Integrated Water Resources Planning and Management of North Cyprus: Case Study on Water Supply and Demand including Drought Conditions

Gozen Elkiran, Mustafa Ergil
European University of Lefke, Department of Civil Engineering
Northern Cyprus

Abstract

Water is vital for human being in order to survive. However, increase in population, contamination of the water resources, salinization of coastal aquifers and over-extraction of the water from the ground water resources due to poor management, reduced the quantity of water on the supply side and increased the water need at demand side. North Cyprus is one of the European countries suffering from limited water resources owing to depletion, salinization and contamination of available groundwater resources. The water scarcity started in 1960s and increased to the alarming level in 2000s and it is still increasing due to lack of any serious measurements. In 1980s, several dams have been constructed with the help of the government of Turkey for the purpose of agricultural irrigation and aquifer recharge. Inasmuch, the alternative water resources to reduce the scarce in the country are under investigation nowadays, like; transferring water from Turkey to North Cyprus through medusa bags and by tankers from nearby land Turkey. Recently, more determinate solutions like; construction of flexible pipes under the sea between two countries and searching the possible deeper aquifers in the island, are under investigation. In spite of this catastrophic situation, no reliable research is available identifying the water balance in the country. And so, a case study, Integrated Water Resources Planning and Management of North Cyprus on supply and demand quantities, will be introduced in order to clarify the present situation of the country. The study considers all the contributing units to the water budget as an input or exit including the drought condition experiences in the country and its consequences. The analysis is performed through three main and seventeen sub-regions and given. The flexibility is considered to evaluate the effect of evaporation, rainfall, domestic use, irrigation use, effluent water reuse, water for animals, small industry and tourism sectors. Furthermore, the water withdrawals from the resources; groundwater, dams, springs, etc. are all studied to identify the deficiency in the groundwater resources. Irrigation need is evaluated considering the monthly and annual extractions for the whole sub-regions. In addition, irrigation techniques and their efficiencies and water losses in the pipeline systems are also accounted and presented.

Key-words: Water scarcity, Northern Cyprus, IWRM, drought conditions, Trans-boundary water transfer, Domestic water, Irrigation water, water deficiency, aquifer deficiency, salinization.

Introduction

Water scarcity in Cyprus started in 1960s. Soon after, several studies and researches were performed to identify the level of water deficiency in the whole island (Konteatis, 1995). The backbone of the economy of the country is the agriculture and small farming. Citrus fruit plantation occupies the majority of the export of Turkish Republic of Northern Cyprus (TRNC) (ASP, 2003).
Uncontrolled irrigation of the fields, late adoption of old irrigation techniques and poor conveyance efficiency of pipelines and network systems, caused the over extraction of water from the available aquifers. That phenomenon resulted with the higher values of salt contamination due to the salt-water intrusion, where the coastal aquifers are invaded by the sea up to several hundred meters inland from the coast and also cause depletion of some of the small volume aquifers at the interior part of the island.

Table 1: Regional land distribution of North Cyprus (2002)

Regions	Type of land (are)					
	Agricultural	Forest	Grazing	Unused	Total	Irrigated
LMR	5,934,320	500,524	455,640	1,943,703	8,834,189	698,323
C. Lefkosa	1,412,262	3,505	51,117	442,598	1,909,482	3,011
Degirmenlik	726,760	183,131	69,271	162,743	1,141,906	13,394
Ercan	1,648,210	2,863	48,214	271,199	1,970,486	9,888
Guzelyurt	1,696,330	42,957	276,563	558,317	2,574,168	611,939
Lefke	450,758	268,068	10,475	508,846	1,238,147	60,091
MMR	9,903,721	3,461,142	1,020,434	3,327,645	17,712,939	201,940
Magosa A	834,279	36,562	79,800	495,508	1,446,148	43,603
Magosa B	1,225,264	1,632	94,475	392,056	1,713,427	5,285
Akdogan	1,774,766	3,358	111,198	783,576	2,672,898	30,774
Y. Erenkoy	1,486,711	1,296,114	112,175	527,495	3,422,494	78,461
Mehmetcik	1,244,689	559,013	96,215	240,510	2,140,426	16,816
Y. Iskele	998,387	602,478	159,506	416,578	2,176,948	15,320
Gonendere	989,490	238,356	165,111	156,362	1,549,320	4,536
Gecitkale	1,350,135	723,629	201,954	315,560	2,591,278	7,145
GMR	2,866,050	2,469,673	158,142	943,163	6,437,026	100,362
Girne East	464,551	850,159	25,218	308,590	1,648,517	16,110
Girne West	272,189	403,895	776	154,048	830,908	45,789
Bogaz	675,469	272,764	72,027	182,262	1,202,522	8,238
Camlibel	1,453,841	942,855	60,121	298,263	2,755,079	30,225
North Cyprus	18,704,091	6,431,339	1,634,216	6,214,511	32,984,154	1,000,625

North Cyprus (NC) has a population of 200 000 with an irrigable land of nearly 87 km^2 (Table 1). On the other hand, the population of stock farming is 300 000. The foreign students within the Universities are about 26 000 and the bed capacity of the hotels within the tourism sector is 3 000 (DPO, 2002).
He country is divided into three main regions, Lefkosa (LMR), Magosa (MMR), and Girne (GMR), and seventeen sub-regions (Fig. 1). The land distribution among regions are tabulated and given in Table 1 (ASP 2003).
In this study, the monthly water requirements of the whole sectors within the country, including municipal needs were investigated in the seventeen sub-regions of the country. Thus, the water deficiencies of the aquifers, water withdrawals from the resources, sector-wise water consumptions, evaporation effects within the region, water losses due to the old conveyance systems, the amount of water wasted due to late adoption of the new irrigation techniques and the additional amount of water required are all determined. Furthermore, the water deficiencies in the aquifers under drought conditions experienced in the country are also studied and the consequences in the aquifers are designated. In NC, rationing of water supply to the users is effectively used in the dry seasons by the authorities in order to reduce the water consumptions. Also, it is believed that only 80 % of the irrigation water can be supplied to the crops or orchards owing to the limitations in the aquifer storages in the drought seasons.

