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Forestry Activities and Surface Water Quality in a Watershed

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Abstract

The characteristics of water and water quality of the mainstream in a watershed can be directly affected by the ecological characteristics of the terrestrial ecosystem and indirectly affected by the species composition and structural change of the forests that interact. The most important causes of the structural changes are both silvicultural treatments and harvesting activities which can be considered as the main forestry activities. While water quality in a watershed is indirectly affected by forestry activities, especially harvesting activities, aquatic habitat can be also significantly affected. Due to the multifaceted interactions between terrestrial and aquatic ecosystems, this issue has not yet been clearly elucidated. Long-term studies on this subject at global scale have become widespread in recent years, which may guide the environmental and natural scientists to understand how the quality and characteristics of the prosperous water resources change with environmental influences. When the forestry activities are evaluated on the watershed basis, the flow regime of the mainstream changes while both the water temperature and the algal population increases, especially after the harvesting and thinning activities in riparian zones. In addition, there is an increase in the amount of sediment and organic matter transported to the main stream due to the decrease in forest vegetation in the watershed. That situation decreases water quality and negatively affects invertebrates, fish and other aquatic organisms. In this study, the impact of forestry activities on the quality of water resources and the indirect impact on the aquatic ecosystem was evaluated based on the relevant studies.

Keywords: Aquatic and terrestrial ecosystems, Forestry activities, Watershed management, Wood production

1. Introduction

As Water is a necessary and important natural resource for all living things on earth. The quantity and quality of fresh water resources has vital importance for continuity and sustainability of life on earth. The total amount of water in the world is about 1 billion 400 million km^3. Hence, 70% of the earth is covered with water (Chang, 2003). The 97.6% of the water is in the ocean and seas as salt water, 1.9% in the poles as fresh water in the ice. The amount of remaining water (i.e. groundwater, rivers, lakes, moisture in the soil) that can be used by the people constitutes only 0.5% of the world's total water (Güler, 1997).

Turkey is a country suffering from water scarcity (Figure 1). It is imperative to study on a watershed basis in order to manage and maintain this restricted natural resource because all available drinking water is produced in the watersheds (Göl, 2008). The quality and quantity of water in a watershed is affected by several factors such as the land use types (i.e. forest, agriculture, pasture, settlements, etc.), plant formations (with or without trees, grass, and bushes), climate, geology, topography, and physical, chemical and biological soil properties. There are significant relationships between the land use types and the various facilities which are built on the streams with regard to their impact on water quality and quantity. One of those adverse effect is the change in the physical, chemical and biological properties of water, which also indicate water quality parameters.

Where forests and pastures are transformed into agriculture, the resistance of the soil to external factors is reduced and the tendency to suffer from erosion is increasing, which leads to significant changes in the amount of sediment reaching the streams. Chemical wastes, domestic wastes and sewage water in industrial zones and settlement areas significantly disturb water quality. Various chemical substances such as fertilizers, pesticides, herbicides used in agricultural areas can negatively affect the quality of water. Hence, the slightest intervention in the watershed will be reflected in all of the watershed, affecting both the quality and quantity of the water produced by the watershed (Figure 2).

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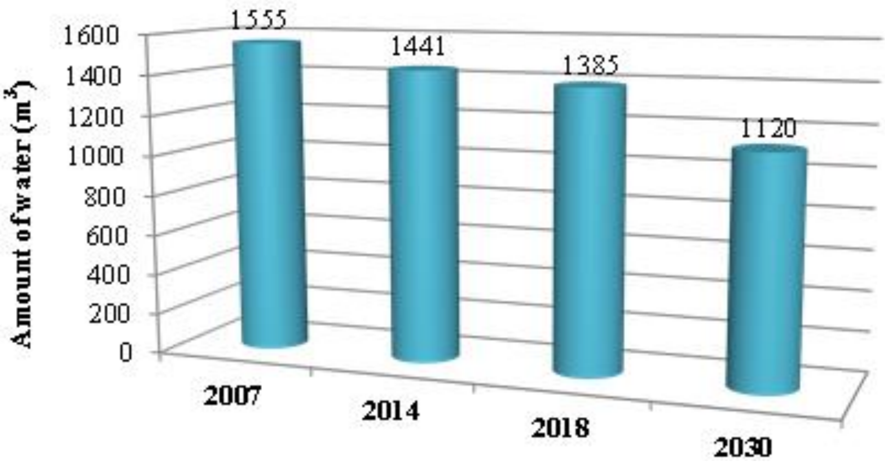


