Water and Sediment Yield from a Deciduous Forest Ecosystem in Istanbul-Turkey

Süleyman ÖZHAN[1], Ferhat GÖKBULAK[1], Yusuf SERENGIL[1]

[1] Istanbul University, Faculty of Forestry, Department of Watershed Management, Bahçeköy, 34473 Istanbul-TURKEY

Abstract

The objectives of this paper are to present annual water yield and sediment loss from a forest ecosystem consisting of completely natural broadleaved old growth oak-beech stands and to show precipitation, streamflow, and sediment discharge trends over time. An experimental watershed has been monitored since 1979 for streamflow and water quality parameters including suspended sediment discharge. Data presented in this paper covered a period of 17 years. Streamflow in the watershed has been recorded with an automatic water level recorder in a 90° concrete sharp-crested V-shaped notch weir. Precipitation data were taken from nearby Bahçeköy Meteorological Station of State Meteorological Works. Water grab samples from streamflow were collected on a weekly basis and analyzed on the same day of collection for suspended sediment. Results show that there are great variations among the years for water yield and suspended sediment loss. Average annual precipitation, water and total sediment yields are 1042,6 mm, 212,37 mm, and 0. 49 tons/ha/year and their coefficient of variations are 22%, 87%, and 66%, respectively. Additionally, total sediment loss was also estimated to be 0.49 tons/ha/year.

Key words: *Water yield, sediment discharge, streamflow, time series, broadleaf vegetation, watershed study*

Introduction

Water supply has always been a vital problem in Istanbul. In order to meet drinking water demand, aqueducts and reservoirs were built during Ottoman Empire. In last five decades, many big dams have been established around Istanbul parallel to population growth and industrial expansion. However, water resources developments are still under progress. The important topic in water resources management is to predict water and sediment yields of watersheds for reservoir planning. As it is well known, each watershed includes various land use types that have different water yields in the same conditions. Thus, runoff coefficients are highly variable depending upon watershed characteristics (Hornbeck et al., 1997; Lewis et al., 2000; Chanasyk et al., 2003). That is why; runoff coefficients are needed for different land use types.

One of the land use types is forest and most of the fresh water generates from forested watersheds. It is not known yet what percentage of precipitation is yielded from the forested lands in Turkey. Hence, an experimental watershed representing Belgrad forest was selected to get information about water yield from forest-covered areas.

Belgrad forest has a long history in terms of providing fresh water for Istanbul city. There are seven historical water reservoirs built between 1620 and 1839 in this forest, which is covered with broad leaf forest ecosystem and under protection because of its hydrological functions. In this paper, our aim was to present water and total sediment yields from this forest ecosystem. It is believed that the data would be useful for developing water resources and effectively managing watersheds providing water for the reservoirs.

Material and Methods

Study site

An experimental watershed located within Belgrad Forest ($41^0\ 13'\ 00''$ - $41^0\ 14'\ 13''$ N, $28^0\ 54'\ 25''$- $28^0\ 56'\ 37''$ E) has been selected and monitored since 1979. The watershed is completely covered with dense oak-beech forest vegetation and represents the surrounding ecosystem.
The study site has a humid, mesothermal and oceanic climate with a moderate water deficit in summer months according to Thornthwaite classification method. Annual mean precipitation is around 1091 mm and most of it falls between October and March. Mean annual temperature is 12.8^0C (Özhan et al., 2005).

The watershed has soil developed from neocene deposits. The soils derived from neocene deposits are deep, loamy clay in surface horizons and clay in the subsoil with medium permeability rates (Balcı et al. 1986). Topsoil of the study area has a saturation capacity over 40% while subsoil has over 25% (Özhan, 1977). Average depth of mull type forest floor is about 5 cm and soil has an organic matter content of 3.2%.

Topography is not steep and elevation varies between104 - 158 for watershed (Table 1). The watershed lies on a gentle southerly slope about 3-4 km far from Black Sea. Drainage density, size, slope, crown closure and standing timber volume are given in Table 1. Vegetation of the area consists of mostly tree species like *Quercus frainetto* Ten., *Quercus cerris* L., and *Fagus orientalis* L. with mixture of *Populus tremula* L., *Alnus glutinosa* L., *Carpinus betulus* L., *Acer trautvetteri* Med., *Castanea sativa* Mill., *Acer campestre* L., *Ulmus campestris* L., and shrubs like *Sorbus torminalis* Crantz. (Yaltırık, 1966).

