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EFFECTIVENESS OF CLASSICAL DAMS IN TORRENT CONTROL WORKS IN WESTERN ANATOLIA: KAYRAN TORRENT

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Abstract

Land use in the Büyük Menderes River basin of western Turkey has been changed from ancient civilizations until today and erosion in different intensities has been experienced. Especially right bank (as to flow) streams of lower Büyük Menderes River basin had caused major torrents until 1970s. In Kayran creek watershed, which was chosen as a representative of the right bank, torrent control works started in 1948 and was completed in 2003. Administrative, technical and biological torrent control works were implemented in the area. In the context of technical works, classical consolidation dams were used for bed stabilization. Results showed that no torrent has been experienced since 1984 and 92.6% of check dams were constructed until that time. While forest land increment was occurred only 1.06% in VIth and VIIth land capability classes via slope stabilization works, classical check dams have prevented bed degradation and stabilized the slopes by supporting toes with storing sediment.

Key words: Torrent control, Check dams, Forestry, Land misuse, GIS.

1. INTRODUCTION

Büyük Menderes River, which is the largest river of Aegean region of Turkey, has a length of 584 km, a drainage area of 24873 km^2, and an annual flow of 3.8 km^3. Geographical term of 'meandering' comes from the ancient name of the river "Meander". Written history of the area starts with Carians in XIIth century BC. Forests of the upper basin had been destroyed since ancient civilizations to modern times. Sediment yield of the river is 519-ton/km^2/year. As Büyük Menderes River drained toward the Aegean Sea, ancient city Miletos, which was an ancient

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harbour, has been silted up and now is 9-10 km inland over a 2000 year period (ANONYMOUS 1982b; ÇAVUŞOĞLU 1991; ATALAY 1986).

The reason of high sediment yield in the lower basin was determined as northern right bank tributaries (ANONYMOUS 1983). 80% of the problematic tributaries of lower and middle Büyük Menderes River basin are in the right bank as to flow. 64% of this part of the basin has experienced soil erosion (ANONYMOUS 1982a). Sediment yields of these creeks are high and major torrents had been experienced by 1970s. These torrents caused loss of life and property, and gave damage to communication, transport and irrigation facilities. Additionally, high sediment loads from these tributaries gave permanent damage to agricultural areas in the Büyük Menderes plain.

High flows in upper watersheds of tributaries are called as torrents, and in valleys they are called as floods. Innumerable combinations of variable climatic and physiographic factors produce floods/torrents of all degrees and severity. Some climatic factors that affect floods are form, amount, duration, and intensity of precipitation; the amount of previous precipitation, which would affect the moisture content of the soil, air temperature which may result in frozen soil or may determine the rate of snowmelt; and the direction of storm movement. The principal physiographic factors of a drainage basin that determine flood flows are drainage area, elevation, soil type, shape, slope, aspect, and vegetation cover. The only parameter of a watershed that could be affected by human being is land use changes, especially from forest to agriculture (ANONYMOUS 1998; UZUNSOY/GÖRCELİOĞLU 1985).

Main reasons of floods can be grouped into as increases in streamflow, irregularities in the flow and decrease of channel capacity (UZUNSOY/GÖRCELİOĞLU 1985). Humans can affect these situations with land misuse. Vegetation cover in the upper watershed can be changed, i.e. from forest to agriculture, and as a result of it high runoff can be observed. Channel capacity can be decreased in the lower watershed by high sediment yield originating from upper watershed, wrong infrastructure, bridges that have inadequate cross sections and wrong urbanization etc.

Improvement works against torrents are administrative, technical and biological (GÖRCELİOĞLU 2003). Administrative measures include preventing illegal human activities through socio-economic and physical measures. Technical measures are to maintain bed and slope stabilization through check dams, spurs, sills, terraces and wattle fences etc. Biological measures are to cover slopes by soil bioengineering. The functions of classical dams are consolidation and retaining.

New approach in torrent control has been in practice since 1970s in Austria. The functions of the older constructed torrent control measures are consolidation and retaining. Storage capacities were not corresponding to disaster potential and for that reason disasters were not prevented only lessened in severity. Torrent control engineer has the problem of preventing the disaster by countermeasures without disturbing the regular bedload transport and the environment. That means generally to maintain the bedload discharge for the stability of the downstream course and the receiving system. Torrent control measures with a small influence on the natural torrent system have to be developed because they will influence the debris and bedload production (FIEBIGER 1997). Main difference between structures of classical and new approach is energy dissipaters. These structures of new approach are made by concrete, reinforced concrete or concrete armored with steel and they are useful especially for rainy areas. Their construction costs are higher than classical dams and after construction they need extra cost for maintenance. If classical masonry check dams give expected results, it is not necessary to change the structures with the expensive ones. It is known that 80% of the Turkey's land needs torrent/erosion control and expensive structures should only be used when necessary.

Improvement works of right bank of the Büyük Menderes River basin started in 1940s (ANONYMOUS 1961). The improvement was held by different governmental bodies, which have different official duties on land improvement. General Directorate of Afforestation (AGM) worked on slope stabilization, State Hydraulic Works (DSİ) on bed stabilization and TOPRAKSU (later General Directorate of Rural Affairs, KHGM) agricultural land improvement on alluvial cone. With continuing works, tens of torrents have been taken under control, some areas on the alluvial cones of the torrents of the river have been opened to agriculture and settlement and some areas have been started to irrigate.

The aims of this study are to give the situations before and after torrent control works, compare these situations (forest cover, land use type changes), and investigate the effectiveness of classical check dams and other torrent control works implemented in the Kayran watershed.

2. MATERIALS AND METHODS

Problematic right bank of the lower Büyük Menderes River basin is very large (approximately 2000 km²). Therefore, Kayran creek watershed having also steep slopes and erodible soils like other tributaries of this part of the basin and intensive improvement works was selected as a study area.

Location: Kayran creek watershed is one of the tributaries of Büyük Menderes River basin on the right bank (as to flow). It lies between 28°29'15"-28°33'50" East and 38°03'34"-38°53'55" North, in Aegean Region, western Anatolia, Turkey. Kayran creek has an area of 66.03 km² with long narrow shape (Fig. 1).

Topography: The topography of the watershed is broken. Elevation increases from south to north direction reaching the maximum elevation of 1469 m. Average slope is 38.5% (Table 1). Mean altitude of watershed is 796 m and 46.19% of watershed stays in 800-1200 m elevation range.