Water Budget of TRNC

The only source replenishes the water resources of NC is the rainfall. An analysis of rainfall over South Cyprus indicates that, there is 14 % reduction of rainfall in the present time than the beginning of this century. Investigations of rainfall on Cyprus also revealed that, only 20 % of the rainfall is in fact, contributing to the water budget. The remaining portion returns to the atmosphere through evapotranspiration (Kypris, 1995).

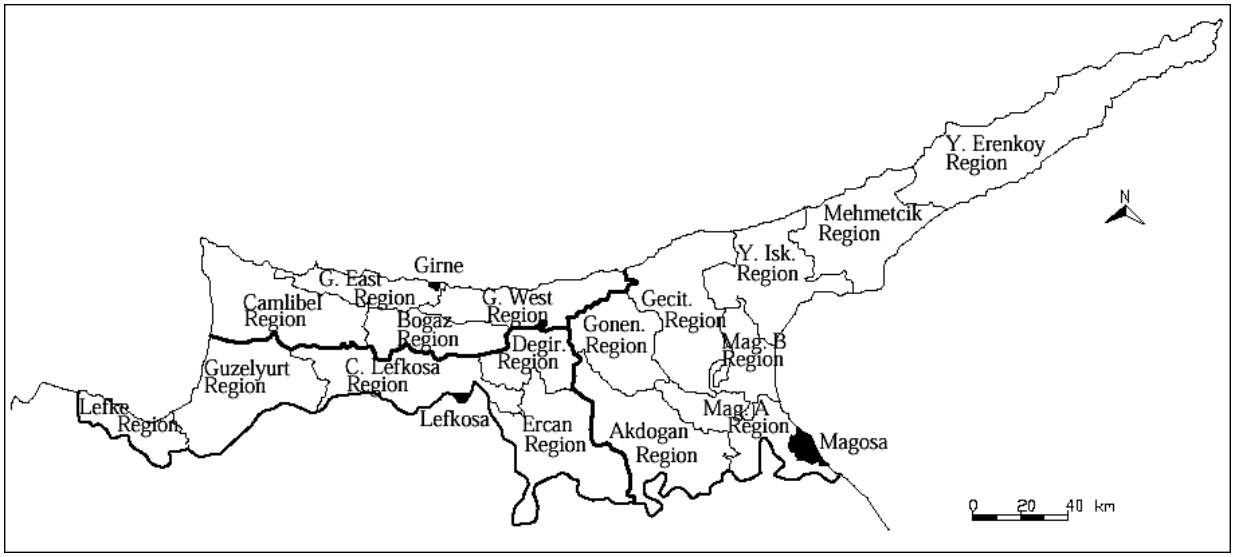

Figure 1: Main Agricultural Regions and Sub-regions of North Cyprus

The rainfall degradation in NC is experienced more effectively. This can also be seen after application of the moving average technique to the annual average values, from 1974 to 2001 (Fig. 2). Unfortunately, it has been discovered that the rainfall trend is decreasing, 2.2 mm per annum (Fig. 3). The same value is observed when alternative years of moving averages are used for the same data (Goymen, 2003).
Since the water deficiency is realized in 1980s, to overcome this situation with the help of DSI of Turkey, 41 dams were constructed, of which, only 16 of them were aimed to store water for irrigation purposes. The remaining were constructed for preventing the direct flow to the sea and thus, contributing more efficiently to the aquifer recharge. Efficient reuse of effluent water for irrigation is out of the concept, due to traditional belief among the society. Desalination plants are introduced by some of the institutions in year 2000, due to shortage of natural resources and availability of brackish water within the coastal regions (Ozturk, 1995).
Water outputs from the water budget are irrigation, municipal needs, industrial water consumption, stock farming, transmission line and the network system losses, unused effluent water and uncontrolled small seasonal spring flows that directly flows to the sea (Fig.2).

Available Water Resources

North Cyprus is a semi-arid country with a typical Mediterranean climate of hot and dry summers and mild winters. The average temperature falls below 0 ^{o}C at the peaks in winters and rise above 40 ^{o}C at the plains in summers (Elkiran, 2002). Rainfall distribution over the country varies considerably among these regions. The minimum average annual value is measured at Central Mesaoria region as 294.7 mm and the maximum annual average at Northern Coast and Besparmak Mountains are as 456.6 mm. The average rainfall value for the overall country is 373.3 mm/year. Based on 50 years data, the analysis reveals that, there is 1 mm/year reduction of the rainfall, whereas, 2.2 mm/year is reached when only the last 15 years values are used (Fig. 3) (Goymen, 2003).
Snow is rarely occurs upon the upper hills of Besparmak Mountains at the North and is usually available at the peaks of Trodos Mountains throughout the year at the South Cyprus. The maximum snowfall over the Northern part of Cyprus in the last ten years (1992-2002) is measured to be as 15 cm on Besparmak, Selvilitepe and Kantara hills (Kibris, 2003; Goymen, 2003). The Southern part of the Island has a snowfall

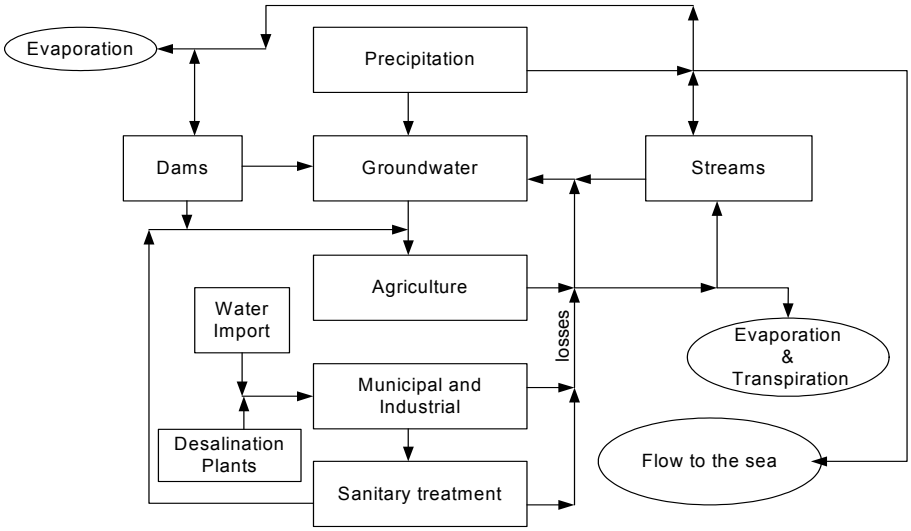

Figure 2: Water Balance Scheme of TRNC

of varying depth from 0.5m to 3m yielding an amount of 100 MCM per year, that are mostly occurring during the months of January and February (Konteatis, 1995).
Since 1998 till 2002, large water bags towed by ships of varying capacity from 10 000 to 30 000 m^3 were used in order to overcome the municipal water needs of NC. These bags were filled at Anamur, Turkey and brought to Kumkoy coast near Guzelyurt. The first ship that was arrived in September 1998 until the end of that year, unfortunately carried only 65 374 m^3 of water in five trips which was highly below the initial expectations. In fact the total quantity of water imported from Turkey during five years (1998-2002) by this way was only 4.1 MCM (Fig. 4). However, the expected amount per annum was about 5 MCM for the initial estimates (SID, 2002).