Table 1. Some characteristics of the experimental watershed.

Watershed characteristics	
Size (ha)	71.90
Slope (%)	10.00
Drainage density (km km^{-2})	3.60
Elevation range (m)	104-158
Average litter depth (cm)	5.00
Crown closure (%)	75-100
Standing timber volume ($m^3\ ha^{-1}$)	311.18

Methods

Streamflow measurements were made in a 90^o concrete sharp-crested V-notch weir instrumented with and automatic water level recorder. Weekly grab water samples was taken from the streamflow above the gaging station and evaporation procedure was used to determine the concentration of suspended sediment (Balcı et al., 1986). Bad-load deposition was taken 18 percent of suspended sediment load (Ozhan at al., 2005). Total sediment yield calculated as the sum of suspended sediment and bed-load. In order to determine relationship among precipitation, streamflow, and total sediment yield in the watershed, straight-line regression equations were developed. Correlation coefficient of regression line was calculated and their significance levels were also tested (Zar, 1996).

Results and Discussion

Some statistical parameters are given for precipitation, streamflow, and total sediment yield for 17 years in Table 2. According to results given in Table 2, mean annual precipitation was 1042.62 mm, whereas streamflow was only 212.37 mm. In another word, runoff coefficient was 20 percent. Annual precipitation varied between 694.00 and 1594.60 mm while streamflow changed from 27.50 to 796.93 mm. When coefficients of variation were compared, precipitation had quite lower than streamflow. This is because of soil moisture content and precipitation characteristics such as intensity, duration and amount. If soil moisture deficit exists in the watershed, precipitation would not generate enough runoff.

Table 2. Some statistical parameters of precipitation, streamflow, and total sediment yield.

Statistical parameters	Precipitation (mm)	Streamflow (mm)	Total sediment yield (ton/ha year)
Mean	1042.62	212.37	0.49
Coefficient of variation	22.42	86.93	65.65
Standard deviation	233.71	184.62	323.15
Max. and Min. values	1594.60 - 694.00	796.93 - 27.50	1.422 – 0.096

But precipitation in the similar characteristics could produce much more runoff in the wet soil conditions. On the other hand, same amounts but different intensities of precipitation generate different amounts of runoff due to infiltration capacity of soils. Therefore, streamflow has greater annual variations than precipitation (Fig. 1).

Total sediment yield from the experimental forested watershed varied from 0.096 to 1.422 ton/ha/yr and average was 0.49 ton/ha/yr. This is very low and under tolerance limit for forestlands, which was 2.24 tons/ha/yr (Hewlett, 1982). Sediment yields were given 0.17 tons/ha/yr for forested watersheds in East Region and 3.93 tons/ha/yr for pacific Coast in the United States (Brooks et al., 1996).