Table 1: Slope classes of the Kayran creek watershed
Tablo 1: Kayran deresinin havzasının eğim sınıfları

Slope Classes (%)	Area (%)
0-6	5.1
6-12	7.7
12-20	8.1
20-30	14.1
>30	65.0

Climate: There are two meteorological stations in the area: Nazilli (37°55' N, 28°19'E, H=60m) which has long term records (1929-2003) in lower altitudes close to watershed and Kayran precipitation station (38°00' N, 28°33'E, H=600m) which has relatively short term records (1970-2000) in the middle of the watershed. According to Kayran station, annual precipitation is about 744.7 mm. Distribution of rainfall throughout the year is not even, and 4% of it falls in summer, 20% in autumn, 27% in spring and 49% in winter. Wettest month is January and driest month is

August. Maximum daily rainfall is 102.5 mm in December. In study area, Mediterranean climate dominates with hot and dry summers and mild and rainy winters. According to records of Nazilli station, annual mean temperature is 17.5°C, hottest month is July (28.4°C) and coldest is January (7.5°C). According to Thorntwaite method, the climate of the area is semi arid-semi humid, mesothermal, with very strong water deficit in summer, very strong water surplus in winter, subordinate climate type close to ocean effect. Maximum daily rainfall records of Kayran station are given in Table 2.

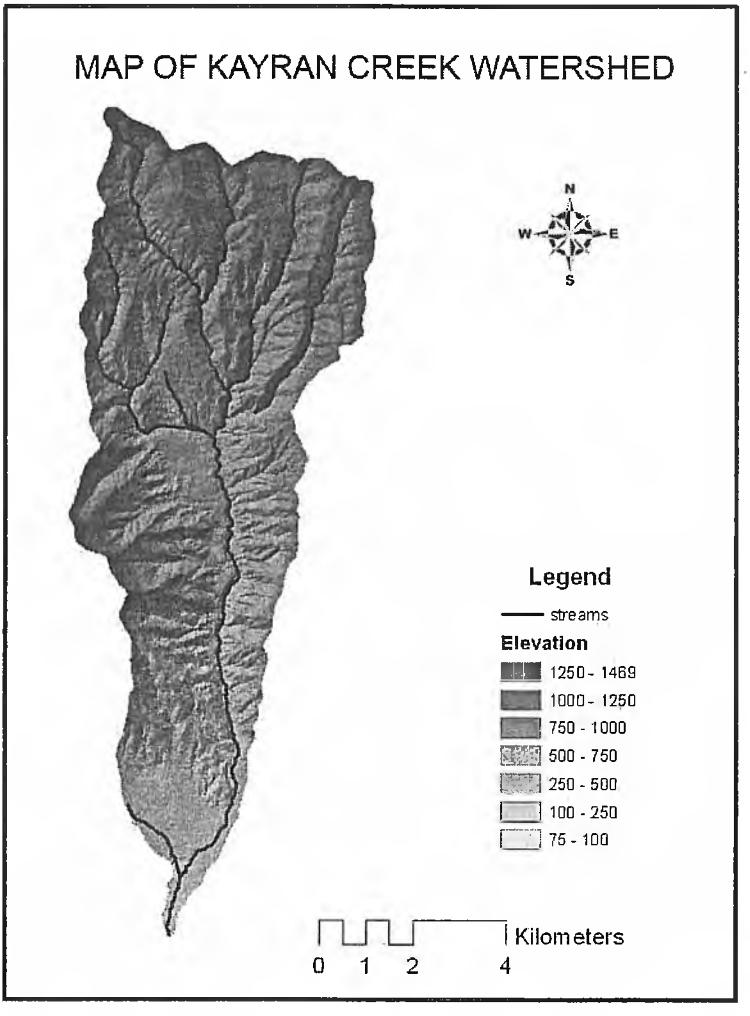

Figure 1: Location of the Kayran creek watershed
Şekil 1: Kayran deresinin havzasının konumu

Table 2: Maximum daily precipitation (mm) in Kayran between 1971 and 2000 (DSİ).
Tablo 2: Kayran'da 1971-2000 arasındaki günlük en büyük yağış (mm)

JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC
75.2	92.5	62.3	66.8	70.7	34.5	111	29.4	30.8	66.0	71.9	102.5

Vegetation Cover: Study area lies in the Mediterranean vegetation region that consists of xerophytes (Atalay, 1983). Vegetation cover in the watershed is made up of two zones. First zone that climbs up to 1000 m is Pyrenean pine (*Pinus brutia* Ten.) zone. Oak groups are dominant in the Pyrenean pine forests that are the main tree species of the area. Second zone starting from 1000-1100 meters is Austrian pine (*Pinus nigra* Arn.) zone. But vegetation limits in the area are not natural. Natural vegetation cover was disturbed by human and cultural plantations climbed up to the 800-1000 meters. Because of overgrazing, soil is bare, topsoil eroded and surface of rangelands covered with stones and non-fodder plants. Some rangelands are used for agriculture. Villagers use open areas in the forest as a rangeland. Some coppice forest areas seen in 1962 dated air photos turned into fig and chestnut agriculture until 1983 (ANONYMOUS 1983).

Land use in the watershed is composed of forest (68%), agriculture (27%), rangeland (3%), sedimentation (1%) and settlement (1%). 60% of the forests are productive and 40% are degraded. Forests are used for timber production; oak forests are managed for fuel wood as a coppice system, pine forests are managed by selection system. Pyrenean pine forests are degraded. Forests consist of 70% deciduous, 20% coniferous and 10% mixed (OGM 2001).

Geology and soil: Büyük Menderes River basin lays down east to west on Büyük Menderes Graben. The basement of the region is formed of Paleozoic and Mesozoic aged schists, marble and dolomitic limestones of the Menderes massive (BARGU/TURGUT 1991-1992-1993). Over the ancient basement there are Neocene lake deposits and south feet of the graben is formed of Plio-Quaternary and Quaternary colluvial deposits.

Soil is generally light, partly moderately textured sandy loam and loam. Topsoil is shallow but subsoil is very deep (ANONYMOUS 1968).

Soil erosion: 23% of the study area is prone to moderate, 24% severe and 52% very severe erosion (KHGM, 2001).

Population: There are three villages in the watershed with a total population of 2022 according to 2000 census of population. While village population of upper watershed, which is more forest dependent, decreased 18.4%, village population in alluvial cone stayed stable between 1980 and 2000 period (DİE 1963, 1973, 1981, 1991, 2003).

Socio-economic situation: Economics of population of watershed is dependent on agriculture (grain, fig, apple, olive and chestnut), livestock and labour in forestry and other work areas.

