Konya Basin Agriculture-Environment Relationships and Sustainability

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Abstract: Soil and water resources have to be used efficiently due to the having agricultural potential in Konya Basin. In this study, soil and water potential of Konya Basin, its use in agriculture and problems resulted from the agriculture and sustainability were analyzed with detail. Nowadays in such basin, some problems have observed about the sustainable agriculture, water resources and environmental sustainability issues. The reason is excess water uses in agriculture. Agriculture performed in the present form has led to the excess water uses in agriculture. The most important cause of excess water use is increase of the planting areas of highly water consumption crops and adding highly water consumption new crops to the crop pattern. In this study, it has estimated that irrigation areas in basin have increased by unplanned and senseless, available water potential of basin is insufficient for these areas and unavailable ground water potential of 1.4 billion m^3 has extracted. In the other word, for irrigation areas, usable water resources are not enough. To solve the problems related to water and sustainable water resources; excess water uses from the basin resources should be stopped and only consumable water potential must be used. In addition, use of waste water and drainage water, developing crop varieties resisted to the drought and salinity conditions, establishment of new irrigation techniques and use of irrigation technologies that are highly efficient are necessarily prerequisite.

Keywords: Agricultural Production, Water Use, Irrigation-Environment Relationships, Sustainability, Konya Basin.

Introduction

Arid and semi-arid climates are more dominated in the world and consist of 26.3% of the total continents. The arid and semi-arid climates account of 12.1% and 14.2%, respectively (Akman 1992).

Drought is one of the most common environmental stresses that may limit agricultural production worldwide. However, in many countries as a consequence of global climate changes and environmental pollution, water use for agriculture is reduced. Water resources are limited for irrigation worldwide; therefore, there is a need for water-saving irrigation practices to be explored. Agriculture is the largest single user of water with 70% of freshwater being currently used for irrigation worldwide (Gerbens-Leenes & Nonhebel 2004). In some cases, it draws up to 90% of the total water available (Allan 1998). Water resources are declining worldwide (Shahnazari et al. 2007) and are already scarce in nearly 80 countries with more than 40% population of the world (Qadir et al. 2003). Projections for 2030 indicate that water withdrawal for irrigation will increase by about 14% because of the increase in the irrigated area from 18% to 34% worldwide (Anonymous 2006). Planning and management for an accurate estimation of irrigation demand by agriculture at a large scale have thus become a main issue worldwide (Maton et al. 2005). Increasing the efficiency of water use within agricultural systems could, therefore, be a necessity for sustainable agricultural development on the global, regional and national level.

Annual rainfall is almost 672 mm in Turkey and semi-arid climate region is presence. Annual available water potential of Turkey is 1540 m^3 per capita and according to this, Turkey is a water poor country. Konya closed basin, average annual 378 mm rainfall, has almost arid climate. Therefore, total semi-arid lands of the world are 14.2% and land potential of Konya basin is within semi-arid lands of the world. In the near past (10-15 year before), the water potential of basin was 900 m^3, but it has reduced from this value in recently.

Under present conditions, 88% available water potential has allocated for agriculture (Anonymous 2007) and currently agriculture has 90% of total water consumption in basin. However, present irrigated agriculture has resulted excess uses of basin water resources (Topak et al. 2008; Anonymous 2007; Göçmez et al. 2008).

In this study, soil and water resources potentials of Konya basin, irrigation and water use status in agriculture were analyzed with detail by considering present problems and some projections about sustainability were discussed.

The Konya Basin

Location

There are 25 main river basins in Turkey (Figure 1). Konya Closed Basin is 4th biggest basin according to its precipitation area which is 53850 km^2 (*approximately 7% of Turkey's area*) (Figure 2). Some characteristics of the basin have been given below. Konya Closed Basin consists of two closed sub-basins that known as Tuz Lake Basin and Konya Basin (Figure 2). These are two of several drainless areas of the Central Anatolian Plateau, which is itself also a closed basin (De Meester 1971).

Each of the basins is characterized by the presence of a large lake, respectively Tuz Lake and Beyşehir Lake (see Figure 2). Tuz Lake is fed by three major rivers, several ephemeral streams, one man-made drain channel (Camur & Mutlu 1995) and groundwater. Konya basin is fed by rivers and groundwater coming mainly from the south and by melt water and rainfall from the mountain range bordering the basin in the south (Fontunge et al. 1999). Besides the two large lakes, numerous smaller fresh water bodies, wetlands and salt steppes are present.

