78.9	7390	
8	Adıyaman	575	566	75.1	195.6	2626	11.3	48.1	4256	86.4	432.2	5000	R6
	Elazığ	590	575	33.1	69.3	2099	9.4	27.9	2981	42.5	212.4	5000	
	Tunceli	607	586	10.3	17.4	1702	0.7	1.2	1800	11.0	54.9	5000	

R: Region; T: Total; CA: Cul. Area (1000 ha); PR: Production (1000 ton) ; Y : Yield (kg/ha); M: Max. Yield (kg/ha); RF: References; R1: Aktaş and Eren. 2014; R2: Öztürk et al., 2015; R3: Dinçer and Yaktubay. 2012; R4: Doğan and Kendal, 2012; R5: Şermet, 2011; R6: Kendal et al., 2012

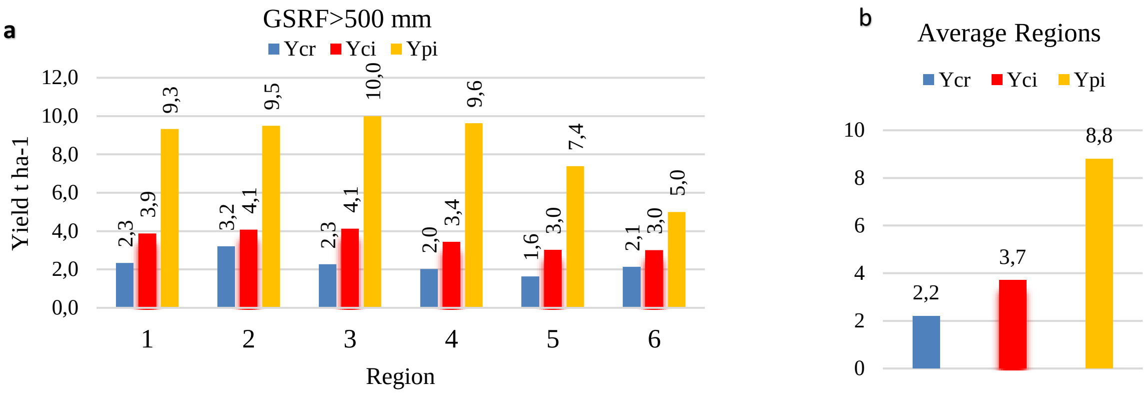

Figure 6 Wheat yield of regions (a) and average regions (b) of GSRF >500 mm

Despite the high yield increase in recent years in Turkey, the yield is still well below Yp and the world average. Yc is about 21 million tons. In our study, Yp was found 54 million tons (Figure 7). Yg is about 33 million tons, in other words, Yc is 39% of Yp. Lower yield is actually an expected result in farmers' conditions. Because technology, financial situation, taking risks and economical factors are driving factors on productivity at farm level. This value varies from 20% to 80% in a wide range in the world. It is 79% in the UK, 67% in some parts of the US and 40% to 95% in India. The fact that wheat potential yield varies from 9 to 10 tons has been demonstrated in the studies carried out in the countries having similar climatic conditions with Turkey (Fischer et al., 2009; Lobell et al., 2009). Neumann et al. (2010) stated that Yg varies from 2 to 8 t ha^{-1}, the highest values are in the regions 4, 5 and 6, in Turkey on his global scale study. In our study, it varies between 2.3 t ha^{-1} (GSRF <500, 1 and 9 region) and 7.7 t ha^{-1} (GSRF> 500, 4 regions) when the regional Yg average is taken into consideration. The yield of the farmers should be close to 80% of the potential yield (Lobell et al., 2009). To reach 43 million tons of Yc can be considered as the first step target for Turkey if the development of knowledge and technology in terms of farming is realized. Yield shows little increase as it approaches to the potential yield. When present production exceeds 70% in the areas where rainfall-related production is done, yield stagnation appears (Cassman, 1999). Yield increase has decreased rapidly and has nearly ended in some regions of the US and in many parts of the world (especially in industrial countries) since 1980s (Calderini and Slafer, 1998; Fischer et al., 2009; Patrignani et al., 2014). However, a steady yield increase has been observed in Turkey since the 2000s. This shows that there has been an increase in awareness of some of the acronomic and cultural practices (selection of varieties, fertilizing, pesticide use, etc.) in recent years, but there are a lot more shortcomings.