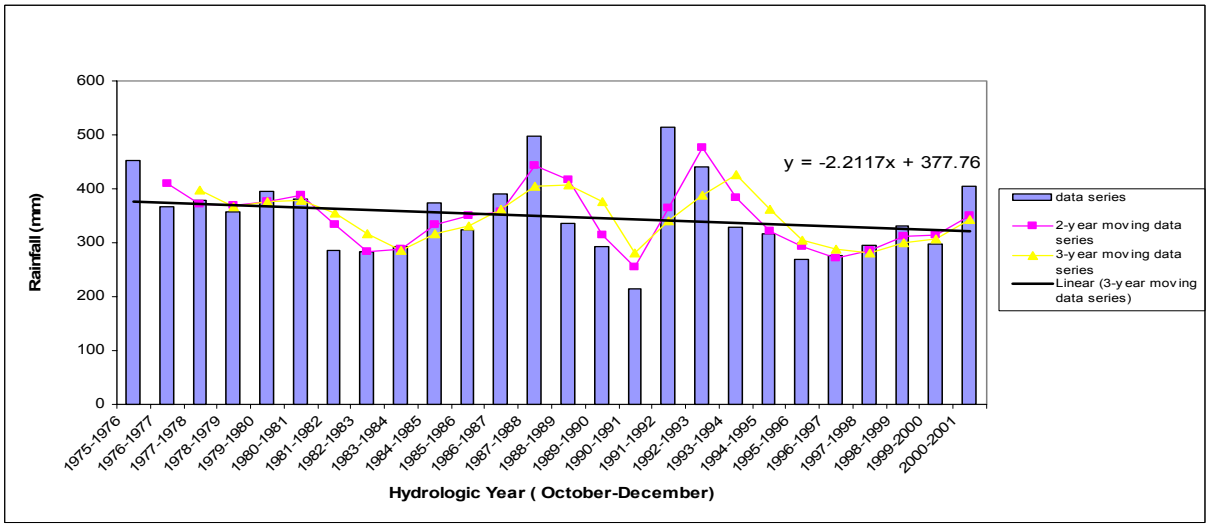

Figure 3: The rainfall trend and two and three years of moving averages

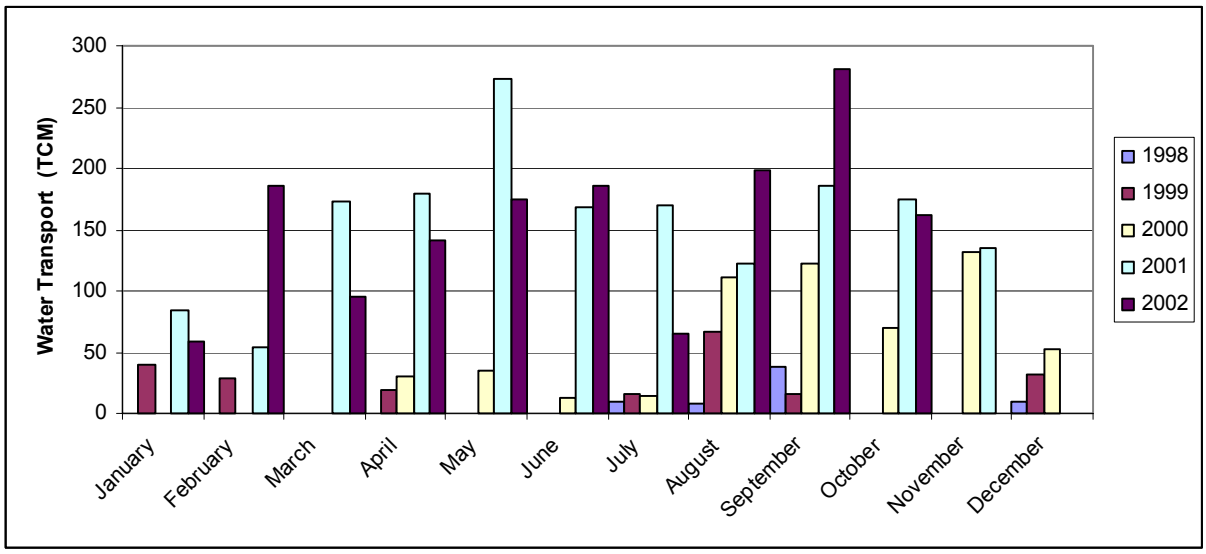

Figure 4: Monthly water transport quantities between years 1998 and 2002 in Thousands Cubic Meter (TCM)