Flooding history: Kayran creek used to flood every year, but big torrents which used to make damage to agriculture, transport and irrigation facilities started in February of 1966 (ANONYMOUS 1983). According to available records, floods occurred generally in winter when soil was saturated (Table 3).

Table 3: Available historic torrent records in Nazilli and Kayran watersheds (ANONYMOUS 1983; DSİ 1961, 1966, 1990).
Tablo 3: Nazilli ve Kayran havzalarının mevcut tarihi sel kayıtları

Torrent dates – Sel tarihleri	
May 1930	August 1959
May 1936	28 December 1960
February 1940	January 1965
December 1942	27 December 1965
July 1945	20-21 January 1966
1948	February 1966
1949	10-11 March 1968
January 1950	12-15 March 1968
August 1956	1981 December
July 1957-14 June 1957	1982 January-February
15 March 1958	1984 December

Runoff and Sediment Yield: Average sediment yield is 25 m^3/ha (ANONYMOUS 1983).

Improvement Plans: First study was carried out in 1940s. Kayran creek study plan for bed stabilization was prepared by DSİ in 1961. This plan was revised later and new version was taken as a basis for improvement works. Slope stabilization plan was prepared by forest service in 1983 (ANONYMOUS 1961, 1968, 1983).

Improvement Works: In alluvial cone, masonry bank pavement with a length of 675 m were constructed in the right bank and 1748 m in left the bank to protect agricultural areas in 1948 (ANONYMOUS 1961). Bed stabilization works in headwaters started in 1970. Ak, Oluk, Girlen, Eskihisar, Acı, Yelli and Akyatak tributaries that take place in middle right bank of watershed were given much debris to main bed with some active landslides and gullies. Check dams were constructed to control bed and bank erosion in these tributaries and in main channel of Kayran.

Some tributaries yielding unimportant quantities of debris were not improved. Main channel bed was improved with systematical consolidation and auxiliary dams. Some dams constructed over fills of older dams after Eskihisar junction (8+500 km) through to the mouth. Duties of dams were to decrease the slope of bed, align channel and store the debris. The heights of masonry check dams varied between 2 and12 m. On little streams and gullies maximum 2 m high dry masonry or mixed sills were constructed. Fill material on back of sills afforested with some deciduous species. Slope stabilization works were implemented according to 1983 plan. Degraded oak forest lands due to overgrazing and fuel wood collection were terraced against runoff, completed with sow and improved. Pyrenean and Austrian pines were planted in pure or mixed with oak stands. In rangelands, rangeland type gradoni terraces were used. Stones that cover the surface were collected and placed in the channels dug parallel to contours. Undesirable forage vegetation was removed in improved areas. In alluvial cone, bed was cleaned to give appropriate channel cross section to flow and slopes of the channel were covered with stone in early 1980s. Watershed has been excluded and bed and slope improvement areas has been fenced off and controlled by rangers (Fig. 2).

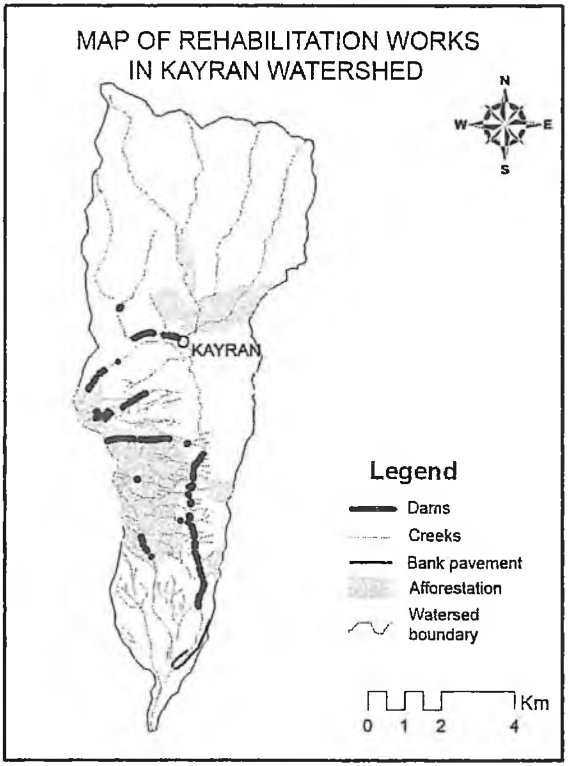

Figure 2: Location of rehabilitation works
Şekil 2: Islah çalışmaları haritası

Effectiveness of the improvement works and role of the classical dams were investigated in the study. First, climatic and physiographic factors affecting the formation of torrents were studied and torrent probability of the watershed was analyzed. Main climatic factor affecting the formation of torrents is precipitation. Therefore, form and amount of precipitation were taken into consideration. Records of Nazilli meteorological station and Kayran precipitation station were used for climatic data. Physiographic factors such as drainage area, slope, direction of slope (aspect), and land use type of the watershed were studied. Next, bed and slope improvement works and precipitations were studied and effects of works in the period of improvement were analyzed. Topographic maps with a scale of 1/25000 and forest management stand type (land use) maps were digitized and maps of digital land capability and erosion classes were used for physiographic factors. Slope, aspect, elevation and area analysis were made with Geographic Information System (GIS).

To investigate the effects of torrent control works in preventing the torrents, relation among precipitations, constructed check dams, forest coverage and its change in time were studied. It is known that a productive forest can intercept 50-80% of the rainfall and prevent torrents up to precipitation rate. For this purpose, study plans, land use, stand type maps made in

1990 and 2001 were studied. Forest management plans were evaluated to figure out whether forest area and/or cover increased or decreased. Available precipitation and torrent records, and return periods of precipitation were investigated. Maximum daily precipitation records of Nazilli and Kayran stations before and after improvement works were compared with the precipitations of different return periods, water budged and torrent records in order to find out if these precipitations generated a torrent.

Information obtained from various maps was superimposed as layers into GIS and were evaluated for effectiveness of improvement works.

3. RESULTS AND DISCUSSION

Torrent probability, situation after torrent control works and their effectiveness were studied. Torrent probability was evaluated in the context of climatic and physiographic characteristics of the watershed.

According to Kayran meteorological records, average yearly snowy days are 1.7. Therefore, the effect of snow on formation of torrents is accepted as negligible. 61% of precipitation falls from December to April. Due to the fact that only 20% of vegetation cover coniferous and 10% is mixed, forest trees and agricultural crops are generally leafless in that period. Yearly average rainy days are 67, and 62% of these days are in dormant season. Furthermore, interception and evapotranspiration decrease due to dormant period and cold weather. According to Thorntwaite method, soil has water surplus in December-March period. As a result, due to leafless canopy intensive precipitation falling over almost bare to soil that has water surplus increases the height of runoff and torrent probability in the watershed.