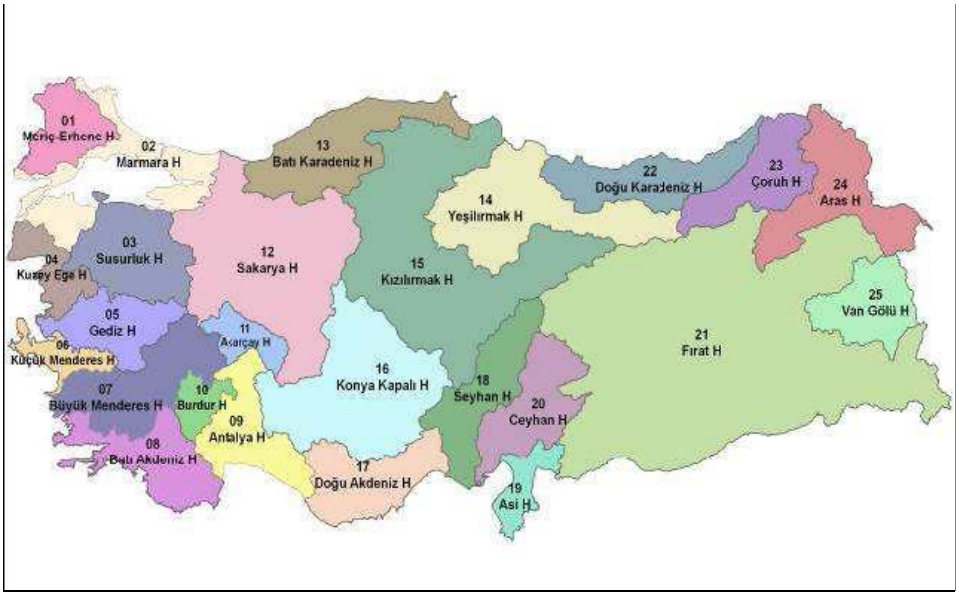

Figure 1. Basin in Turkey and position of Konya Closed Basin

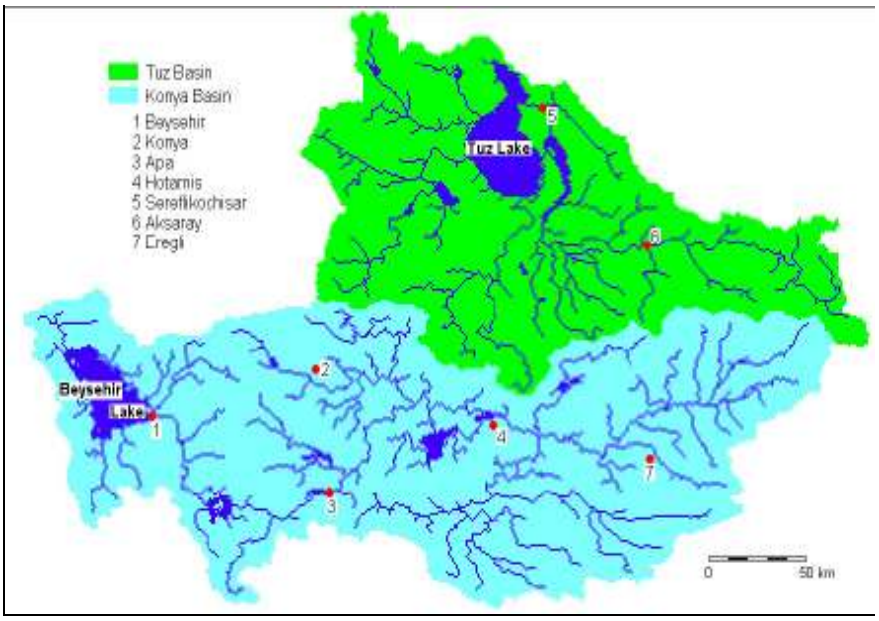

Figure 2. Konya Closed Basin (Schipper & Schot, 2004)

Climate and Drought

The annual precipitation varies from 280 mm to 350 mm in most parts of the Konya Basin and is the second grade drought region of Turkey according to the rainfall amount. This area is in Southern part of Middle Anatolia Region within curve of Konya, Karaman and Ulukışla provinces. Rainfall amounts in some important agricultural locations within this curve are given in Table 1.