In North Cyprus, three central treatment plants were constructed to treat the sewerage waste water of the cities Girne, Lapta, and Lefkosa. The first two of these plants that are located in GMR have capacities only to treat black water up to 600 m^3/day, but this quantity reduces to 50 % during winter season since the utilization of the freshwater is reduced. Lefkosa Central Plant, treats about 10 000 m^3/day of the sewerage water where 6 000 m^3 of this black-water is collected from the North and the remaining is pumped from the Southern part of the city (SID, 2002).
Yearly an average of 3.6 MCM of effluent water is treated at Lefkosa Plant and diverted into the stream channel for evaporation, since the reuse of this treated water for the irrigation of alternative crop patterns are not accepted by the farmers psychologically. However, recently, farmers are using restricted quantity of this treated water for irrigation purposes, but neither the amount of the water nor the types of the crop patterns grown are known officially (SID, 2002).
There is no perennial stream in North Cyprus. Ten of the streams that are originated from the South carry an average of 43 MCM of water. However, most of these streams are controlled at their upper reaches by the recently constructed dams at the South, hence, reducing the water potential of the North. The other 28 streams that are located at the North are approximately discharging 27 MCM of water annually (Ozturk, 1995).
In the period of 1974-1984, 20 dams have been constructed for water storage and recharge purposes. The approximate storage of the water within these dams is around 20 MCM per year. Furthermore, until 1990, 15 more dams were constructed of having an extra storage capacity of 15 MCM per year (Ozturk, 1995).
The amount of municipal drinking water that is supplied from 162 wells and boreholes is about 24.5 MCM and from the streams is nearly 0.34 MCM per year. It is believed that, 500 m^3/day of water is pumped to the South from the North and nearly the same amount of water has been pumped back due to common piping systems within the cities (SID, 2002).
Irrigation water is supplied both from the available dams and the nearby wells. Variable values had been proposed for this utilized quantity of water in the literature due lack of measurements and control facilities. These values are within the range of 82.5 MCM (Bicak, 2000) and 144 MCM (Ozturk, 1999).

Agriculture

Agriculture, contributes a lot to the economy of the island. Citrus fruit occupies the greatest part of the production in agriculture and hence, its contribution to the export is also considerably high. The main crop

patterns grown in the agricultural sector are, cereals, pulses, fodder crops, grapes and citrus fruits, of which they constitute 52 % of the agricultural land (ASP, 2003). The ratio of population working in agricultural sector in TRNC is 16.5 % based on census 2001, but this value was reaching up to 37.34 % in 1982. The reason of reduction is due to the existing embargoes for the exports (ASP, 2003).

Municipal Needs

The municipal water supply overcomes the needs of the householders, the farmers that are dealing with the stock farming, the tourism sector and the small industrial sector of NC. The amount of the water, that is supplied to the public needs, in drought seasons is controlled and restricted by applying a twice in a week type rotational water supply scheme. However, the tourism sector is highly affected by limitations and recently, they found a way to reuse the effluent water for irrigating their gardens (SID, 2002).
The rotational supply of water to the public caused the home gardens to be dried up. This scheme is also effectively experienced in the South reducing 33 % of the water consumption (Georgiou, 2002). It is unfortunate to note that, in NC, the losses within the pipelines and network systems are in the range of 30-60 % due to late non-renewal of the rather old pipes (SID, 2002).

Consumptive Water Requirements

The consumptive water requirements (CWR) of different sectors in TRNC are given in Table 2.

Table 2: Consumptive water requirements of different sectors in TRNC.

Sectors	CWR (l/day/capita)
House holders	250
Cattle	50
Sheep	15
Universities	150
Tourism	200

In Southern part of Cyprus, investigations revealed that, more than 80% of the rainfall over the land surface returns to the atmosphere through evapotranspiration (Socratous, 2000). Although there is no detailed study in the North, it is assumed that, nearly 90% of this precipitated water returns to the atmosphere. The total annual rainfall on TRNC is about 1250 MCM and the evaporation from the surface is hence, estimated to be 1000 MCM, indicating that, only 250 MCM of water is contributing to the water resources budget of TRNC.

Groundwater

Groundwater constitutes the major part of the water resources in the North. Available unconfined aquifers are used to supply potable water for the public needs and for the irrigation requirements. However, over extraction of water from these aquifers and due to poor recharge capacities resulted in the depletion of available freshwater within the aquifers. It is important to note that, due to this excess pumping, the contamination of the aquifers by sea water intrusion within the coastal regions reaches to an alarming stage and in some localized areas, the NaCl concentration is even reaching as high as 5000 ppm that is high beyond the world standards (Elkiran, 2002).
In NC, domestic and irrigation water are supplied mainly from the groundwater resources, dams and from the semi-perennial small springs. The aquifers in the island characterized into 13 groups within 8 hydrologic regions, which are having variable capacities (JMD, 2002). Based on 1970s estimates, the annual safe yield of these aquifers were nearly 74.1 MCM however, it is estimated that 28.9 MCM of water is over extracted from these aquifers (UNDP, 1970; DSI, 2002).

Table 3: Aquifer capacities and the consequences after annual extractions in NC (DSI 2003)

Aquifers	Recharge (10^6 m^3)	Safe Yield (10^6 m^3)	Withdrawals (10^6 m^3)	Situation (10^6 m^3)
Guzelyurt	37	37	57	-20 (deficit)
Akdeniz	1.5	1.5	1.5	-
Lefke-G.Konagi-Y. dalga	15.5	6	6	-
Yesilirmak	7	1.5	1.5	-
Girne Mountains	11.5	11.5	11.5	
Magosa	2	2	8.5	-6.5 (deficit)
Beyarmudu	0.5	0.5	0.5	-
Cayonu-Guvercinlik-Turkmenkoy	2	2	2	-
Lefkosa-Serdarli	0.5	0.5	0.5	-
Yesilkoy	1.6	1.6	3	-1.4 (deficit))
Girne Coast	5	5	5	-
Yedikonuk-Buyukkonuk	0.3	0.3	0.3	-
Dipkarpaz	1.5	1.5	1.5	-
Korucam	1.2	1.2	1.2	-
Others	2	2	2	-
Total	**89.1**	**74.1**	**103**	**-28.9** (deficit)

Guzelyurt aquifer, which is the biggest coastal aquifer in the North located at the westernmost of the island, supplies water, not only for irrigation requirements of the region but also for the municipal needs of Lefkosa and Gazi Magusa cities. Although the total storage capacity of the aquifer is 920 MCM, recent studies proves that, the aquifer is depleting and the average water table level is reaching 70 meters below the mean sea level in some local areas (Ergil, 1999).
The second important aquifer is the Girne Coastal Aquifer. The aquifer is elongated through the Northern coast of the island with a thin strip of 1.5 km in width. The aquifer area is about 40 km^2 with an average annual replenishment of 10.5 MCM (Mollaoglu, 1985).