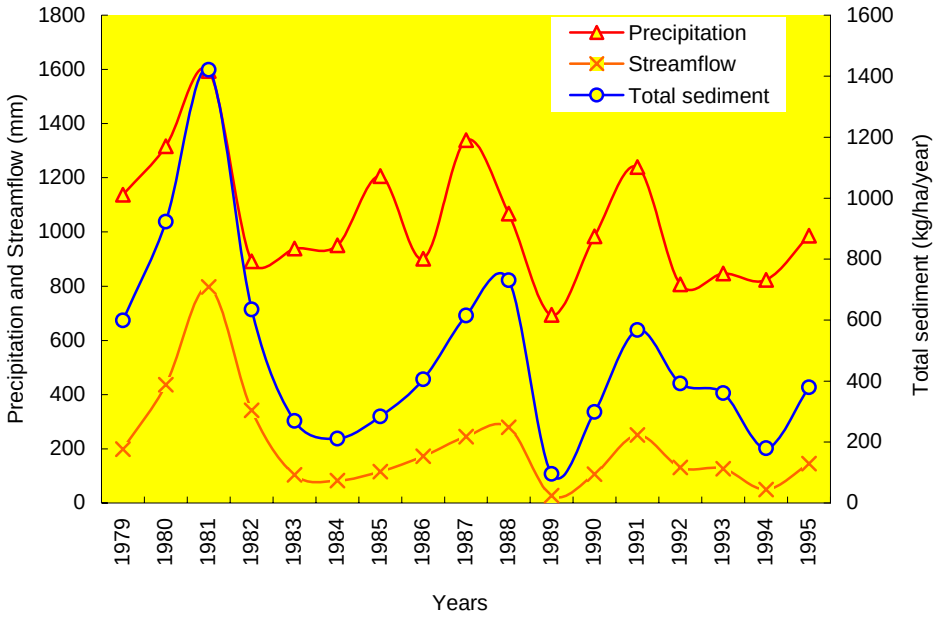

Figure 1. Annual variation of precipitation, streamflow and total sediment yield.

This variation could be explained as a result of differences in ecological conditions for these regions. This statement is supported a study conducted by Peel et al. (2004). High correlations were found between precipitation and streamflow, precipitation and sediment yield, and streamflow vs sediment yield (Fig. 2a,b,c). These figures were derived from annual values. It is believed that these regression equations could be used to predict streamflow and sediment yield in similar forest ecosystems.