In order to reach or approach to the attainable yield, agronomics variables must be well known and applied (Lobell et al., 2009). The yield is under the influence of biotic and abiotic factors. Abiotic factors include radiation, irradiation, irrigation, temperature, vernalization, fertilization, photoperiod, variety and agronomic applications (irrigation, fertilization, sowing time, etc.) (Licker et al., 2010; Lollato et al., 2017). Losses due to biotic factors in wheat production (Weeds, animal pests, pathogens) have a significant place. Pesticide use is directly related to the cultural level and economic conditions of the farmers. Weeds (8%), animal pests (8%), pathogens (10%) and viruses (2%) cause total 28% yield loss worldwide. This loss potentially reaches 50% (Oerke, 2006).

The most important factor restricting yield in farmer conditions is water and insufficient fertilization (Boling et al., 2010). The yield is directly related to nitrogen fertilization in wheat production (Nielsen and Halvarson, 1991; Fiez et al., 1994; Kara, 2010) and about half of the yield increase in developed countries is related to nitrogen use (Bruinsma, 2003; Heisey and Norton, 2007). Inadequate fertilization is reported to cause yield loss up to 35-63% (Boling et al., 2010). Use of nitrogen fertilizer ranges from 45 to 75 kg ha^{-1}, and as for phosphorous fertilizer, its use ranges from 22 to 32 kg ha^{-1} in wheat production in Turkey (Kacar and Katkat, 2009). According to this nitrogen amount, maximum yield per hectare is 3500 kg ha^{-1}, and this situation is compatible with Turkey's average yield. The amount of nitrogenous fertilizer needs to be folded 2 or 3 times according to the regions to reach the potential yield. 15 kg nitrogen for 6 t ha^{-1} and 20 kg for 8 t ha^{-1} yield is required in the Mediterranean climate zone (Savin et al., 2006).

Most of the land is suitable for farming even if 62% of the soil is slightly alkaline, 30% are neutral, 92% are loamy or clay and loamy, and with low organic matter in Turkey (Doğan, 2012). But especially in the regions 1.5.6.8 and 9, the most important limiting factor on yield is the lack of rainfall. The ongoing drought is seen in these regions starting especially from the middle of May or end of June and July (Soylu and Sade, 2012). Smaller sized wheat varieties can increase productivity up to a certain level in low-rainfall environments (Brancourt-Hulmel et al., 2003; Condon et al., 2004). Selecting bread wheat that is smaller sized, early and less affected by climatic fluctuations in these regions will be effective in increasing production. In regions where GSRF is above 700 mm, high rainfall may result in yield loss (Patrignani et al. 2014). There is not a region that receives more than 700 mm of rainfall during the growing season in Turkey. It is difficult to say that the surplus of precipitation is a limiting factor in the wheat production of our country since the rainfall generally takes place at the beginning of the growing season (the characteristic of Mediterranean climate) in the provinces that have high precipitation.

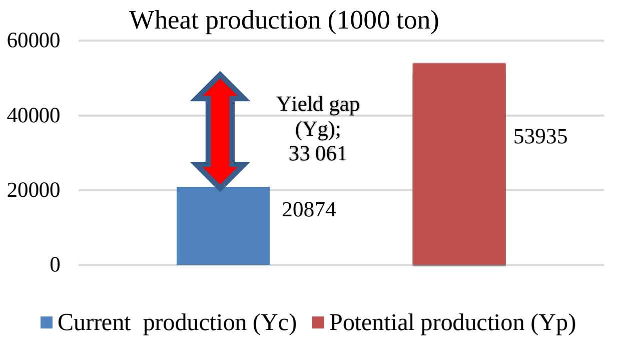

Figure 7 Turkey wheat yield gap, current production and potential production

Conclusion

Seasonal climate anomaly that have been common in recent years, increases in input costs, declining agricultural land, etc. can be considered as the most important obstacles to the increase of wheat production. A meaningful yield increase trend has been observed in Turkey in recent years. This increase has to be reached to higher rates and made permanent. While the gap between Ycr and Yci is low, Yg is quite high throughout Turkey. This shows that other factors (variety, fertilization, agronomic applications, etc.) are more effective on the low yield more than soil characteristics and precipitation. Turkey is engaged in wheat production in a wide topography of up to 2000 m above sea level. It is obvious that regional based planning is a necessity. The protection of agricultural lands is significant for the permanence of production. Seasonal climate irregularities, increases in input costs, declining agricultural land, etc., which are common in recent years can be considered as the most important obstacles to increase in wheat production.

References

Aktaş B, Eren H. 2014. Determination of quality characteristics and stability analysis of grain yield of some bread wheats (*Triticum aestivum* L.) varieties. Journal of Field Crops, Central Research Institute, 23(2): 69-76.