Integrated Water resources Analysis

In order to evaluate the water resources of the country, integrated water resources management is considered to reduce the diversity in the management. Therefore, the data collected from the departmental offices are worked until the unity satisfied and then a program prepared in excel are applied for complete evaluation. In the calculation, above mentioned units and those others have not been specified are considered and the budget prepared (Elkiran and Ergil 2004). For specification of the irrigation water, crop base consumptive water requirements are determined through Blaney-Criddle and Penman method (Kilickaya, 1977, Allen et al, 1998, Elkiran, 2004). The irrigation techniques available and the corresponding efficiencies are considered for sensitive results. The available surface water data values are used directly, however the data for missing months are derived using interpolation and extrapolation techniques. Additionally, the surface water is considered to be used in the whole sectors initially and the remaining excess need is let to be subtracted from the groundwater resources. All the calculations are performed separately so that to evaluate the water consumptions as, home base, universities, livestock, agricultural irrigation, water losses, and tourism sector, in monthly base and in total. The water resources used in water supply is also considered separately in order to clarify the water deficits within the aquifers. The management under drought conditions is also studied to give the reader an idea about the quantity of the water that can be saved during the rationing of water. The results of the analysis are presented in Tables 4 through 7.

Table 4: Sub-regional details of water consumptions and water supplies in 2002 (m^3)

LMR	Agricultural Use			Domestic Use						Total Consump.	Available Resources					Gr. Water Extract.
	Irrigation	Losses	Total	L. Stock	Hotels	Univ.	Houses	Loses	Total		Springs	Sanitary	Dams	Balloon	Desal. Water	
C. Nicosia	107,014	90,255	197,269	86,802	18,834	251,762	4,563,048	1,476,134	6,396,579	6,593,848	0	3,539,160	197,269	0	0	0
Degirmenlik	656,420	581,778	1,238,198	181,097	0	0	1,751,453	579,765	2,512,314	3,750,512	20,220	0	277,380	0	0	3,452,912
Ercan	431,911	431,910	863,821	191,391	0	0	144,905	100,889	437,185	1,301,006	0	0	0	0	0	1,301,006
Guzelyurt	37,019,737	14,518,964	51,538,701	303,633	2,774	0	7,040,183	2,203,977	9,550,566	61,089,267	0	0	0	1,694,720	0	65,813,605
Lefke	3,169,043	2,276,200	5,445,243	27,917	5,256	38,647	689,668	228,446	989,934	6,435,177	0	0	2,858,384	0	0	3,576,793
Total	**41,384,124**	**17,899,108**	**59,283,232**	**790,840**	**26,864**	**290,408**	**14,189,256**	**4,589,210**	**19,886,578**	**79,169,810**	**20,220**	**3,539,160**	**3,333,033**	**1,694,720**	**0**	**74,144,316**
MMR	**Agricultural Use**			**Domestic Use**						**Total Consump.**	**Available Resources**					**Gr. Water Extract.**
	Irrigation	**Losses**	**Total**	**L. Stock**	**Hotels**	**Univ.**	**Houses**	**Loses**	**Total**		**Springs**	**Sanitary**	**Dams**	**Balloon**	**Desal. Water**	
Magosa A	1,816,751	1,602,683	3,419,434	125,412	125,414	343,711	2,735,036	998,872	4,328,445	7,747,879	0	36,870	0	0	0	7,711,010
Magosa B	223,475	202,612	426,087	92,360	0	0	259,789	105,645	457,793	883,880	0	0	0	0	0	883,880
Akdogan	1,502,041	1,244,703	2,746,744	179,180	0	0	667,129	253,893	1,100,202	3,846,946	0	0	0	0	0	3,846,946
Y.Erenkoy	2,498,582	2,309,537	4,808,119	180,396	4,672	0	843,515	308,575	1,337,158	6,145,277	0	0	0	0	0	6,145,277
Mehmetcik	739,200	718,485	1,457,685	96,517	0	0	458,258	166,432	721,207	2,178,892	5,188	0	0	0	0	2,173,704
Y. Iskele	489,297	471,558	960,854	120,054	39,420	0	854,191	304,100	1,317,765	2,278,619	43,559	5,422	306,562	0	0	1,923,075
Gonendere	244,861	244,861	489,722	71,728	0	0	492,750	169,343	733,821	1,223,543	13,354	0	489,722	0	0	720,467
Gecitkale	359,569	352,241	711,810	145,553	0	0	133,316	83,661	362,530	1,074,340	26,384	0	707,038	0	0	340,918
Total	**7,873,776**	**7,146,679**	**15,020,455**	**1,011,200**	**169,506**	**343,711**	**6,443,984**	**2,390,520**	**10,358,920**	**25,379,375**	**88,485**	**42,292**	**1,503,322**	**0**	**0**	**23,745,276**
GMR	**Agricultural Use**			**Domestic Use**						**Total Consump.**	**Available Resources**					**Gr. Water Extract.**
	Irrigation	**Losses**	**Total**	**L. Stock**	**Hotels**	**Univ.**	**Houses**	**Loses**	**Total**		**Springs**	**Sanitary**	**Dams**	**Balloon**	**Desal. Water**	
Girne East	924,090	899,334	1,823,424	73,812	317,696	40,892	1,988,246	726,194	3,146,840	4,970,264	12,648	41,026	870,424	0	109,500	3,936,666
Girne West	2,852,639	2,762,887	5,615,526	8,588	251,193	0	1,028,661	386,533	1,674,976	7,290,502	107,053	7,321	0	0	0	7,176,128
Bogaz	374,964	365,139	740,103	146,343	0	0	1,043,900	357,073	1,547,316	2,287,419	2,209	0	283,042	0	0	2,002,168
Camlibel	1,312,878	1,164,990	2,477,868	156,691	0	0	261,523	125,464	543,677	3,021,545	153,914	0	1,382,644	0	0	1,484,987
Total	**5,464,572**	**5,192,349**	**10,656,921**	**385,435**	**568,889**	**40,892**	**4,322,330**	**1,595,264**	**6,912,809**	**17,569,730**	**275,824**	**48,347**	**2,536,109**	**0**	**109,500**	**14,599,950**
TRNC	**54,722,472**	**30,238,136**	**84,960,608**	**2,187,474**	**765,259**	**675,011**	**24,955,569**	**8,574,994**	**37,158,307**	**122,118,915**	**384,529**	**3,629,798**	**7,372,465**	**1,694,720**	**109,500**	**112,489,542**

Table 5: Regional basis monthly water consumptions and water supplies in 2002 (m^3)