Figure 1. The amount of water per capita in Turkey (2007-2030)

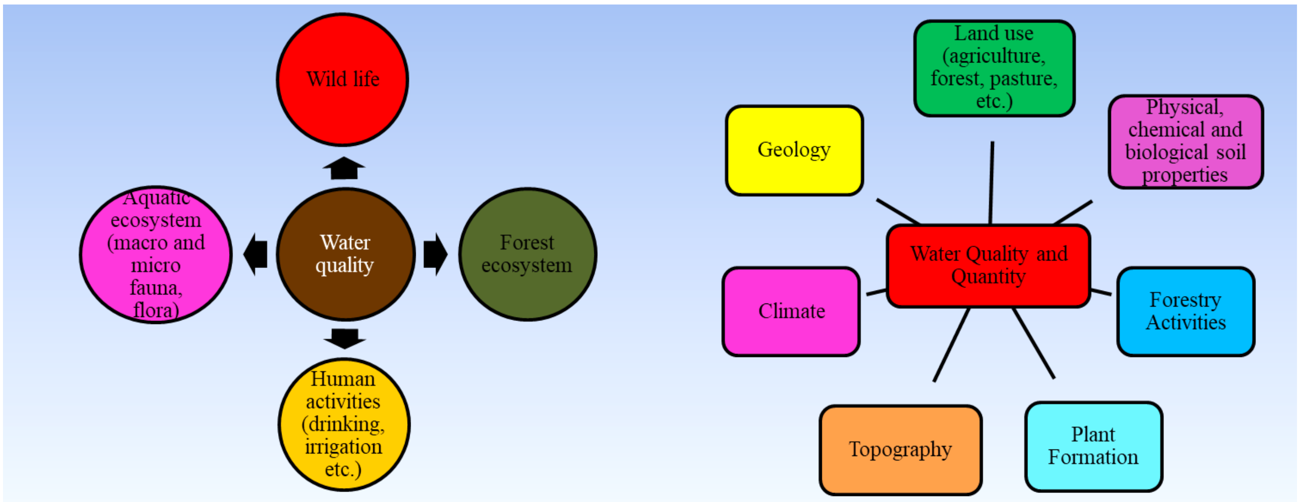


Figure 2. a) The importance of water quality and b) parameters affecting quality and quantity of the water

In the same way, the physical, chemical and biological structure of the water is deteriorated due to various reasons (i.e. removal of the existing vegetation cover, construction of various facilities on the rivers, fertilizer, pesticide use in agricultural areas, etc.) in the rivers and streams, which negatively affects macro and micro fauna living on this stream, vegetation cover around the river, and wild life around settlement areas (Li and Migliaccio, 2011).

One of the main objectives of the watershed management is to provide water production in the required quantity and quality at a high rate in the watershed (Özhan, 2004). The effects of the forests on the quality and quantity of the water are quite high (Gülcü et al., 2008). The water produced in the forested areas is both high quality and in the desired amount. Trees in the forests provide the formation of a dead organic matter which covers and protects the soil. This dead organic matter helps to heal the soil structure and improves soil properties such as soil crumbliness, amount of organic matter, infiltration capacity, and permeability. Due to existence of the dead organic matter ensures, rain water is kept more on the soil surface, the quality of water reaches to the underground without passing to the surface flow, and water is filtered without causing any erosion.

Forestry practices in forest ecosystems have very different ecological and impacts. In this study, possible effec environmental ts of silvicultural treatments and harvesting activities on water quality and aquatic ecosystem were investigated. In this research, basin hydrology, sedimentation, temperature, dissolved oxygen, nutrients, fertilizers and some chemicals used on forests were assessed to evaluate the effects of forestry practices on water quality and aquatic.

2. Watershed Management and Forestry Activities

A watershed is the convex topographic structure which is separated from adjacent ones by a continuous ridgeline and which transport the falling rainfall water through a single structure. On the other hand, watershed management is necessary in order to control erosion, flood and other undesirable events in a watershed, to produce water at the highest quality and quantity, to handle the socio-economic conditions, and to manage and protect the natural resources in the watershed (Özhan, 2004).