Alexandratos N, Bruinsma J. 2012. World agriculture towards 2030/2050: the 2012 revision. ESA Working Paper No. 12-03. Rome, FAO. Available from: http://www.fao.org/docrep/009/a0607e/a0607e00.htm [Accessed: 01.12.2017].

Anonymous. 2016. Evapotranspiration guide of the irrigated plants in Turkey. Available from: http://www.tarim.gov.tr. [Accessed: 10.01.2017].

Aydın N, Mut Z, Bayramoğlu H, Özcan H. 2009. Effects of genotype and location on grain yield and some quality traits in bread wheat (*Triticum aestivum* L.) genotypes. Anadolu J. Agric. Sci. 24(2): 84-92.

Boling AA, Tuong TP, Van Keulen H, Bouman BAM, Suganda H, Spiertz JHJ. 2010. Yield gap of rainfed rice in farmers' fields in Central Java. Indonesia Agricultural Systems, 103(5): 307-315.

Brancourt-Hulmel M, Doussinault G, Lecomte C, Berard P, Le Buanec B, Trottet M. 2003. Genetic improvement of agronomic traits of winter wheat cultivars released in France from 1946 to 1992. Crop Sci. 43(1): 37-45.

Bruinsma J (ed). 2003. World Agriculture towards 2015/2030: An FAO Perspective. FAO, Rome. ISBN: 92-5-104835-5. Available from: http://www.fao.org/3/a-y4252e.pdf [Accessed: 10.02.2017].

Calderini DF, Slafer GA. 1998. Changes in yield and yield stability in wheat during the 20th century. Field Crops Res. 57: 335-347. https://doi.org/10.1016/S0378-4290(98)00080-X

Cassman KG. 1999. Ecological intensification of cereal production systems: Yield potential, soil quality, and precision agriculture. Proc. Natl. Acad. Sci. 96: 5952-5959. https://doi.org/10.1073/pnas.96.11.5952

Chapagain T, Good A. 2015. Yield and production gaps in rainfed wheat, barley, and canola in Alberta. Frontiers in Plant Science, 6: 990. https://doi.org/10.3389/fpls.2015.00990

Condon AG, Richards RA, Rebetzke GJ, Farquhar GD. 2004. Breeding for high water-use efficiency. Journal of Experimental Botany, 55(407): 2447-2460. https://doi.org/10.1093/jxb/erh277

Connor DJ. 2004. Designing cropping systems for efficient use of limited water in southern Australia. European Journal of Agronomy, 21(4): 419-431. https://doi.org/10.1016/j.eja.2004.07.004

Connor DJ, Loomis RS, Cassman KG. 2011. Crop Ecology: Productivity and Management in Agricultural Systems. Cambridge Univ. Press, Camb., UK. ISBN: 9780521744034.

Dinçer MN, Yaktubay Ş. 2012. Bread Wheat Breeding Programme in Çukurova Region. Project No; TAGEM/TA/008 (2008-2012).

Doğan O. 2012. Productivity status of Turkey soils. Available from: https//:www.cem.gov.tr. [Accessed: 13.12.2017].

Doğan Y, Kendal E. 2012. Determination of grain yield and some quality traits of bread wheat (*Triticum aestivum* L.) genotypes. Journal of Agricultural Faculty of Gaziosmanpasa University, 29(1): 113-121.

FAO and DWFI. 2015. Yield gap analysis of field crops – Methods and case studies, by Sadras VO, Cassman KGG, Grassini P, Hall AJ, Bastiaanssen WGM, Laborte AG, Milne AE, Sileshi G, Steduto P. FAO Water Reports No. 41, Rome, Italy. ISBN 978-92-5-108813-5. Available from: http://www.fao.org/3/a-i4695e.pdf [Accessed: 11.08.2017].

Fiez TE, Miller BC, Pan WL. 1994. Assessment of spatially variable nitrogen fertilizer management in winter wheat. J. Prod. Agric. 7: 86-93. https://doi.org/10.2134/jpa1994.0086

Fischer RA, Byerlee D, Edmeades GO. 2009. Can technology deliver on the yield challenge to 2050. In How to feed the World in 2050. Proceedings of a technical meeting of experts, Rome, Italy, ISBN: 978-92-5-106363-7. 24-26 June 2009, pp. 1-48, FAO.