LMR	Agricultural Use			Domestic Use						Total Consump.	Available Resources					Gr. Water Extrac.
	Irrigation	Losses	Total	L. Stock	Hotels	Univ.	Houses	Loses	Total		Springs	Sanitary	Dams	Balloon	Desal. Water	
October	3,247,400	1,405,406	4,652,806	67,167	2,282	34,587	1,214,115	395,445	1,713,597	6,366,403	1,566	274,874	469,207	173,990	0	5,721,640
November	121,907	103,659	225,566	65,001	2,208	33,471	1,174,951	382,689	1,658,319	1,883,885	2,063	380,010	57,950	135,070	0	1,688,802
December	0	0	0	67,167	2,282	34,587	1,214,115	395,445	1,713,597	1,713,597	3,047	392,677	0	0	0	1,710,550
January	0	0	0	67,167	2,282	34,587	1,214,115	395,445	1,713,597	1,713,597	2,471	392,677	0	58,180	0	1,652,946
February	0	0	0	60,667	2,061	10,419	1,078,331	345,444	1,496,922	1,496,922	1,406	354,676	0	186,180	0	1,309,336
March	11,046	11,046	22,091	67,167	2,282	27,575	1,207,104	391,238	1,695,367	1,717,458	1,324	392,677	7,365	95,110	0	1,613,659
April	3,163,124	1,242,936	4,406,059	65,001	2,208	26,685	1,168,165	378,618	1,640,677	6,046,736	1,531	304,008	342,245	140,610	0	5,562,350
May	5,073,842	2,241,907	7,315,749	67,167	2,282	27,575	1,207,104	391,238	1,695,367	9,011,116	1,786	274,874	790,202	175,230	0	8,043,898
June	7,282,396	3,324,080	10,606,476	65,001	2,208	26,685	1,168,165	378,618	1,640,677	12,247,153	1,172	190,005	1,146,965	185,170	0	10,913,846
July	8,732,943	3,803,648	12,536,591	67,167	2,282	11,536	1,193,867	382,456	1,657,308	14,193,899	1,484	196,339	480,365	64,720	0	13,647,330
August	7,932,473	3,295,888	11,228,361	67,167	2,282	11,536	1,193,867	382,456	1,657,308	12,885,669	1,348	196,339	30,298	198,750	0	12,655,273
September	5,818,994	2,470,539	8,289,533	65,001	2,208	11,164	1,155,355	370,118	1,603,846	9,893,379	1,022	190,005	8,436	281,710	0	9,624,689
Total	**41,384,124**	**17,899,108**	**59,283,232**	**790,840**	**26,864**	**290,408**	**14,189,256**	**4,589,210**	**19,886,578**	**79,169,810**	**20,220**	**3,539,160**	**3,333,033**	**1,694,720**	**0**	**74,144,316**
MMR	**Agricultural Use**			**Domestic Use**						**Total Consump.**	**Available Resources**					**Gr. Water Extrac.**
	Irrigation	**Losses**	**Total**	**L. Stock**	**Hotels**	**Univ.**	**Houses**	**Loses**	**Total**		**Springs**	**Sanitary**	**Dams**	**Balloon**	**Desal. Water**	
October	338,550	304,126	642,676	85,883	14,396	37,382	547,297	205,487	890,445	1,533,121	5,314	3,869	31,681	0	0	1,492,257
November	114,992	109,046	224,038	83,112	13,932	36,175	529,643	198,859	861,721	1,085,759	9,803	2,808	4,439	0	0	1,068,709
December	0	0	0	85,883	14,396	37,382	547,297	205,487	890,445	890,445	16,995	2,418	0	0	0	871,032
January	0	0	0	85,883	14,396	37,382	547,297	205,487	890,445	890,445	13,874	2,418	0	0	0	874,153
February	0	0	0	77,571	13,003	11,265	494,333	178,852	775,024	775,024	7,366	2,184	0	0	0	765,474
March	18,273	18,273	36,545	85,883	14,396	37,382	547,297	205,487	890,445	926,990	6,723	2,418	3,877	0	0	913,972
April	513,789	410,701	924,490	83,112	13,932	36,175	529,643	198,859	861,721	1,786,211	6,149	3,276	82,363	0	0	1,694,423
May	1,789,769	1,548,319	3,338,088	85,883	14,396	37,382	547,297	205,487	890,445	4,228,533	6,745	3,869	348,854	0	0	3,869,065
June	1,909,331	1,804,996	3,714,327	83,112	13,932	36,175	529,643	198,859	861,721	4,576,048	4,356	4,680	306,874	0	0	4,260,138
July	1,381,466	1,266,879	2,648,345	85,883	14,396	12,472	547,297	198,014	858,062	3,506,407	4,414	4,836	315,920	0	0	3,181,237
August	1,107,131	1,038,190	2,145,321	85,883	14,396	12,472	547,297	198,014	858,062	3,003,383	3,974	4,836	274,912	0	0	2,719,661
September	700,475	646,150	1,346,625	83,112	13,932	12,069	529,643	191,627	830,383	2,177,008	2,772	4,680	134,402	0	0	2,035,154
Total	**7,873,776**	**7,146,679**	**15,020,455**	**1,011,200**	**169,506**	**343,711**	**6,443,984**	**2,390,520**	**10,358,920**	**25,379,375**	**88,485**	**42,292**	**1,503,322**	**0**	**0**	**23,745,276**

Table 6: Regional basis monthly water consumptions and water supplies in 2002 (m^3)