A watershed may consist of various land use types such as forest, agriculture, pasture, settlement areas etc. In Turkey, the sections formed by each land use type in the watershed need to be managed by related institution and each institution aims to manage its section independently based on their own rules. For instance, forested areas are subject to different management scheme, while agricultural or pasture areas are subject to different management scheme. On the other hand, Integrated Watershed Management approach emphasizes that all these land use types cannot be independent of each other but they should be organized in a systematic manner as a whole unit. Although the interventions implemented in a basin seem to concern the region it applies, we still have to treat the watershed as a whole. The slightest intervention (forest, agriculture etc.) implemented in the upstream will reflect the whole watershed. For example, when improper forestry activities are applied in a part of the forested areas in upstream, natural disasters may occur which can lead to loss of life and property, not only in the area where it is applied but also in the settlements and agricultural areas which are located in downstream. Therefore, we need to consider a watershed as upstream and downstream as whole in the interventions that will be implemented in the watershed. Activities within the watershed will affect the quality and quantity of the water produced there and eventually that affects people's living conditions. Because the water starts to collect from the upstream part of the watershed and flows towards the downstream part, not only quantity but also quality of the water are important concerns for the people living downstream.

Water quality is assessed as a function of the intended use of the water and is a term used to describe the chemical, physical and biological properties of water. These characteristics are key to determine whether water is suitable for human consumption (drinking, irrigation, industrial use) and ecosystem health (Li and Migliaccio, 2011). The chemical properties of soluble water include gases (oxygen, carbon dioxide, etc.), metals (iron, lead, etc.), nutrients (nitrogen, phosphorus etc.), pesticides and other organic compounds (polychlorinated biphenyls etc.). The most common physical properties of water are color, smell, temperature, taste and turbidity. The biological components of the water are living organisms that are bacterium (*Escherichia coli* etc.), viruses, protozoans (*Cryptosporidiosis* etc.), phytoplankton (microscopic algae), zooplankton (small animals), insects, plants and fish etc. (Li and Migliaccio, 2011) (Figure 3). Water quality measurements are used to determine the chemical, physical and biological properties of rivers, lakes, coastal waters and underground waters and it gives information about whether it is sufficient for special uses such as the drinking, swimming, irrigation and ecosystem services (for wildlife use, macro and micro fauna, and plant cover around the rivers). The quality of the water produced in the forest watershed is quite high.

2.1. Forestry Activities and Water Quality-Aquatic Ecosystem Relations

Streams supply mineral and oxygen by feeding underground and surface waters (Girgin, 2010). Although the quality of the water flowing through the forest watershed is quite high, some forestry activities can lead to significant deterioration in the water quality of the rivers (Görcelioğlu, 1993). Water quality produced in forest areas can be adversely affected by silvicultural and forestry activities. Silvicultural applications are characterized as non-point applications which consist of harvesting, thinning, timber transportation, land preparation, rejuvenation activities, fertilization, incineration, processes of using herbicide and pesticide (Gülcü et al., 2008; Wear and Greis, 2002) (Figure 4).

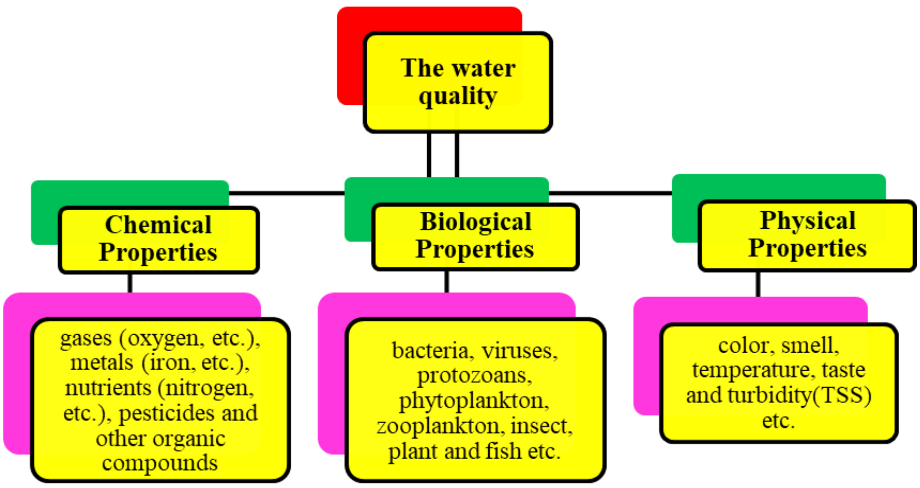


Figure 3. The water quality parameters

Figure 4. Forestry activities in a watershed (Kunduz Forests of Vezirköprü in Samsun province of Turkey)

The effect of pollution caused by non-point silvicultural applications depends on the land ownership, climatic conditions and workers who perform forestry applications. The main pollution sources are sediment yield, hazardous liquids, fertilizers, herbicides and pesticides (Wear and Greis, 2002). Comparing with the agricultural and urban pollution, forestry practices have a short-term and regional pollution in a smaller area (Bethea, 1985; Dissmeyer, 2000). Methods used in forestry practices may negatively affect water resources and aquatic ecosystems (fish, invertebrates, etc.) at high levels if they are not adequately implemented (Wear and Greis, 2002) (Figure 5).