French RJ, Schultz JE. 1984a. Water use efficiency of wheat in a Mediterranean-type environment. I. The relation between yield. water use and climate. Australian Journal of Agricultural Research, 35(6): 743-764. https://doi.org/10.1071/AR9840743

French RJ, Schultz JE. 1984b. Water use efficiency of wheat in a Mediterranean-type environment. II. Some limitations to efficiency. Australian Journal of Agricultural Research, 35(6): 765-775. https://doi.org/10.1071/AR9840765

Fuentes JP, Flury M, Huggins DR, Bezdicek DF. 2003. Soil water and nitrogen dynamics in dryland cropping systems of Washington State, USA. Soil and Tillage Research, 71(1): 33-47. https://doi.org/10.1016/S0167-1987(02)00161-7

Hay R, Porter J. 2006. The physiology of crop yield. 2nd ed. Blackwell Publishing. Oxford. UK. ISBN: 978-1-405-10859-1

Heisey P, Norton GW. 2007. Fertilizer and other chemicals. In: Handbook of Agricultural Economics (Ed: Eveson R, Pingali P.) 3: 2747-2783. ISBN: 978-0-444-51874-3

Kaçar B, Katkat V. 2009. Gübreler ve Gübreleme Tekniği. Nobel Yayın Dağıtım Tic. Ltd. Şti. Ankara. ISBN: 978-605-5426-20-0

Kale S, Tarı AF. 2012. Evaluation of FAO-AQUACROP model performance for winter wheat under irrigated and rainfed conditions. Soil Water Journal, 1(2): 119-131. https://doi.org/10.2166/wst.2013.305

Kanber R (Ed.). 1982. Türkiye'de Sulanan bitkilerin Su tüketim Rehberi. Topraksu Genel Müdürlüğü Yay 718, Ankara.

Kara B. 2010. Influence of late-season nitrogen application on grain yield, nitrogen use efficiency and protein content of wheat under Isparta ecological conditions. Turkish Journal of Field Crops, 15(1): 1-6.

Kendal E, Tekdal S, Aktaş H, Karaman M. 2012. Comparison of some local and Italy durum wheat varieties in terms of yield and quality parameters in irrigation conditions of Diyarbakir and Adiyaman. Journal of Agricultural Faculty of Uludağ University, 26(2): 1-14.

Kruse J. 2010. Estimating demand for agricultural commodities to 2050. Global Harvest Initiative (prepublication draft). Available from: http://www.globalharvestinitiative.org [Accessed: 05.04.2017].

Leggett GE. 1959. Relationships between wheat yield, available moisture, and available nitrogen in eastern Washington dryland areas, Washington Agricultural Experiment Station Bull. 609, Washington State University, Pullman, WA.

Licker R, Johnston M, Foley JA, Barford C, Kucharik CJ, Monfreda C, Ramankutty N. 2010. Mind the gap: How do climate and agricultural management explain the 'yield gap' of croplands around the world? Global Ecology and Biogeography, 19(6): 769-782. https://doi.org/10.1111 /j.1466-8238.2010.00563.x

Lobell DB, Cassman KG, Field CB. 2009. Crop yield gaps: their importance. magnitudes. and causes. Annual Review of Environment and Resources, 34, 179-204. https://doi.org/10.1146/annurev.environ.041008.093740

Lollato RP, Edwards JT, Ochsner TE. 2017. Meteorological limits to winter wheat productivity in the US southern Great Plains. Field Crops Research, 203, 212-226. https://doi.org/10.1016/j.fcr.2016.12.014

MGM. 2017. Turkish State Meteorological Service Available from: https://www.mgm.gov.tr. [Accessed: 15.01.2017].

Neumann K, Verburg PH, Stehfest E, Müller C. 2010. The yield gap of global grain production: A spatial analysis. Agricultural Systems, 103(5): 316-326. https://doi.org/ 10.1016/j.agsy.2010.02.004

Nielsen DC, Halvorson AD. 1991. Nitrogen fertility influence on water stress and yield of winter wheat. Agronomy Journal, 83(6): 1065-1070. https://doi.org/10.2134/ agronj1991.00021962008300060025x

Oerke EC. 2006. Crop losses to pests. The Journal of Agricultural Science, 144(01): 31-43. https://doi.org/ 10.1017/S0021859605005708

Öztürk İ, Avcı R, Tuna B, Kahraman T, Aşkın O. 2015. Determination of stability parameters and some agronomic traits of the bread wheat (*Triticum aestivum* L.) cultivars grown in Trakya Region. Harran Journal of Agricultural and Food Science, 19(1): 81-94.