GMR	Agricultural Use			Domestic Use						Total Consump.	Available Resources					Gr. Water Extrac.
	Irrigation	Losses	Total	L. Stock	Hotels	Univ.	Houses	Loses	Total		Springs	Sanitary	Dams	Balloon	Desal. Water	
October	252,740	247,317	500,057	32,736	48,317	4,450	367,102	135,781	588,385	1,088,442	23,029	4,256	43,445	0	9,300	1,008,412
November	1,122	1,055	2,177	31,680	46,758	4,306	355,260	131,401	569,405	571,582	32,477	3,594	0	0	9,000	526,511
December	0	0	0	32,736	48,317	4,450	367,102	135,781	588,385	588,385	21,738	2,713	0	0	9,300	554,634
January	0	0	0	32,736	48,317	4,450	367,102	135,781	588,385	588,385	13,792	2,713	0	0	9,300	562,580
February	0	0	0	29,568	43,641	1,335	331,576	121,836	527,956	527,956	9,013	2,450	0	0	8,400	508,093
March	259	259	518	32,736	48,317	4,450	367,102	135,781	588,385	588,903	11,705	3,255	0	0	9,300	564,644
April	29,294	28,951	58,245	31,680	46,758	4,306	355,260	131,401	569,405	627,650	19,646	3,675	50,337	0	9,000	544,992
May	616,522	578,845	1,195,367	32,736	48,317	4,450	367,102	135,781	588,385	1,783,752	36,015	4,340	583,280	0	9,300	1,150,817
June	1,310,393	1,213,543	2,523,936	31,680	46,758	4,306	355,260	131,401	569,405	3,093,341	30,208	5,250	1,341,042	0	9,000	1,707,841
July	1,459,658	1,363,326	2,822,984	32,736	48,317	1,478	367,102	134,890	584,522	3,407,506	31,758	5,425	518,005	0	9,300	2,843,018
August	1,122,033	1,100,516	2,222,549	32,736	48,317	1,478	367,102	134,890	584,522	2,807,071	25,414	5,425	0	0	9,300	2,766,932
September	672,550	658,538	1,331,088	31,680	46,758	1,431	355,260	130,538	565,667	1,896,755	21,029	5,250	0	0	9,000	1,861,476
Total	**5,464,572**	**5,192,349**	**10,656,921**	**385,435**	**568,889**	**40,892**	**4,322,330**	**1,595,264**	**6,912,809**	**17,569,730**	**275,824**	**48,347**	**2,536,109**	**0**	**109,500**	**14,599,950**
NC	**Agricultural Use**			**Domestic Use**						**Total Consump.**	**Available Resources**					**Gr. Water Extrac.**
	Irrigation	**Losses**	**Total**	**L. Stock**	**Hotels**	**Univ.**	**Houses**	**Loses**	**Total**		**Springs**	**Sanitary**	**Dams**	**Balloon**	**Desal. Water**	
October	3,838,690	1,956,849	5,795,539	185,785	64,995	76,418	2,128,515	736,714	3,192,427	8,987,966	29,909	282,999	544,333	173,990	9,300	8,222,309
November	238,021	213,760	451,781	179,792	62,898	73,952	2,059,853	712,949	3,089,444	3,541,225	44,343	386,412	62,389	135,070	9,000	3,284,021
December	0	0	0	185,785	64,995	76,418	2,128,515	736,714	3,192,427	3,192,427	41,780	397,808	0	0	9,300	3,136,216
January	0	0	0	185,785	64,995	76,418	2,128,515	736,714	3,192,427	3,192,427	30,137	397,808	0	58,180	9,300	3,089,679
February	0	0	0	167,806	58,705	23,019	1,904,240	646,131	2,799,902	2,799,902	17,785	359,310	0	186,180	8,400	2,582,903
March	29,577	29,577	59,154	185,785	64,995	69,407	2,121,503	732,507	3,174,197	3,233,351	19,752	398,350	11,242	95,110	9,300	3,092,274
April	3,706,207	1,682,587	5,388,794	179,792	62,898	67,167	2,053,068	708,877	3,071,802	8,460,596	27,326	310,959	474,945	140,610	9,000	7,801,764
May	7,480,134	4,369,070	11,849,204	185,785	64,995	69,407	2,121,503	732,507	3,174,197	15,023,401	44,546	283,083	1,722,336	175,230	9,300	13,063,780
June	10,502,120	6,342,619	16,844,739	179,792	62,898	67,167	2,053,068	708,877	3,071,802	19,916,541	35,736	199,935	2,794,881	185,170	9,000	16,881,824
July	11,574,066	6,433,854	18,007,920	185,785	64,995	25,486	2,108,266	715,360	3,099,892	21,107,812	37,656	206,600	1,314,290	64,720	9,300	19,671,585
August	10,161,638	5,434,593	15,596,231	185,785	64,995	25,486	2,108,266	715,360	3,099,892	18,696,123	30,736	206,600	305,210	198,750	9,300	18,141,866
September	7,192,019	3,775,227	10,967,246	179,792	62,898	24,664	2,040,258	692,284	2,999,895	13,967,141	24,823	199,935	142,838	281,710	9,000	13,521,319
Total	**54,722,472**	**30,238,136**	**84,960,608**	**2,187,474**	**765,259**	**675,011**	**24,955,569**	**8,574,994**	**37,158,307**	**122,118,915**	**384,529**	**3,629,798**	**7,372,465**	**1,694,720**	**109,500**	**112,489,542**

Table 7: The aquifer capacities and the water extractions in wet and dry season in 2002 (MCM)

Aquifer	Region	Sub-region	Safe Yield		Water Withdrawals		Aquifer Situation	
			Wet	Drought	Wet	Drought	Wet	Drought
Guzelyurt	**Lefkosa**	Guzelyurt	37.00	17.50	65.80	52.40	-28.80	-34.90
Lefke		Lefke	15.50	4.00	3.60	2.30	18.90	1.70
Yesilirmak		Lefke	7.00	2.00				
Lefkosa		Lefkosa	6.00	0.30	0.00	0.00	6.00	0.30
Girne Montains		Degirmenlik	10.00	5.00	4.80	2.70	5.20	2.30
		Total	**75.50**	**28.80**	**74.20**	**57.40**	**1.30**	**-30.60**
Girne Coast	**Girne**	Girne	9.00	1.50	11.10	8.80	-2.10	-7.30
Korucam		Camlibel	1.10	0.20	1.50	0.90	-0.40	-0.70
Akdeniz		Camlibel	1.50	0.25	2.00	1.60	-0.50	-1.35
		Total	**11.60**	**1.95**	**14.60**	**11.30**	**-3.00**	**-9.35**
E. Mesaoria	**Magosa**	Magosa A	5.00	1.00	7.70	6.20	-1.20	-4.70
Maras		Magosa A	1.50	0.50				
Turkmenkoy		Akdogan	0.50	0.30	3.80	3.10	-1.20	-2.00
Beyarmudu		Akdogan	0.50	0.20				
Cayonu		Akdogan	0.80	0.30				
Incirli		Akdogan	0.80	0.30				
Guvercinlik		Magosa B	0.60	0.40	0.90	0.70	-0.30	-0.30
Buyukkonuk		Mehmetcik	0.50	0.20	2.20	1.80	-1.70	-1.60
Karpaz		Y. Erenkoy	1.50	0.20	6.10	5.00	-3.10	-4.10
Yesilkoy		Y. Erenkoy	1.50	0.70				
Jips Aquifers	**Scattered**	Scattered	3.60	0.75	3.00	2.40	-1.50	-1.70
		Total	**16.80**	**4.85**	**23.70**	**19.20**	**-9.00**	**-14.40**