Brown and Binkley (1994) emphasizes that the negative effect of water quality on the study is caused by the fact that the forestry activities are conducted without complying with the required rules. If adequate measures are not taken, the drainage structure of the soil can deteriorate and the concentration of sediment in the stream water can increase due to the accelerated erosion, the accumulation of organic matter in the water can increase which reduces the level of dissolved oxygen in the water, the water temperature may increase as a result of reaching the river edge zones that are shaded on the stream. Organic and inorganic chemical concentrations in water may increase after the application of fertilizer and pesticide (Brown, 1985). As generally assessed, the impact of silvicultural activities on water quality are hydrological changes in the watershed, increased sediment content, increased water temperature, decreased dissolved oxygen content, increased nutrient content in the water below, changes in the aquatic ecosystem and wetlands in forested areas (Wear and Greis, 2002).

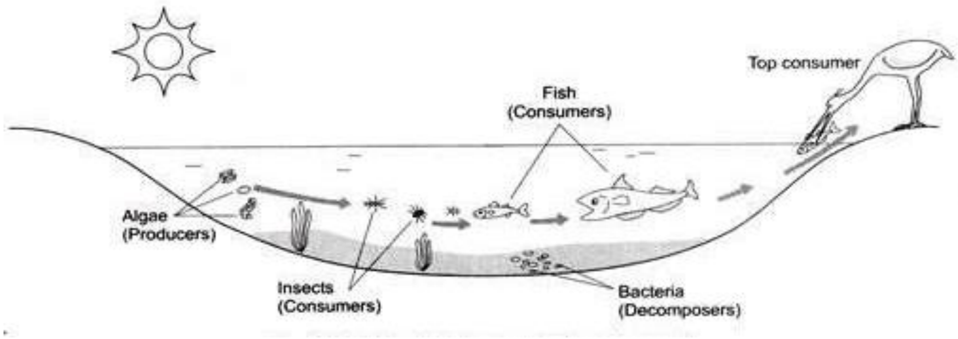


Figure 5. Freshwater ecosystem (URL1)

2.1.1. Effects of Harvesting Activities on Watershed Hydrology

Silvicultural applications can affect the hydrological cycle by soil compaction, overground vegetation change, evapotranspiration change, infiltration change, interception loss, soil nematode, snow melting or accumulation and water quality parameters such as color, turbidity, pH, temperature etc. (Reid, 1993; Gökbulak et al. 2007) (Figure 6). Forestry practices can change the hydrological regime by altering the land structure (Wear and Greis, 2002). The tractor and the timber deplete the land and cause an impermeable layer of water causing the soil to be compacting during removal of the logs with a tractor (Balcı, 1996, Gülcü et al., 2008). Compaction of the soil not only can increase runoff but also can change direction of runoff (Reid, 1993). At the same time, the amount of surface flow precipitation depends on past climatic factors (drought, heavy precipitation, etc.), the amount of wood removed from the environment, soil moisture, soil compaction and soil infiltration capacity (Wear and Greis, 2002). Tractor tracks distort the structure of the terrain by generating rut depths and causing abrasive flows (Wear and Greis, 2002). As heavily loaded vehicles travel on the same road, repeated motions on the road will compress the resulting soil and reduce large pores, infiltration and percolation in the soil. This situation leads to increases in the runoff and erosion (Balcı, 1996).

The amount of water and base currents increase in the forest areas after tree cutting (Wear and Greis, 2002). Peak flows on the stream accelerate channel erosion and increase the accumulation of eroded material downstream of the watershed (Patric, 1978). The stream can return its normal state with the re-plantation of the area (Wear and Greis, 2002). According to the results of previous studies, it has been found that the flow of stream in areas where trees are cut is reduced when compared to the undisturbed control sections. It was also reported that this unexpected phenomenon can be caused by the large blank and cracked structure in the soil where the environment can be disturbed by the plowing of the soil, the old roots can bring big holes to the field and the animals can open nests and open spaces there. They have argued that rainwater can pass through these spaces and reduce the current in the stream (Scoles et al., 1996).