With respect to observations, return periods of daily maximum precipitation records are smaller than 25-years and only one record is greater than 25-years return period in Kayran (Table 4).

Table 4: Frequencies of certain amount of daily precipitation in the watershed (DSİ 1990)
Tablo 4: Havzadaki günlük yağışların tekerrür aralıkları

Return Period (years)	Precipitation (mm)
2	57.81
5	71.86
10	82.16
25	96.29
50	107.65
100	119.75
Annual mean	744.7
Daily maximum	102.50 (December 1981)
Annual maxima	1112 (1981)

The precipitation between 1971 and 2000 showed fluctuations. Mean precipitation was 744 mm and there was not important change in precipitation rates during improvement works (Fig. 3).

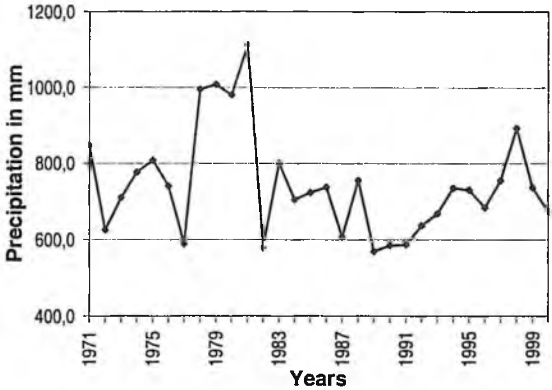

Figure 3: Annual precipitation in Kayran watershed.
Şekil 3: Kayran havzasındaki yıllık yağış

There is no coincidence between long term Nazilli precipitation records and available torrent records. According to Kayran precipitation records there is one coincidence between December 1981 precipitation and torrent record. In December 1981 watershed received 102.5 mm daily precipitation. Same weather conditions may not be seen in these two places because there is considerable distance between Nazilli and Kayran stations, 70 km horizontally and 540 m vertically. Furthermore, it is known that there are many factors affecting formation of a torrent such as antecedent precipitation and soil moisture before torrent event. It is not aimed here to investigate the reasons of torrents happened in the watershed. However, no torrent has been recorded after improvement works.

According to forest management plan, 68% of the watershed is used for forest, 27% for agriculture, 3% for rangeland, 1% for settlement and 1% of the area has been covered by sediment (OGM 2001). According to land capability classes, there are no classes Vth and VIIIth in the watershed. 82% of VIth and VIIth land capability classes is covered with forest, 14% are practiced agriculture and 4% is rangeland. Furthermore, 40% of forests are degraded (Table 5, Table 6; Fig.4; OGM 2001; KHGM 2001). According to land use criteria, lands from Vth to VIIIth land capability classes must be covered with good forests or rangeland, and agriculture must never be practiced on. Torrent probability is high in the watershed due to 14% forest cover deficit, cultivation on the forestlands, 40% degraded forest coverage and coppice management system in oak forests.

Table 5: Land capability classes of Kayran creek watershed (KHGM 2001)
Tablo 5: Kayran deresinin havzasının arazi yetenek sınıfları

Land capability classes	I	II	III	IV	V	VI	VII	VIII
Watershed Area (%)	0.36	0.02	8.42	19.42	0	14.14	56.89	0

Table 6: Actual land use in the Kayran creek watershed according to land capability classes (OGM 2001; KHGM 2001)
Tablo 6: Kayran deresinin havzasında arazi yetenek sınıflarına göre güncel arazi kullanımı

LAND CAPABILITY CLASSES	LAND USE					
	FOREST	AGRI-CULTURE	RANGE-LAND	SEDI-MENT	SETTLE-MENT	TOTAL (Ha)
VI-VII (FOREST)	3878,74	642,37	171,43	8,03	20,86	**4721,42**
I-IV (AGRICULTURE)	634,72	1131,92	18,50	56,29	39,88	**1881,31**
TOTAL	4513,46	1774,29	189,92	64,32	60,74	**6602,73**

Kayran creek watershed was improved by technical, biological and socio-economic torrent control measures. In the context of technical measures, bed stabilization took place first and socio-economic and biological measures followed it.

Forest villagers were encouraged to raise fruits after ORKÖY (General Directorate of Forest Village Relations) built a refrigerated depot in the context of socio-economic measures. Villagers were employed in dry or irrigated agriculture, animal breeding, forest improvement and forest harvesting. They were given 80% of forest product they harvested with price of harvesting cost and 20% with market price for sale. These socio-economic measures increased legal incomes of villagers. In 2000 census of population, there has been a decrease in the upper village population of watershed after 1980 (DİE 1981, 2003). Improvement in people's standard of living, and decrease in the village population resulted in a decrease in the destruction of forest.

Bed improvement works started before slope improvement works. During first years of dam construction period (1970-2003), while frequency of most precipitations was less than 25 years, torrent flow estimations depending on land remarks and empirical formulas were 100. Reasonable explanation of this imbalance may be mass movements and land misuse. Mass movements occurred as a result of degradation of channels, toe digging and destabilization of slopes. The channel was temporarily dammed up by debris of mass movement. A big torrent was occurred when this natural dam broken by water pressure. Both in main channel and tributaries of Kayran creek, there are high and steep banks like a wall reaching 20 m in places. Technical structures in beds were mainly check dams and auxiliary dams. Given duties of check dams are stabilization of beds, slopes and landslides in 7 tributaries. In dam construction period, dams in the main channel were revised and heights of some weirs were increased as to volume of flow and debris. After mass and bed stabilization in main channel and tributaries, torrents were not repeated. Classical check dams in the Kayran creek prevented mass movements in both main channel and tributaries and the slopes were stabilized. Effectiveness of classical check dams was maintained, and considerations of disturbing regular bedload transport were prevented through step-by-step construction. Projected check dam heights were not applied at a one time. This method did not disturb bedload transport and maintained economy, and if this height of dam was enough, construction of dam was stopped. After being filled by sediment, height of dam was increased when necessary. If some maintenance and repair costs are excluded, there is no operation cost of classical dams. Classical dams can be easily projected and constructed by less qualified labour and low powered construction machines. Channel reactions of systematic dams and adaptation processes of classical dams are less complicated and homogenous.