Conclusions and Recommendations

1. Almost 50 % of the irrigation water is lost due existing poor irrigation system. Hence, adoption of new irrigation techniques will save annually 20 MCM of water and will reduce the water extraction from the aquifers.
2. The total annual conveyance losses in pipelines and pipe networks are about 8.6 MCM. New installations of pipes may save up to 5.7 MCM of water within the conveyance system.
3. In summer seasons, the monthly water withdrawals from the aquifers reach to the maximum values. Knowing that the safe yield capacity is limited, grow of rainfed crop patterns should be encouraged in the country which does not require any irrigation water in summer times.
4. The total amount of water that is used in year 2002 is 101.8 MCM of which 93.2 MCM is obtained from the groundwater resources. It should be noted, that this extraction is highly above the aquifers safe yield capacity and it is expected that, if this policy continues, the aquifer will be depleted in 15 years time.
5. Considering the total annual rainfall within the region, it is obvious that construction of new dams at suitable locations will serve for the irrigation requirements and will also reduce the water extractions from the aquifer.
6. Water of 3.6 MCM that is treated by the sanitary plants and is diverted to the sea without any utilization, needs better planning so as to gain this amount. Therefore, the farmers must be educated and trained systematically.
7. It is interesting to note that, although the water bags that are not functioning now, but were filled free of charge from Turkey, costs nearly 0.33 USD per m^3. Since there is no proper metering system and appropriate payment policy within NC, the utilization of this distributed water could not be controlled and hence, caused the municipalities to be in depth. For this reason, a water law must be established soon and a proper distribution and costing of water within different sectors

should be defined according to the world standards. By this way, it is expected that, not only the utilized amount of water will be reduced but also the income of municipalities will be controlled.

8. Although both technical and economical studies are still continuing for floating pipeline system between Turkey and TRNC with an average diameter of pipe varying 0.8-1.0 m that will be designed to carry 75 MCM per annum, the cost of water is estimated to be around 1.0 USD per m^3. This cost is incomparable with the medium size desalination plant that is constructed in Gazi Magosa for Eastern Mediterranean University needs (1000 m^3 /day) which is 0.55 USD. Therefore, it will be a good and feasible practice to construct similar plants which is more reliable, along the coasts of NC so as to overcome the water needs as it is practiced in South Cyprus since the end of 90s.

References

1. Alkaravli M., 2002: Groundwater Resources of Northern Cyprus, Rep. No: 118/98, Department of Geology and Mining, Ministry of Interior, NC
2. Allen et al., 1998: Crop evapotranspiration, Guidelines for computing crop water requirement, FAO irrigation and drainage paper 56, Rome
3. Agricultural Structure and Production (ASP), 2003: (ed) Annual Statistics, The Ministry of Agriculture and Forestry, Department of Agriculture, Nicosia, NC
4. Bicak H. A., Jenkins G., 2000: Transporting water by Tanker from Turkey to North Cyprus: Cost and Pricing Policies. Water Balances in Western Mediterranean, ICRC, Canada.
5. DPO, (2002): Economic and Social Indicators, Department of Statistics and Planning, Lefkosa, TRNC.
6. Elkiran G., Ergil M., 2002: A general outlook of aquifers in TRNC. Proceedings of Second FAE International Symposium, Gemikonagi, TRNC.
7. Elkiran G., Ergil M., 2004: The water budget analysis of Girne region, North Cyprus, Ozturan T. (ed) Proc. Advances in civil engineering 6th Int. Cong., Bogazici University, Istanbul, Turkey, pp 1238-1247
8. Ergil M., 1999: The salination problem of Guzelyurt aquifer and rehabilitation scenarios. Ph.D. Thesis, Eastern Mediterranean University, Gazi Magosa, TRNC.
9. Georgiou E.G., 2002: Xeriscope guidelines adopted to residential gardens in Cyprus, The School of Landscape Architecture, Louisiana State University, Agriculture and Mechanical College, New Orleans, USA.
10. Goymen H., 2003: Meteorological Information and Data about Northern Cyprus, No: M9/03/2, Department of Meteorology of State, Prime Ministry, NC
11. Kibris, 2003: The first snowfall of the year has seen on Selvilitepe, Kibris Newspaper, Nicosia, TRNC, February 24.
12. Kilickaya H., 1977: How often should irrigate and how much water should released, published by Ministry of Agriculture and Forestry Department of Agriculture, Nicosia, Northern Cyprus, 1977
13. Konteatis C.A.C., 1995: Integrated water resources management in Cyprus under shortage conditions. Water Resources Management under Drought or Water Shortage Conditions, Edited by Nicos X. Tsiourtis. Proceedings of EWRA 95 Symposium, Nicosia, S. Cyprus.
14. Kypris D.C., 1995: Diachronic changes of rainfall and the water resources in Cyprus. Water Resources Management under Drought or Water Shortage Conditions, Edited by Nicos X. Tsiourtis. Proceedings of EWRA 95 Symposium, Nicosia, S. Cyprus.
15. Mollaoglu G., 1985: Natural Resources of Northern Cyprus, Proceedings of First Water Congress of Chambers of Civil Engineers (KTMMOB), Nicosia, Northern Cyprus, February 19-22.
16. Ozturk S., 1995: Up to date water potential of TRNC, Proceedings of Second Water Congress of KTMMOB, Nicosia, Northern Cyprus, February 23-24.
17. SID, 2002: Unpublished documents. Department of Hydraulic Works, Lefkosa, TRNC.
18. Socratous G., (2000); Water Pricing in Cyprus. Symposium of Water Resources Management, Efficiency, Equity and Policy, University of Cyprus, Nicosia, S. Cyprus.
19. UNDP, 1970: Survey of Groundwater and Mineral Resources of Cyprus. United Nations Development Plan, United Nations, New York.