The roads in which forestry activities are carried out are also influential on the amount of water and sediment amount that reach the river (Figure 6). The rainfall coming directly to the road surface passes directly to the runoff. As a result, the peak flows increase and the amount of sediment reaching the stream increases (Gülcü et al., 2008). Decrease or increase of peak flow deteriorate water quality and will cause not only harm to the living beings but also decrease biodiversity (Jackson, 2006). Harvesting activities can disrupt stream hydrology and cause irregular flows (high flows or low flows) in the stream. Aquatic creatures cannot adapt to high flow rates and plants where they hide their eggs and pups are destroyed at high flow rates. Habitat areas of the benthic invertebrates deteriorate and their populations are damaged by dragging with increased or decreased irregular flow of stream. The amount of food the organism gets is limited during irregular flows and the population of the organism is reduced due to low nutrients. Harvesting residuals accumulated in the water may reduce fish and invertebrate populations.

There are certain environmental conditions in which species live their habitats. For example, species need high oxygen at low flow times. When the riparian vegetation near the stream are removed, the water temperature at the stream water is increased. The increased water temperature at the site causes oxygen to decline and the chances of survival for aquatic life are reduced. As a result, benthic invertebrates move away from the environment since they are primarily fed with aquatic organisms. As the benthic invertebrates move away from the environment, the density, size and shape of the fish population change (Jackson, 2006; Olson et al., 2014).

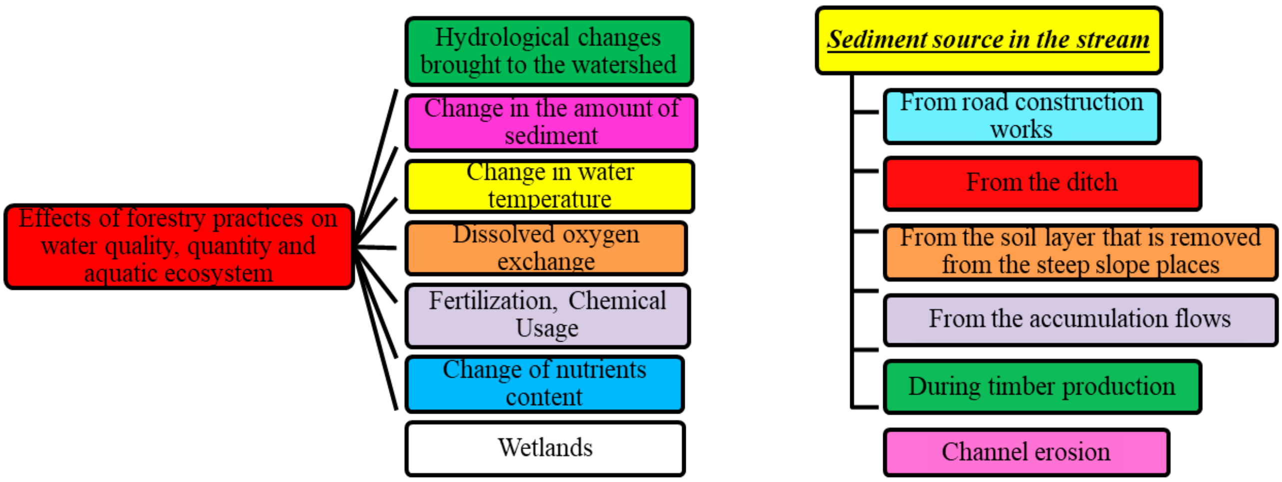


Figure 6. Effects of forestry activities and sediment source in the stream

2.1.2. Impact of Harvesting Activities on Sediment Quantity

Sediment in water consists of inorganic and organic structures (Chang, 2003). Sediment affects the physical, chemical and biological properties of water. Altering the physical properties of water changes color, odor, taste, temperature condition and effect of haze, reduces light permeability, increases heat absorption from surface of water, decreases capacity by providing quick filling of dam reservoir, which causing clogging along the stream. The elements which the sediment contain can interact with other materials and affect the chemistry and quality of the water (Tessier, 1992).