Passioura JB, Angus JF. 2010. Improving productivity of crops in water-limited environments. Advences in Agronomy, 106: 37-75. https://doi.org/10.1016/S0065-2113(10)06002-5

Patrignani A, Lollato RP, Ochsner TE, Godsey CB, Edwards J. 2014. Yield gap and production gap of rainfed winter wheat in the Southern Great Plains. Agronomy Journal, 106(4): 1329-1339. https://doi.org/10.2134/agronj14.0011

Ray DK, Mueller ND, West PC, Foley JA. 2013. Yield Trends Are Insufficient to Double Global Crop Production by 2050. PLoS ONE 8(6). https://doi.org/10.1371/journal.pone. 0066428

Savin R, Sadras VO, Slafer GA. 2006. Do Mediterranean environments set up an upper limit in wheat nitrogen use efficiency. IX Congress of the European Society of Agronomy. Bibliotheca Fragmenta Agronomica, Volume 11, Book of Proceedings, Part I. 339-340.

Schillinger WF, Schofstoll SE, Alldredge JR. 2008. Available water and wheat grain yield relations in a Mediterranean climate. Field Crops Research, 109(1): 45-49. https://doi.org/10.1016/j.fcr.2008.06.008

Sezen SM, Yazar A. 2006. Wheat yield response to line-source sprinkler irrigation in the arid Southeast Anatolia region of Turkey. Agricultural Water Management, 81(1): 59-76. https://doi.org/10.1016/j.agwat.2005.04.011

Sinclair TR, Wherley B, Dukes M. 2013. Transpiration: moving from semi-empirical approaches to first principles. In: Fleisher, D. (Ed.), Symposium-Improving Tools to Assess Climate Change Effects on Crop Response: Modeling Approaches and Applications: I.ASA, CSSA, and SSSA. Tampa. FL. Available from: https://scisoc.confex.com/ crops/2013am/webprogram/Session11501.html [Accessed: 07.06.2017].

Soylu S, Sade B. 2012. İklim Değişikliğinin Tarımsal Ürünlere Etkisi Üzerine Bir Araştırma Projesi. Mevka TR51-12-TD-01 nolu Proje Sonuç Raporu. Konya. Available from: http://www.konyadayatirim.gov.tr [Accessed: 08.06.2017].

Şahin M, Göçmen Akçacık A, Aydoğan S, Yakışır E. 2016. Determination of yield and quality performance of winter wheat genotypes in rainfed conditions quality of central Anatolian. Journal of Field Crops, Central Research Institute, 25: 19-23.

Şermet, C. 2011. Orta Karadeniz sahil bölümünde yetiştirilebilecek ekmeklik buğday (*Triticum aestivum* L.) çeşitlerinde verim, verim unsurları ve kalite kriterlerinin belirlenmesi üzerine bir araştırma. Yüksek lisans tezi. Ondokuz Mayıs üniveristesi Fen Bilimleri Enstitüsü, S 65.

Tilman D, Fargione J, Wolff B, D'Antonio C, Dobson A, Howarth R, Schindler D, Schlesinger WH, Simberloff D, Swackhamer D. 2001. Forecasting agriculturally driven global environmental change. Science, 292: 281-284. https://doi.org/10.1126/science.1057544

Tiryakioğlu M, Demirtaş B, Tutar H. 2017. Türkiye'deki buğday veriminin karşılaştırılması: Hatay ve Şanlıurfa illeri örneği. Süleyman Demirel Üniversitesi Ziraat Fakültesi Dergisi, 12(1): 56-67.

TURKSTAT. 2017. Crop Production Statistics Database. Turkish Statistical Institute. Available from: http://www.turkstat.gov.tr. [Accessed: 20.01.2017].

United Nations. 2017. World Population Prospects: The 2017 Revision.

Van Ittersum MK, Cassman KG, Grassini P, Wolf J, Tittonell P, Hochman Z. 2013. Yield gap analysis with local to global relevance-a review. Field Crops Research, 143: 4-17. https://doi.org/10.1016/j.fcr.2012.09.009

Zhang H, Oweis T. 1999. Water–yield relations and optimal irrigation scheduling of wheat in the Mediterranean region. Agricultural Water Management, 38(3): 195-211. https://doi.org/10.1016/S0378-3774(98)00069-9

Zhang X, Pei D, Li Z, Li J, Wang Y. 2002. Management of supplemental irrigation of winter wheat for maximum profit. In: Deficit Irrigation Practices. FAO. Water Reports 22. Available from: http://www.fao.org/tempref/docrep/fao/004 /y3655e/y3655e07.pdf [Accessed: 03.06.2017].