		MONTHS												
	Stations	1	2	3	4	5	6	7	8	9	10	11	12	**Total**
	Seydişehir	125.0	91.1	73.9	62.7	46.4	**25.5**	**10.2**	**11.5**	**14.7**	55.3	101.1	142.4	**759.8**
	Beyşehir	68.6	49.2	46.4	50.4	45.1	**23.5**	**8.6**	**8.8**	**15.1**	42.3	60.9	76.0	**494.9**
	Kulu	42.8	33.4	36.1	51.0	48.6	**28.9**	**12.9**	**6.9**	**12.5**	28.7	40.8	51.4	**394.0**
LONG TERMS	**Cihanbeyli**	31.2	30.8	32.4	43.1	37.4	**23.7**	**7.6**	**5.1**	**9.9**	27.1	36.1	37.1	**321.0**
	Ereğli	30.0	25.8	30.3	44.0	38.2	**23.9**	**5.3**	**3.9**	**6.6**	22.6	28.7	35.2	**294.5**
	Çumra	36.8	28.5	32.9	44.0	39.2	**19.0**	**5.9**	**3.3**	**7.5**	31.6	35.3	42.5	**326.5**
	Karapınar	29.0	23.5	26.5	36.5	36.1	**26.2**	**5.6**	**3.1**	**7.1**	20.5	29.2	36.5	**278.8**
	Konya	34.8	24.1	26.5	39.5	43.5	**21.9**	**7.9**	**5.5**	**10.0**	32.4	36.1	41.4	**323.6**
	Karaman	36.0	36.2	33.9	34.6	37.8	**25.3**	**3.3**	**7.2**	**7.3**	22.1	24.8	42.5	**311.0**

Niğde	32.8	33.2	38.6	47.8	40.8	**24.6**	**4.1**	**6.0**	**10.8**	28.7	25.2	39.2	**330.0**
Evaporation	-	-	-	94.9	161.0	**216.0**	**277.0**	**255.0**	**184.0**	107.0	24.4	3.1	**1322.4**

Table 1. Long Term Rainfall in Some Important Locations in Second Drought Lands at Konya Basin (mm) (Topak et al. 2008).

Following results may be obtained by considering the rainfall records in basin:

- Semi-arid climate is dominated.
- Annual rainfall distribution is not uniform in different seasons.
- In general, rainfall reduces at the end of the spring and almost none precipitation is observed in summers.
- The rainfall is insufficient and not uniformly distributed during the crop growth period.
- In Konya Closed Basin, severe agricultural drought may be seen for all agricultural crops.
- Irrigation is a necessarily prerequisite for agricultural production under these conditions.

Konya basin has the arid climate due to the geographical position, rainfall amount and not uniform distribution. It is the special region due to having agricultural drought. As we all know that agricultural drought is not recently occurred in such basin. In recently, the increase of the cultivated land used for high water consumption in Konya plain, transition to the new crop cultivation such as maize and senseless water uses have accelerated the excess water uses. This situation has resulted water level depletion in groundwater so that hydrological drought has observed in Konya basin.

Agricultural Potential of Basin

Soil and Water Potential

Most parts of Konya, Karaman, Niğde and Aksaray cities belong to the Konya basin. Total arable land potential of those cities is 3.158 million hectare and accounts of 12.2% of total arable land of Turkey. The 72.5% of total amount is Konya plain. On the other hand, it has the 2.5% of total available water potential of Turkey (Table 2). Water resources of basin are mostly groundwater and very scant.

	Agricultural Land (million ha)	%	Available Water Potential (million ha)	%
Basin (Konya, Karaman, Aksaray, Niğde)	3.158*	12.2	2.74**	2.5
TURKEY	26.0*	100	110	100

Table 2. Arable and Available Water Potential in Both Konya Basin and Turkey
***:Anonymous 2008**
****:Anonymous 2007**

Annual available water potential is 1540 m^3/person in Turkey and almost 900 m^3/person in Konya basin. The water potential, available water for irrigation and drinking-residential usage, allocated amount for usage and estimated usage in present condition are presented in Table 3.