Some researchs suggest that the techniques applied in wood production and land preparation cause erosion to increase by opening the upper part of the soil and exposing it to rain drops (Wear and Greis, 2002). The sediment which is transported to stream in a watershed continues to run in a stream as suspended solids. The amount of sediment transported can vary depending on of the soil erosion intensity, the field slope and the erodibility of the soil. Soil erodibility depends on the soil texture, the amount of organic matter contained, the presence of dead organic matter, the infiltration capacity and the blanks in the soil (Kantarci, 2000). Sediment in the stream is generally caused by construction of roads and ditches, removal of the soil layer in areas with steep slope, and the production of wood (Wear and Greis, 2002).

The effect of harvesting activities on sediment arise from the movement of the machines used in the applications during loading and unloading. The vegetation and protective cover on the soil are removed with the action of the working machines which leads to the soil erosion (Wear and Greis, 2002). Moreover, field studies and timber production activities will increase the flow of streams by reducing the percolation and infiltration capacity of the soil, which will lead to more sediment reaching (Wear and Greis, 2002). If there is a litter layer covering the soil, it protects the soil during cutting of the tree and operations do not cause soil erosion (Patric, 1978). The sediment effect is usually seen in short-term after forestry applications. The study in California suggest that the amount of suspended solids increased eight-fold in the first year and reached normal levels in the second year (Rice and Wallis, 1962).

The researches of forestry practices have reported that the most important effect of the sediment caused due to traces of roads and forestry machines (Weir and Greiser, 2002) (Figure 7). Scole et al. (1996) reported that 90% of the sediments in a harvesting area were produced after the production of wood and that was related with the forest roads. The tractor and logs skidded on the ground will distort the soil and cause the soil to be compacted during timber logging with tractors (Balcı, 1996). This increases the runoff and leads to more sediment reaching in the streams (Figure 7). Lieberman and Hoover (1948) reported that the lowest sediment was 96 mg/L and the highest was 5700 mg/L during uncontrolled tree cutting, while the lowest was 4.3 mg/L and the highest was 80 mg/L in the controlled areas. They emphasized that sediment yield is caused mainly due to hauling on the roads in forest, the construction of forest roads, and the lack of adequate measures.

Figure 7. Impact of production activities on sediment quantity: a) Kunduz Forest of Vezirköprü in Samsun province of Turkey) and b) Solaklı stream in Trabzon province of Turkey

Increasing sediment content on the stream reduces the density of fish and invertebrates (Waters, 1995). The recommended amount of suspended solids for fish should be less than 30 mg/L, most preferably 100 mg/L for optimal conditions (Chang, 2003). Atay and Pulatsu, (2000) have been reported that the amount of suspended solids less than 50 mg/L for trout species in Turkey. High amounts of suspended solids clog the gills of fish, make it difficult for them to breathe and cause them to leave the field (Reynolds et al., 1989). Suspended solids cause clog to stony and collapse into the gravel areas which not only fish have chosen to lay eggs but also needed for protection. That limits the habitat of fish. When the offspring leave the egg, they prefer gravel and stony areas to escape the more fine sediment (Grant and Lee, 2004). The habitats of the young and the morphology of the stream will be negatively affected due to the high amount of suspended material (Koralay et al., 2018).

2.1.3. Impact of Harvesting Activities on Temperature

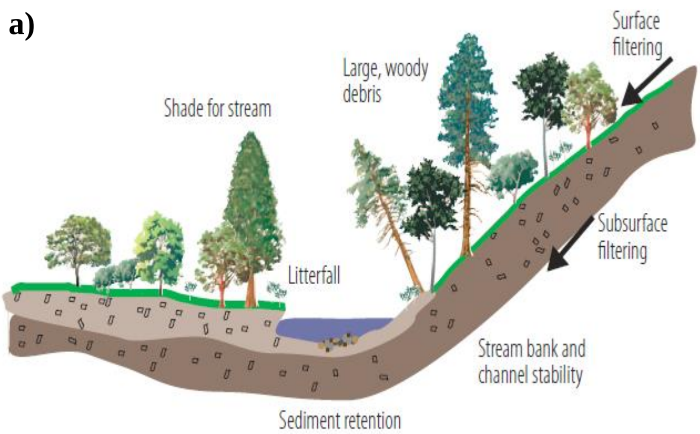
Temperature is a measure used to show the heat density of water or other substances. Water temperature is the most important factor affecting the physical and chemical properties of water (Chang, 2003). Solar radiation, evaporation rates, the density and length of vegetation cover around it, the amount of stream flows, the depth and direction of the stream and the temperature of the water coming from the underground water are all dependent on the temperature of the water (Wear and Greis, 2002; Scoles et al., 1996).