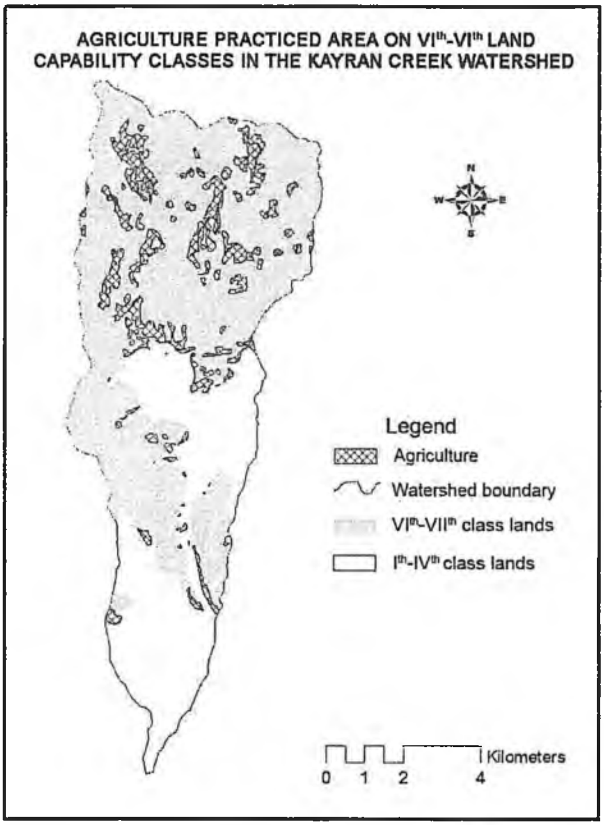

Figure 4: Cultivated area in the VIth and VIIth land capability class in Kayran creek watershed.

Şekil 4: Kayran deresinin havzasının VI ve VII sınıf arazilerinde tarım yapılan alanlar

In the beds of the watershed, classical masonry weight consolidation check dams and dry masonry spills were used but not concrete, since concrete weight dams cost approximately double the amount of masonry dams. Totally 223 masonry check and auxiliary dams, 1 mixed check dam and 5 dry masonry sills were constructed into the tributaries and main channel. 69 of check dams and auxiliary dams with heights changing between 2 and12 meters were made for main bed stabilization. 92.6 % of check dams constructed until 1984 in which slope stabilization works started, and last check dam was constructed in 2003 (Fig. 5). One check dam with auxiliary dam on 7+000 km from mouth collapsed during a high flow while spillway was working in 1984. Clean waters due to trapped debris by check dams dug basement of this dam and cracked it and toppled down. Water mass behind the dam could be trapped behind the other consolidation dams through the gorge. Holding capacity due to wide (approximately 100 m) bed, the other check dams could hold this extra water before gorge and not caused any damages. This is another example that classical dams were sufficient in torrent control in this watershed. After this event, any torrents were not realized in Kayran. These consolidation check dams were effective to raise the bed, lower the bed slope, and stop the landslides in tributaries.

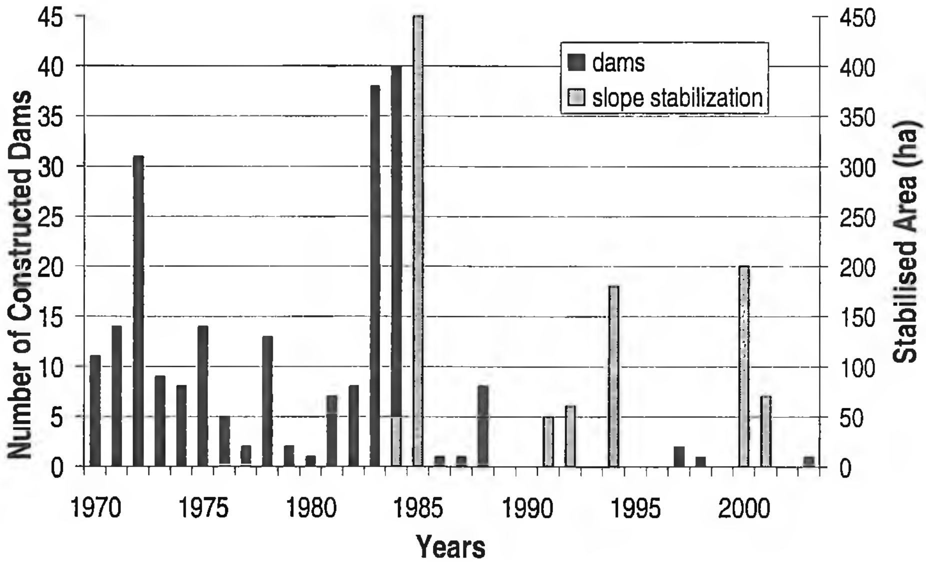

Figure 5: Constructed dams and slope stabilization works in years.
Şekil 5: Yıllara göre inşa edilen barajlar ve yamaç ıslah çalışmaları

1060 ha area were stabilized by different kinds of terraces and plantations with oak and pine species. Improvement areas were fenced and watched by rangers. According to comparison of 1990 and 2001 forest management plans, forest area increased only 1.06%, but productivity and canopy cover increased 57% in forest area in watershed (Fig. 6).

In the lower watershed of the Kayran creek, fruit growing is practiced on some high slopes on stone-reinforced terraces. Wide flood plains are not used for other purposes like agriculture or settlements. Therefore, high flows could be deposited behind check dams and torrent peaks could be decreased.

During bed improvement works, there were not slope stabilization works, except for fences, in the seven problematic tributaries until 1984. Torrents repeating every year, after February of 1966, have decreased with constructions of dams and stopped after completion 92.6% of dams until 1984. Therefore, check dams have played an important role in preventing torrents. After fence was installed and area protected, grazing and other harmful activities stopped and degraded forest structure may be regenerated until slope stabilization started and this could be helpful in prevention of torrents. Slope stabilization works took place in the middle watershed near Kayran village and they were mostly oak improvements (Fig 6).