Water Resources	Annual Potential	Available Water Potential			
		Finally Available		Open for Usage	
	General Basin	Agriculture	Residential	Agriculture	Residential
Surface	5.949	1.000	0.069	0.900	0.047

Groundwater	1.671	1.360	0.311	1.408	0.263
Total	7.620	2.360	0.380	2.308	0.311

Table 3. Water potential and Available Water potential in Konya Basin (billion m^3 /year) (Topak et al. 2008)

It is possible to make some evaluations by analyzing the Table 3. These are as follows;

- Available water potential of basin is 2.74 billion m^3 and 2.36 billion m^3 (86.1%) of it is allocated for agriculture,
- Available groundwater potential of Basin is 1.671 billion m^3 and 81.4% of this is allocated for agriculture,

Crop Patterns of Basin

According to the Turkish Statistical Organization (TUIK) records, in general of basin, the fallowing and field crops cultivated lands are 40% and 60%, respectively. Cereals are mostly dominated. The most common cereals are wheat (57%) and barley (33%). The 17.2% of the agricultural land of basin was opened to the irrigation but, dry farming has been performed in other parts. In dry areas, winter sowing cereals, chickpea and lentil crops etc. have growth. Although agricultural drought is very serious in basin, 10% of the total wheat production is obtained from such basin. The sugar beet cultivation land and production in basin are 21% and 35% of Turkey, respectively. Therefore, industry fed by agricultural production is common in such basin. For instance, there are 6 sugar beet factories in basin and 4 of them are in Konya province. The crops types and patterns of Konya basin are presented in Table 4.

Area	**Field crops**					
	Cereals	Starch-Sugar crops	Grain Legumes	Oil crops	Forage crops	Vegetable
ha	1567910	154000	160000	15000	41000	45000
%	79.1	7.8	8.0	0.8	2.0	2.3

Table 4. The Fallowing Lands and Crop Patterns in Konya Basin *(%) (Topak et al. 2008)
*:2000-2006 (7 years mean)

Irrigation and Structure of Irrigated Agriculture

The irrigated land with project or without project of basin is almost 542118 ha. The irrigated land with project of 370000 ha is in Konya plain. According to the TUIK records of 7 years means (2001-2007), crop patterns in irrigated lands of basin are given in Table 5.

Area	**Crops**								
	Winter wheat	Sugar beet	Beans	Maize (grain+silage)	Potato	Sunflower	Vegetable	Alfalfa	Others
ha	203,836	111,130	33,174	28,413	42,541	14,920	43,739	31,448	33,677
%	**37.6**	**20.5**	**6.1**	**5.2**	**7.8**	**2.7**	**8.1**	**5.8**	**6.2**

Table 5. Crop Patterns in Irrigated Lands of Konya Basin, % (Topak et al. 2008)

According to the Table 5;

- The 85% of the winter cereals are not irrigated (production is performed under rainfed conditions).
- The winter cereals production area is 37.5% of the irrigated lands of Basin.

- In irrigated lands, the major crop is sugar beet (20.5%) and the percentages of production of vegetable, potato, dry bean, maize, alfalfa-sainfoin and others are 8.1%, 7.8%, 6.1%, 5.2%, 5.8%, 8.9%, respectively with a total of 62.5%.

Irrigation Water Requirement and Water Use

In a study conducted by Topak et al. (2008), crop patterns in irrigated conditions, net water requirement and water amounts used in irrigation are present in Table 6.

Area	Crops grown in irrigated-area								
	Winter wheat	Sugar beet	Beans	Maize (grain+silage)	Potato	Sunflower	Vegetable	Alfalfa	Others
ha	203,836	111,130[a]	33,174	28,413	42,541	14,920	43,739	31,448	33,677
%	**37.6**	**20.5**	**6.1**	**5.2**	**7.8**	**2.7**	**8.1**	**5.8**	**6.2**
Net water requirement	**499**	**783**	**158.8**	**177.8**	**228.2**	**73.2**	**309.5**	**314.4**	**168.0**
Water used (Billion m^3/year	**815**	**1167**	**158.8**	**177.8**	**228.2**	**73.2**	**309.5**	**314.4**	**168.0**
Total water use(Billion m^3/year)									**3.69**
Basin General Irrigation Efficiency									**73%**