Forestry practices can change the water temperature by changing the size and shape of the stream channel and changing the flow in the stream by remove the riparian zone that provides canopy to the water (Wear and Greis, 2002, Gülcü et al., 2008) (Figure 8). Increased water temperature in the stream reduces dissolved oxygen uptake, decrease the presence of dissolved oxygen in the water, increases aquatic metabolic activity, increases biological oxygen demand and accelerates chemical processes (Curtis et al., 1990).

In an American study was observed that summer vegetation temperature was changed between 2-12°C by removal of the vegetation near the stream (Wear and Greis, 2002). A study in Pennsylvania was reported that the summer temperature changed by 5-11 °C when the riparian zone was removed and the summer temperature changed 1-2 °C when the application was restricted to the riparian zone (Lynch et al., 1985) (Figure 9). The temperature in summer rises in stream after the forestry practices (Merten et al., 2010). High temperatures affect the growth of fish and invertebrate creatures (Weatherley and Ormerod, 1990). Aquatic organisms can adapt to seasonal changes in temperature. However, the stream temperature suddenly rises because of remove the riparian zone vegetation negatively affects aquatic life and habitats (Brown 1972; Curtis et al., 1990, Megahan, 1980). When a 10°C increase in stream temperature, rate of metabolism fish and other aquatic organisms increase 2 times (Şengül and Müezzinoğlu, 2005; Wear and Greis, 2002). Dissolved oxygen saturation is reduced by approximately 20% (Wear and Greis, 2002).

The temperature reduces the amount of dissolved oxygen and causes more evaporation in the water. Biologically, unwanted blue-green algae and other destructive microorganisms increase in the environment. Blue-green algae also degrade the water quality by release toxic substances in the water environment. The increase in water temperature by one or two degrees adversely affects the lives of fish, the migratory movements of fish, their laying and reproduction (Chang, 2003).

a)



b)

Figure 8. Riparian zone: a) Function of riparian zone (Withrow-Robinson et al., 2011), b) Riparian zone near Solakli stream in Trabzon province of Turkey

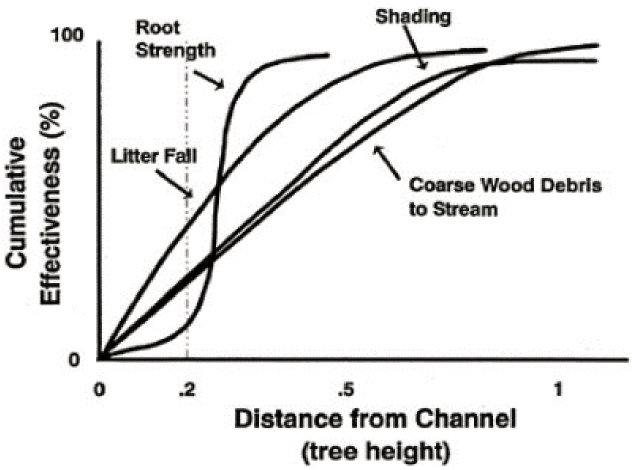


Figure 9. Effect Riparian Forest on stream as function of buffer width (NRC, 2002)

Fish are cold-blooded creatures. The body temperature of fish is closely related to the temperature of the environment which they live. Increase of 1 °C in the temperature of the environment in which they live causes 10% increase in metabolic activity of fish. Increasing the temperature of the stream increases the oxygen demands of the fish and reduces the amount of oxygen in the water. Cold waters contain more oxygen than warm waters. Fish and water value for aquatic organisms depend on many factors such as water temperature, living species composition, life cycle etc. There are individual temperature requirements for each species. The growth and development temperatures of fish are usually between 0-25 ° C (Chang, 2003).

When the optimal limit values for living in aquatic life are exceeded, epidemic diseases increase, growth and development are adversely affected, fish migration becomes difficult and fish deaths occur. High summer temperatures and accompanying low oxygen levels cause changes in the appearance of fish, such as the speck state, mouth structure (Chang, 2003). For this reason, water temperature is a critical factor with vital importance for aquatic ecosystem on the ground (Grant and Lee, 2004).

2.1.4. Effect of Harvesting Activities on Dissolved Oxygen

Dissolved oxygen (DO) means the dissolved oxygen concentration in water (Chang, 2003). The dissolved oxygen concentration in the water depends on the temperature of the air, the atmospheric pressure depending on the height, the respiration of plants and animals in the stream, the resolution of oxygen passing from the atmosphere to the water, the photosynthesis events in stream and the amount of nutrients reaching the stream. The oxygen concentration in stream varies daily depending on the respiration of plants and animals in the stream (Wear and Greis, 2002).