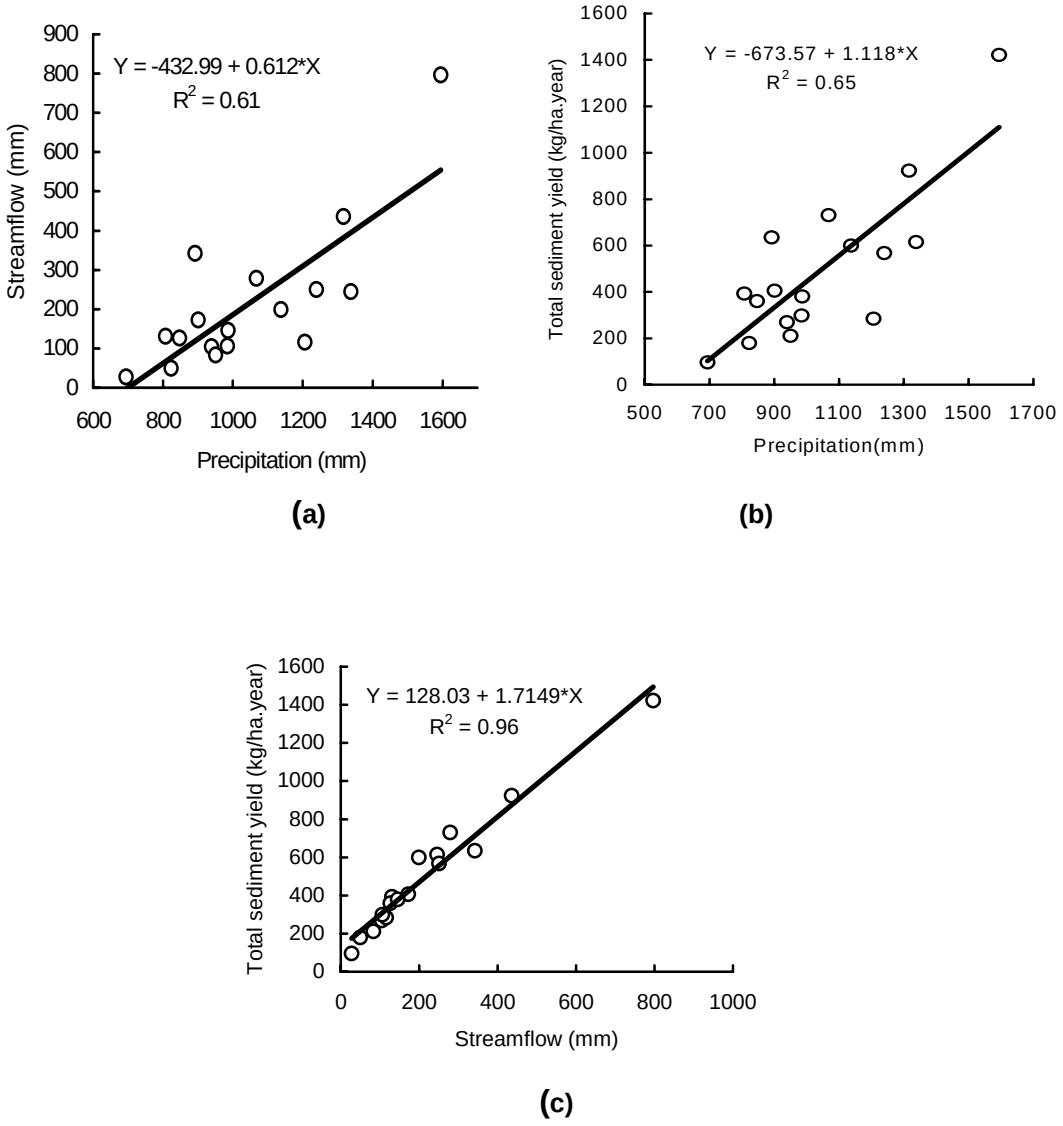

Figure 2. Relationships among annual precipitation, streamflow, and total sediment yield.

Conclusions

Fresh water usually generates from forested watersheds in Turkey and neighboring countries. Therefore, estimation of water yield and quality particularly sediment yield has become a very important issue in managing forests towards a water production objective. The findings of this study provide very significant information related to forest-water production interaction as there is very limited data in the region.

Similar studies in various forest types and densities should be conducted in order to compare the results and to select best management practices for water production.

Acknowledgment

The authors would like to acknowledge Prof.Dr. Nihat Balcı and Prof.Dr. Necdet Özyuvacı who initiated this long term monitoring study.

References

Balcı A.N., Özyuvacı N., Özhan S. (1986). Sediment and nutrient discharge through stream water from two experimental watersheds in mature oak-beech forest ecosystems near Istanbul, Turkey. *Journal of Hydrology*, 85: 31-47.

Brooks K.N., Ffolliott P.F., Gregersen H.M., Thames J.L. (1996). Hydrology and the Management of Watersheds. Sixth edition. Iowa State University Press, Ames, Iowa, USA.

Chanasyk, D.S., Mapfumo E., Willms W. (2003). Quantification and simulation of surface runoff from fescue grassland watersheds. *Agricultural Water Management*, 59:137-153

Gökbulak F., Serengil Y., Özhan S., Özyuvacı N., Balcı A.N. (2007). Effect of timber harvest on physical water quality characteristics. Water Resources Management DOI 10.1007/s11269-007-9183-y.

Hewlett J. D. (1982). Principals of Forest Hydrology. The University of Georgia Press, Athens, USA.

Hornbeck J.W., Bailey S.W., Buso D.C., Shanley J.B. (1997). Streamwater chemistry and nutrient budgets for forested watersheds in New England: variability and management implications. *Forest Ecology and Management,* 93:73-89.

Lewis D., Singer M.J., Dahlgren R.A., Tate K.W. (2000). Hydrology in a California oak woodland watershed: a 17-year study. *Journal of Hydrology*, 240(1-2): 106-117

Özhan S. (1977). Variation in some hydrologic properties of forest floor as related to certain environmental factors in Ortadere Watershed of Belgrad Forest. Publication of Istanbul University, Faculty of Forestry Publication No: 235

Özhan S., Balcı A.N., Özyuvacı N., Hızal A., Gokbulak F., Serengil Y. (2005). Determination of cover and management factor of the Universal Soil-Loss Equation for forest ecosystems in Marmara Region, Turkey. *Forest Ecology and Management*, 214:118-123.

Peel M.C., McMahon T.A., Finlayson B.L. (2004). Continental differences in the variability of annual runoff-update and reassessment. *Journal of Hydrology,* 295:185-197.

Ryan D.F., Glasser S. (2000). Goals of this report. In: proceedings of drinking water from forests and grasslands. A synthesis of the scientific literature. U. S. Forest Service, Southern Research station, General Technical Report SRS-39

Yaltırık F. (1966). Floristic analysis of Belgrad Forest and Main Stand Composition. Publications of General Directorate of Forestry. Serie: 6, No: 436, Ankara.

Zar J.H. (1996). Biostatistical Analysis. Third Edition. Prentice-Hall, Upper Saddle River, New Jersey, USA.