Table 6. Crop Pattern, Crop Water Consumption, Net Water Requirement and Total Water Use in Konya Basin (Topak et al. 2008)

According to the Table 6, in basin general (Topak et al. 2008);

- In the exception of winter cereals, it is impossible to growth crops without irrigation.
- The largest cultivated lands of high evapotranspiration crops in basin are 33% (sugar beet) and vegetable (13%), respectively
- Sugar beet is the most water consumption with a value of 1.167 billion m^3.
- In basin irrigated lands, net irrigation water requirements of crops are 2.707 billion m^3.
- In present estimation, annual consumed water in agriculture for basin is almost 3.690 billion m^3.
- In basin, irrigation efficiency is 73% and this value is quite good. The reason of high irrigation efficiency is that irrigation water is mainly obtained from groundwater and sprinkler irrigation system has been intensely used.
- A remarkable example is that only water consumption of maize crop (227 million m^3) is 1.5 fold of water that will be obtained from Bağbaşı Dam.

Evaluation of Present Case

In order to evaluate the water uses in arable lands of basin, water potential allocated for use, amounts of potential according to resources, net water requirement for present irrigated areas, amount of water uses in present irrigated area and distribution of water used according to resources should be known. These are presented in Table 7.

Resources	Finally Available Water Potential * (billion m^3)		Present Available Water Potential* (billion m^3)		Net Water Requirement in Present Irrigated Area ** (billion m^3)	Present Water Uses in Agriculture** (billionm^3)
	Total	Agriculture	Total	Agriculture		
Surface	1.509	1.390	0.947	0.900		0.900

Groundwater	1.671	1.360	1.671	1.408	2.707	2.790
Total	3.180	2.750	2.618	2.308		3.690

Table 7. Available Water Potential of Basin, Net Water Requirement of Irrigated Lands and Water Uses in Irrigated Areas.

*: Anonymous 2007
**:Topak et al. 2008

According to Table 7, net irrigation water requirement of crops in basin is almost 2.707 billion m^3 for present open the irrigation area of 542000 ha. This is 0.4 (2.707-2.308= 0.4) billion m^3 higher than present water potential allocated for irrigation (2.308 billion m^3). Irrigation water used basin agriculture is estimated as 3.690 billion m^3. However, according to DSI 4th Central Directorate records, the water allocated for agriculture and residential uses are 2.308 billion m^3 and 0.263 billion m^3, respectively. According to the data, annual 1.382 billion m^3 (3.690-2.308=1.382) more basin water resources have been used in agriculture. A total of 3.690 billion m^3 water is used in basin agriculture and 2.790 billion m^3 of groundwater and 0.9 billion m^3 of surface water resources. To use the water from the surface resources, planned water conveyance and distribution networks are necessary. In currently, available water potential of surface water resources conveyed by irrigation networks is almost 0.9 billion m^3 in basin (Anonymous 2007). It is obviously seen that the used excess water of 1.382 billion m^3 (3.690-2.308=1.382) in basin agriculture is obtained from groundwater resources. However, groundwater potential allocated for agriculture is limited as 1.408 billion m^3 but ground water potential used in basin agriculture is 2.790 billion m^3 in present condition and is two fold of water potential allocated for utilization.

Reasons of excess water use

Crop Patterns and Size of The Irrigation Area

Although the safely available water potential of basin is 2.308 billion m^3, net irrigation water requirement of irrigated area is 2.707 billion m^3 under present condition. This is the main and maybe the most important reason of excess water uses in basin. It means that net water requirement of irrigated area is notably greater than the available water potential of basin. There are two reasons; firstly maize crop having high water consuming has added to present crop patterns of basin so that irrigated land of those crops has increased. Second is the most important reason that the cultivated land of high water consuming crops has increased by two fold. In summary, land of high water consuming crops has increased in last 5-6 years.