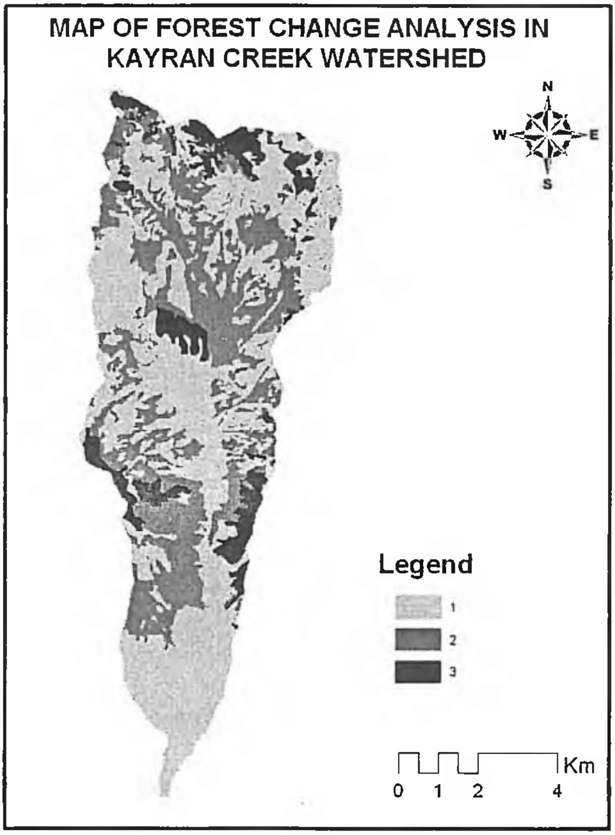

Figure 6: Change detection result of forest management plans of 1990 and 2001 in Kayran creek watershed. 1: no change, 2: improvement in deciduous forests, 3: improvement in coniferous forests.

Şekil 6: Kayran deresinin havzasının 1990 ve 2001 orman amenajman planlarına göre değişim analizi. 1: değişim yok, 2: yapraklı ormanlarda iyileşme, 3: ibreli ormanlarda iyileşme

There are less than 1 m^3/s runoff after the improvement works (check dams and biological measures) after 1984 from Girlen tributary and 1987 Eskihisar tributary. Maximum discharge at the weir of check dams on the Kayran creek gorge is about 7-8 m^3/s and maximum 12-13 m^3/s. Debris size on the back of check dams of the main channel around 8+500 km (Eskihisar tributary) is about 20 mm and around 7+000 is about 2-3 mm. Before improvement works particle size was boulders on these points. Check dam wings that lie through the wide floodplain created extra depot capacity.

Results showed that torrent probability in the Kayran creek watershed was high due to climatic and physiographic factors. Integrated torrent control works, primarily bed stabilization works with check and auxiliary dams and secondarily slope improvement works were used in the area. While precipitation stayed nearly same between 1971 and 2000, and forest area increased only 1.06% between 1990 and 2001, classical check dams were effective to lower the longitudinal gradient, prevent bed and toe degradation, and stabilize the slopes. Dams have prevented the torrents before slope stabilization works started in 1984. Forests, even if they are unproductive, might have positive influences on preventing torrents. Slope stabilization works improved forests and increased the effectiveness of dams and sustainability of improvement works. After twenty years from 1984 in which 92.6% check dam constructions completed, any torrents have not been experienced in Kayran watershed. Therefore alluvial cone of the Kayran creek and flood plain of Büyük Menderes River became safer for practicing agriculture, settlement, communication, transportation and irrigation utilities etc.

BATI ANADOLUDAKİ SEL KONTROL ÇALIŞMALARINDA KLASİK TAŞINTI BARAJLARININ ETKİNLİĞİ: KAYRAN SEL DERESİ

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Büyük Menderes nehri havzasındaki arazi kullanımı eski medeniyetlerden günümüze kadar değişmiş ve çeşitli şiddetlerde erozyon yaşanmıştır. Erozyon Büyük Menderes nehrinin aşağı havzasında özellikle akışa göre sağ sahil derelerde 1970'lere kadar büyük sellere neden olmuştur. Aşağı havzadaki sağ sahili temsil etmek üzere seçilen Kayran deresi havzasında sel kontrol çalışmaları 1948 yılında başlamış ve 2003 yılında bitmiştir. Bölgede selleri önlemek amacıyla idari, teknik ve kültürel sel kontrol önlemleri uygulanmıştır. Yatak stabilizasyonu için klasik taşıntı barajları kullanılmıştır. Sonuçlara göre, taşıntı barajlarının %92,6'sının tamamlanmış olduğu 1984 yılından sonra bir sel meydana gelmemiştir. Yamaç ıslah çalışmaları ile VI-VII sınıf arazilerdeki orman alanı ancak %1,06 artmasına rağmen, klasik taşıntı barajları yatak kazılmasını önlemiş ve depoladığı sedimentle topuklara destek olarak yamaçları stabilize etmiştir.

Anahtar kelimeler: Sel kontrolu, taşıntı barajları, ormancılık, yanlış arazi kullanımı, CBS.

1. GİRİŞ

Büyük Menderes nehrinin aşağı havzasına gelen fazla miktardaki sedimentin sağ sahil derelerden kaynaklandığı belirlenmiştir (ANONYMOUS, 1983). Sağ sahil derelerde 1970'li yıllara kadar büyük seller meydana gelmiştir.

İklimsel ve fizyografik değişkenlerin sayısız kombinasyonu çeşitli büyüklüklerde seller/taşkınlar meydana getirebilir. Havzanın fizyografik faktörlerinden, sel oluşumunda etkili olan arazi kullanımı insan tarafından etkilenebilir, ormandan tarıma dönüştürülebilir ve seller meydana gelebilir (ANONYMOUS 1998; UZUNSOY/GÖRCELİOĞLU 1985). Sellerin ana nedenleri derelere ulaşan akımdaki artış ve düzensizlikler ile kanal kapasitesinin azalmasıdır (UZUNSOY/GÖRCELİOĞLU 1985). Arazi kullanımındaki yanlışlıklar sonucunda orman örtüsünün kaldırılması ve kanal kapasitesinin önceki akımlar veya yanlış kentleşmeyle daraltılması seller/taşkınlara neden olmaktadır.

Sellere karşı ıslah çalışmaları yönetsel, teknik ve biyolojiktir (GÖRCELİOĞLU 2003). Yatak ve yamaç stabilizasyonunu sağlamak amacıyla kullanılan teknik önlemlerin başında taşıntı barajları gelmektedir. Klasik taşıntı barajlarının ana fonksiyonları yatağın eğimini azaltmak, taşıntıyı tutmak ve yamaçlara destek olmaktır.

Avusturya'da sel kontrolunda 1970'lerden beri uygulanmakta olan yeni yaklaşıma göre yatak yükünü tutan klasik taşıntı barajları yerine yatak yükünü ve çevreyi fazla etkilemeyen ancak depolama kapasitesi büyük olan yeni tip taşıntı barajları kullanılmaktadır. Klasik taşıntı barajları ile yeni yaklaşım arasındaki temel fark enerji kırıcı barajlardır. Beton, betonarme veya çelikle karışık olarak yapılmakta olan yeni yaklaşım yapıları özellikle yağışlı alanlar için uygundur (FIEBIGER 1997).