Irrigation Efficiency

The low irrigation efficiency is an indicator of excess water utilization. In present study, general irrigation efficiency is almost 73% (Table 7) and can be acceptable as good value. This 73% irrigation efficiency shows that farmers in basin do not apply excess water and the effect of farmer's irrigation on excess groundwater uses is very little. The high irrigation efficiency may be resulted from two main reasons. The first, sprinkler irrigation systems are very common in Konya plain and others or second, the farmers have applied irrigation water with required amounts. By using the groundwater in sprinkler systems, irrigation efficiency may be reached up to the 85% under well planned and operated systems (Keller& Bliesner 1990; Clemmens &Dedrick 1994; Topak 1996; Topak et al. 2005). There are 200780 sprinkler systems in Turkey and 46589 (23.2%) of them are in Konya basin (Anonymous 2008). However there are 95000 open wells in basin and this shows that the number of the sprinkler systems are higher than 46589 (75000-8000). Thus, irrigation efficiency may be increased up to 83-85% and 10% water saving in groundwater potential will be realized under such conditions. In previous study conducted in Konya Plain results also showed that irrigation efficiency could be increased from 73% to 85%. According to a research carried out in Konya-Çumra Plain, water application efficiency and evaporation losses were found as 80% and 10%, respectively in sprinkler systems (Topak 1996; Topak et al. 2005). It is possible to increase the irrigation efficiency by organizing the education program for farmers related to the irrigation program and

proper design and operation of sprinkler systems. Nowadays, the effect of farmer irrigation applications on excess groundwater uses in basin irrigation is very low (10%).

Importance of water in Society

People especially in rural areas and other whole society are senseless about the importance of water resources and dangers of drought. The main reason is poor organization of the civil society organization (CSO).

Reliable projections in basin: sustainability

Total safely available water potential of basin agriculture for current conditions has allocated as 2.308 billion m^3 (Anonymous 2007). In respect to the sustainability of water resources, water use in agriculture has to be limited by available safely water potential of 2.308 billion m^3/ year. On the other hand, new solutions about the more efficient available water use in water allocated to the agriculture must be studied. Projections about solutions are summarized as follows.

Present Crop Pattern and Remain of Current Irrigation Applications

In this condition, allowed water in agriculture for basin is 2.308 billion m^3/ year and this can irrigate 340 000 ha land. Under this condition, 200 000 ha of total 542 000 ha, opened the irrigation, will be reduced. This projection can not be accepted as a solution. Thus, some alternative solutions must be developed for irrigation land size of 542 000 ha.

Improvement of Irrigation Efficiency in Accordance of Current Crop Patterns

It possible to increase irrigation efficiency from 0.73 to 0.85. Especially in sprinkler irrigation water is directly obtained from groundwater and irrigation efficiency can be as 85% in well design and managed systems (Keller & Bliesner 1990; Clemmens & Dedrick 1994; Topak 1996; Topak et al. 2005). Under same conditions, efficiency will be also over 85% in drip irrigation. In such case, 384 000 ha land size will be irrigated by 2.308 billion m^3 available water potential. This means that current irrigation land size is reduces as 30%. This shows that obtaining target irrigation efficiency is not only solution for improvement of current situation.

Changes in Crop Patterns

Changes of crop patterns in irrigated areas of basin is necessary prerequisite for sustainability. Land size of high water consuming crops can be reduced and land size of low water consuming crops may be increased or alternative crops can be included to the patterns. However, it is necessary rigid radical decisions to change the crop patterns for preventing the excess water uses in basin under present conditions. High water consuming crops in basin are sugar beet, potato and maize. It can be overcome this problem by 50% land size reduction of such crops even grain maize completely can be count out from the pattern.

New Irrigation Techniques Use Result More Low Water Use and Improvement in Irrigation Efficiency Under Present Crop Patterns

Beside use of conventional irrigation techniques, application of full crop water requirement, new deficit irrigation techniques, not resulted significant yield reduction, must be applied. These techniques are prerequisite in water shortage and large land size conditions and some studies show that these are suitable for mainly sugar beet and then potato, maize, wheat, sunflower, bean and some vegetables. For instance, if we make a 25% deficit in present consuming water of basin, water amount will be 2.75 billion m^3 instead of 3.69 billion m^3 and it means that there is a 0.925 billion m^3 more low water use from ground water resources. Irrigated land will still remain as 542 000 ha.