Çalışmanın amacı Kayran havzasındaki sel kontrol çalışmalarından önceki ve sonraki durumu ortaya koymak ve sel kontrol çalışmalarında klasik taşıntı barajlarının etkinliğini irdelemektir.

2. MATERYAL VE YÖNTEM

Büyük Menderes nehrinin aşağı havzasının sellerden etkilenen sağ sahilinin alanı çok geniştir (yaklaşık 2000 km²). Bu nedenle, dik yamaçları, erozyona hassas toprakları ve yoğun ıslah çalışmaları ile alanı temsil etmek üzere Kayran deresi seçilmiştir.

Dar-uzun şekli olan Kayran deresi havzası 28°29'15"-28°33'50" doğu ve 38°03'34"-38°53'55" kuzey koordinatları arasında yer alır (Şekil 1). Havza arızalı bir topografyaya sahiptir. Ortalama eğim % 38,5 (Tablo1), ortalama yükselti 796 m'dir. Havzanın % 46,19'u 800-1200 m kuşağında yer alır.

Kayran meteoroloji istasyonuna göre (1971-2000) yıllık yağış 744,7 mm'dir. Yağışın mevsimlere dağılışı düzenli değildir; yağışın % 27'si ilkbahar, % 4'ü yazın, % 20'si sonbahar ve % 49'u kışın düşer. En fazla yağışlı ay ocak, en az yağışlı ay ağustostur. En büyük günlük yağış 102,5 mm ile 1981 yılı aralık ayında düşmüştür (Tablo 2). Thorntwaite yöntemine göre havzanın iklimi yarı kurak yarı nemli, mezotermal, yazın kuvvetli su açığı, kışın kuvvetli su fazlası bulunan deniz etkisine yakın subordinate iklim tipidir.

Araştırma alanı kurakçıllardan oluşan Akdeniz bitki bölgesinde yer alır. Bitki örtüsü 1000 m'ye kadar meşe gruplarının egemen olduğu kızılçam (*Pinus brutia* Ten.), 1000 m'den sonra karaçam (*Pinus nigra* Arn.) olmak üzere iki zondan oluşur (ATALAY 1983). Ancak bitki örtüsünün sınırları doğal değildir, aşırı otlatma nedeniyle toprak çıplaktır, üst toprak erozyona uğramıştır, meralar yem değeri olmayan otlar ve taşlarla kaplanmıştır. 1962 tarihli hava fotolarında baltalık orman olan bazı alanların incir ve kestane tarımına dönüştüğü görülmüştür (ANONYMOUS 1983).

Havzanın % 68'i orman, % 27'si tarım, % 3'ü mera, % 1'i sediment ve % 1'i yerleşim olarak kullanılmaktadır. % 60'ı verimli olan ormanların % 70'i yapraklı, % 10'u karışık, % 20'si ibrelidir (OGM 2001).

Toprak genellikle hafif, kısmen kumlu balçık ve balçıktır. Üst toprak sığdır ancak alt toprak çok derindir (ANONYMOUS 1968). Havzanın % 23'ünde hafif, % 24'ünde şiddetli ve % 54'ünde çok şiddetli erozyon görülmektedir (KHGM 2001).

Havzada bulunan üç köyün nüfusu 2000 genel nüfus sayımına göre 2022'dir. 1980-2000 döneminde yukarı havzadaki nüfus %18,4 azalmıştır (DİE 1963, 1973, 1981, 1991, 2003). Havzada geçim kaynakları tarım, hayvancılık ve ormancılıktır.

Kayran deresinde her yıl meydana gelen seller, 1966 yılının şubat ayından sonra tarım, ulaşım ve sulama sistemine büyük zararlar veren boyutlara ulaşmıştır. Seller genellikle kışın toprak doymuşken meydana gelmiştir (Tablo 4). Havzanın sediment verimi 25 m^3/ha'dır (ANONYMOUS 1983).

Havzada ıslah amacıyla ilk etüd 1940'larda yapılmıştır. Yatak ıslahı amacıyla DSİ tarafından 1961 yılında yeni bir etüd yapılmıştır. Bu plan daha sonra revize edilmiş ve ıslah çalışmalarına temel olmuştur. OGM yamaç ıslahına 1983 yılında başlamıştır (ANONYMOUS 1961, 1968, 1983). Alüvyal konide tarım alanlarını korumak amacıyla 1948 yılında kıyı duvarı yapılmıştır (ANONYMOUS 1961). Yatak ıslah çalışmaları 1970 yılında başlamıştır. Ana yatak, sistematik taşıntı barajları, kontr barajlarlar ve önceki barajların taşıntısı üzerine yapılan barajlarla ıslah edilmiştir. Barajların yapım amacı yatağın eğimini azaltmak, yatağı doğrultmak ve taşıntıyı depolamaktır. Harçlıtaş tipindeki barajların yükseklikleri 2-12 m arasında değişmektedir. Küçük derelerde ve oyuntularda maksimum 2 m yüksekliğinde kurutaş veya miks eşikler yapılmıştır. Eşiklerin arkasındaki dolgunun üzeri bazı yapraklı türlerle ağaçlandırılmıştır. Yamaç ıslahı 1983 yılında hazırlanan plana göre yapılmıştır. Bozuk meşe ormanları yüzeysel akışa karşı teraslanıp ekimle tamamlanarak ıslah edilmiştir. Karaçam ve kızılçam ormanları dikimle tamamlanmıştır. Meralar teraslanmış, yem değeri olmayan otlar kaldırılmıştır. Alüvyal konide yatak temizlenmiş, kanala yeterli kesit verilmiş ve yatak 1980'lerin ilk yarısında taşla kaplanmıştır. Havzaya giriş yasaklanmış, havza çitle çevrilmiş ve bekçi ile kontrol altına alınmıştır (Şekil 2).

Çalışmada klasik taşıntı barajlarının etkinliği araştırılmıştır. Önce iklimsel faktörler Nazilli ve Kayran meteoroloji istasyonunun verilerine göre değerlendirilmiştir. Çalışmalardan önceki ve sonraki yağış miktarları, yağışların tekerrür aralıkları, su bilançosu dikkate alınarak yağışların sel üretme olasılığı irdelenmiştir. Sayısallaştırılan topografik, orman amenajman ve arazi yetenek haritalarından CBS ile fizyografik faktörler elde edilmiş, bu veriler CBS ortamında değerlendirilmiştir.

Sel kontrol çalışmalarının etkinliğini anlamak amacıyla taşıntı barajları, orman örtüsü ve zaman içindeki değişimi irdelenmiştir.

3. SONUÇ VE TARTIŞMA

Kayran havzasında Thorntwaite yöntemiyle hazırlanan su bilançosuna göre aralık-mart döneminde toprakta su fazlası vardır. Bitki örtüsünün yapraksız olduğu bu dönemde yağan şiddetli yağmurlar sel olasılığını artırmaktadır. Günlük maksimum yağışların tekerrür aralığı –bir değer dışında- 25 yıl tekerrürlü yağıştan küçüktür (Tablo 3). 1971 – 2000 döneminde yağışların yıllık bazda fazla değişmediği gözlenmiştir (Şekil 3).

Kayran meteoroloji istasyonunun kayıtları daha kısa süreli olduğu için, Kayran deresinde meydana gelen mevcut sel kayıtları (Tablo 4) ile Nazilli meteoroloji istasyonunun yağış kayıtları karşılaştırılmış ancak bir ilişki bulunamamıştır. 1970 yılında çalışmaya başlayan Kayran meteoroloji istasyonu kayıtlarından 1971 yılının aralık ayında bir günde düşen 102,5 mm yağış ile sel kayıtları arasında ilişki bulunabilmiştir. Islah yapılarından sonra sel meydana gelmemiştir.

Havzanın orman amenajman planı ve arazi kullanma durumu karşılaştırılmış ve orman örtüsü altında bulunması gereken VI-VII sınıf arazilerin % 14'ünde tarım yapıldığı görülmüştür. Mevcut ormanların % 40'ı verimsizdir (Tablo 6; Şekil 4; OGM 2001; KHGM 2001). Usulsüz tarım ve verimsiz ormanlar sel olasılığını artırmaktadır.

Kayran deresi havzasında yatak stabilize edilmiş, yamaç ıslahı ve sosyoekonomik önlemler daha sonra gelmiştir. Orman köylüleri meyve tarımına yönlendirilmiş, ürettikleri orman ürününün % 80'i üretim maliyetine, % 20'si pazar fiyatına köylüye verilmiştir. 2000 genel nüfus sayımına göre yukarı havza köy nüfusunda 1980 yılından itibaren % 18,4 azalma görülmüştür (DİE 1981, 2003). Köylünün gelirinin artması ve nüfusunun azalması orman tahribinde azalma şeklinde yorumlanmıştır.

Taşıntı barajı yapım döneminin (1970-2003) ilk yıllarında düşen yağışların tekerrür aralıkları 25 yıldan küçükken, meydana gelen sellerin büyüklüğü 100 yıl olarak tahmin edilmiştir. Bu dengesizliğin açıklaması kitle hareketleri ve yanlış arazi kullanımı olabilir. Yatak stabilizasyonu çalışmalarının % 92,6'sının tamamlandığı 1984 yılından sonra sel meydana gelmemesi, kitle hareketlerinin durdurulmasıyla açıklanabilir. Klasik taşıntı barajları hem ana kanalda, hem de yan derelerde kitle hareketlerini durdurmuş ve yamaçları stabilize etmiştir. Klasik taşıntı barajlarının etkinliğini sağlamak ve yatak yükünü etkilememek amacıyla, tasarlanan baraj yüksekliği bir defada uygulanmamış, barajlar kademe kademe yapılmıştır. Barajın arkası dolarsa yüksekliği artırıldığı için bu yöntem ekonomi de sağlamıştır. Eğer bazı bakım ve onarım masrafları hariç tutulursa, klasik taşıntı barajlarının işletme masrafı yoktur. Klasik taşıntı barajları daha kolay projelendirilebilir ve daha az kalifiye iş gücü ve iş makineleri ile yapılabilir. Klasik sistematik barajların kanal reaksiyonları ve adaptasyon süreci daha az karmaşık ve homojendir.

Yataklarda harçlıtaş ağırlık barajları, kurutaş eşikler kullanılmış, harçlıtaşın yaklaşık iki katına mal olduğu için beton kullanılmamıştır. Ana ve yan yataklara toplam 223 harçlıtaş taşıntı barajı ve kontrbaraj, 1 miks baraj ve 5 kuruduvar eşik yapılmıştır. Barajların % 92,6'sı yamaç ıslah çalışmalarının başladığı 1984 yılına kadar inşa edilmiştir.

1060 hektar yamaç teraslar ve meşe ekim ve çam dikimiyle ıslah edilmiştir. Alan çitle çevrilmiş ve bekçi ile korunmuştur. 1990 ve 2001 amenajman planlarına göre orman alanı sadece % 1,06 artarken verimlilik ve kapalılık % 57 oranında artmıştır (Şekil 6).

Taşıntı barajı yapımı 1970 yılında başlamış, 1984 yılına kadar yamaçlarda çalışılmamıştır. 1966 yılının şubat ayından itibaren her yıl tekrarlayan seller barajların yapımı ile durmuştur. Yamaç ıslah çalışmaları havzanın orta kısmında yer almıştır (Şekil 4).

Islah çalışmalarından sonra bazı yan kollarda akım 1 m^3/san'nin altına düşmüştür. Kayran deresinin boğaz bölgesinde akım en fazla 12-13 m^3/san tahmin edilmektedir. Çalışmalardan önce yatağın orta kısımındaki malzeme iri kaya boyutunda iken çalışmalardan sonra 2-20 mm boyutuna inmiştir.

İklimsel ve fizyografik faktörlere göre Kayran havzasında sel olasılığı yüksektir. Havzada önce taşıntı barajları ve kontrbarajlar, sonra yamaç ıslah çalışmaları uygulanmıştır. 1971-2000 döneminde yağışın yaklaşık aynı kalmasına ve orman alanının ancak % 1,06 artmasına karşın, yatak stabilizasyonunu sağlamak amacıyla yapılmış olan taşıntı barajları boyuna eğimi azaltma, yatak ve topuk kazılmasını önleme ve yamaçları stabilize etmede başarılı olmuştur. Barajlar 1984 yılında başlayan yamaç ıslah çalışmalarından önce selleri önlemiştir. Verimsiz olsa bile ormanların selleri önlemede olumlu etkisi olmalıdır. Yamaç ıslah çalışmaları ormanları iyileştirmiş ve barajların etkinliğini ve ıslah çalışmalarının sürdürülebilirliğini artırmıştır. Barajların % 92,6'sının tamamlanmış olduğu 1984'yılından bu yana Kayran havzasında herhangi bir sel yaşanmamıştır. Dolayısıyla Kayran derenisin alüvyal konisi ve Büyük Menderes nehrinin taşkın yatağı tarım, yerleşim, iletişim, ulaşım, sulama vb. için tehlikesiz hale gelmiştir.

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