Conclusion

In summary, irrigated agriculture results in two fold more irrigation water uses than amount of groundwater potential allocated safely uses under present conditions. The main reason of excess water uses is that crop patterns in basin are high water consuming crops and the cultivated lands of those crops have increased. The utilization of water in agriculture is 92.2% under present conditions at basin. If this trend continues, groundwater potential of basin will be wiped out in near future. Thus, irrigated agriculture in basin accelerates the wipe out of the groundwater resources in current conditions. In basin, irrigation agriculture should be performed by allocated water amount and this is necessary prerequisite for sustainability.

References

Akman, Y. (1992). *İklim ve Bioiklim.* Palme Yayın Dağıtım, Ankara (in Turkish).

Allan, J.A. (1998). Virtual water: a strategic resource, global solutions to regional deficits. *Ground Water 36*, 545–546.

Anonymous. (2006). Water: A Shared Responsibility. *The United Nations World Water Development Report 2.* http://unesdoc.unesco.org/images/0014/001444/144409E.pdf (accessed 19 January 2010).

Anonymous. (2007). Present Water Resources of Konya Basin, Facing problems, Preferential Projects and Turn out Solution Proposals. General Directotare of State Hydraulic Works, 4 th Reginal Directorship, Konya.

Anonymous. (2008). htttp://www.tuik.gov.tr

Camur M.Z. & Mutlu H. (1995). Major-ion geochemistry and mineralogy of the salt lake (Tuz Gölü) basin,Turkey. *Chemical Geology,* 127, 313-329.

Clemmens, A.J & Dedrick, A. R. (1994). Irrigation Techniques and Evaluation, Tanji, K. K., Yanon, B (Eds.), *Advances in Series in Agricltural Sciences*, Springer, Berlin, 64-103.

Fontunge M., Kuzucuoğlu M., Karabiyikoğlu, C., Hatté C & Pastre J.F. (1999). From Pleniglacial to Holocene: a 14C chronostratigraphy of environmental changes in the Konya Plain, Turkey. *Quaternary Science Reviews* 18, 573 – 591.

Gerbens-Leenes, P.W & Nonhebel, S. (2004) Critical water requirements for food, methodology and policy consequences for food security. *Food Policy*, 29, 547–564.

Göçmez, G., Dıvrak, B.B & İş, G. (2008). *A Research Summary Report on Determination of Groundwate Changes in Konya Closed Basin.* WWF- Turkey (in Turkish).

Keller, j & Bliesner, R. D. (1990). *Sprinkle and Trickle Irrigation*. AVI Book. Van Nostrand Reinhold. Ne York.

Maton L., Leenhardt D., Goulard M., & Bergez J.-E. (2005) Assessing the irrigation strategies over a wide geographical area from structural data about farming systems. *Agricultural Systems*, 86, 293–311.

De Meester, T. (1971). *Highly Calcareous Lacustrine Soils in the Great Konya Basin, Turkey.* Centre for Agricultural Publishing and Documentation, Wageningen.

Qadir, M., Boers Th.M., Schubert S., Ghafoor, A & Murtaza, G. (2003) Agricultural water management in water-starved countries: challenges and opportunities. *Agricultural Water Management*, 62, 165–185.

Schipper, AM & Schot, PP. (2004). A Water Balance Model for Konya Closed Basin (Turkey). http://www.ru.nl/contents/pages/34390/websitemk-reportaschipper.pdf

Shahnazari, A., Liu, F., Andersen, M.N., Jacobsen, S.E & Jensen C.R. (2007) Effects of partial root-zone drying on yield, tuber size and water use efficiency in potato under field conditions. *Field Crops Research,* 100, 117–124.

Topak, R., Süheri, S., Çiftçi, N & Acar, B. (2005). Performance evaluation of sprinkler irrigation in a semi-arid area. *Pakistan Journal of Biological Sciences,* 8 (1), 97-103.

Topak, R. (1996). Application Problems in Konya-Çumra Plain Sprinkler Irrigated Lands. PhD Thesis Konya (Unpublished).

Topak, R., Süheri, S., & Acar, B. (2008). İklim-Tarımsal Kuraklık-Sulama ve Çevre Etkileşimi Yönünden Konya Havzası. *Konya Kapalı Havzası Yer altı Suyu ve Kuraklık Konferansı, 11-12 Eylül 2008*, Bildiri Kitabı, Konya, 67-76 (in Turkish).