The effect of forestry activities such as thinning which is applied near the stream channel on dissolved oxygen are firstly increase the temperature of the stream water. The removal of the vegetation riparian zone near the stream increases the temperature of the water. As the temperature increases, the amount of dissolved oxygen in the stream will decrease (Koralay, 2015). It has not been fully explained how the water has an effect on dissolved oxygen by increasing the amount of sediment in the water after the forestry practices. However, some researchers have reported that the sediment which accumulates in the stream increases and that can reduce the dissolved oxygen concentration on uncontrolled forestry practices studies (Chapman and McLeod 1987, Everest et al., 1987). Another effect of forestry practices in the reduction of dissolved oxygen concentration is the reduction of the level of dissolved oxygen by accumulating in the water organic materials coming from cutting wastes in the water. The organic substances are needed oxygen for the biodegrade in water. This is called biological oxygen demand. The amount of dissolved oxygen in the environment is reduced by the increase of biological oxygen demand. Hynes (1977) emphasized that as the amount of organic matter increases, the amount of oxygen required to biodegrade this organic substance increases and the amount of oxygen in places where organic matter enters is reduced.

One of the most important parameters used in determining the characteristics of aquatic environments is dissolved oxygen. Oxygen is one of the most basic elements for the survival of life in the water. Dissolved oxygen regulates and limits the lives of living beings in the aquatic environment. The amount of dissolved oxygen is 5.0 mg/L for the continuation of freshwater life (EPA, 1979). If the oxygen concentration is less than 5 mg/L, it affects the functions of biological communities and the survival of living beings become difficult (Sen, 2007). Low concentrations of dissolved oxygen reduce the chances of survival of aquatic insects and fish eggs (Wear and Greis, 2002). The oxygen level in the northern western US should be at least 11 mg / L for the larvae and baby of salmon fish. A sudden decrease in oxygen level to 9 mg / L leads to mild impairment, while a decrease to 7 mg / L causes severe impairment of production (EPA, 1986).

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2.1.5. Effect of Harvesting Activities on Some Nutrients

The nutrients coming from forest areas depend on the type of soil, the genus of the material, the climate, the age of the stands, the combination of species and atmospheric accumulation. The amount of nutrients that come from forest areas is very low (Wear and Greis, 2002). The stands take nutrients from the soil to grow. The amount of nutrients reaching the streams may occur with the increase of erosion due to the removal of the vegetation from the environment, (Scoles et al., 1996). The nutrients usually start to rise in the next few years after forest production activities. As the removed stand starts to grow, the amount of nutrients also begins to decrease in the stream (Wear and Greis, 2002). When stream flow increase, the amount of nutrients increases and causes accumulation in the downstream, especially in lakes and reservoirs.

Nitrogen (primarily nitrate) and phosphorus (primarily phosphate) are primary nutrients which affect the ecological processes in rivers and lakes (Wear and Greis, 2002). Increased nitrogen and phosphorus levels in the stream can increase not only the fluctuations in oxygen concentrations but also productivity in the stream and increase or decrease species diversity. Very high amounts of nutrient input cause to explode the algal population in the area. Higher algal populations limit sunlight entry in the stream, increase turbidity and biological oxygen demand so dissolved oxygen levels reduces. The eutrophication event takes place with the progress of these events (Tuğrul et al., 2011; Chislock, 2013).

Many studies in the United States have reported that increased concentrations of nitrate in the stream after production activities (Binkley and Brown, 1993). Richter (2000) suggests that the nitrate level increase 1 mg/L after the production activities. Some studies have reported that phosphorus, ammonium, nitrate and nitrite levels in the stream are not much of an effect before or after the production activities. Amatya and Skaggs (2008) suggest that thinning did not influence nutrient concentrations, excluding NO3 and total P in a drained pine forest of Coastal North. Furthermore, Carolina. Scoles et al. (1996) emphasized that nitrogen and phosphorus values increased during the first year after the harvesting activities and returned to normal levels within four years in their study.

2.1.6. Effect of Fertilization and Use of Chemicals on Water Quality and Aquatic Ecosystem

Chemical substances such as fertilizers, pesticides, herbicides etc. pass with hand, directly by air or indirectly by runoff and underground waters in the stream (Wear and Greis, 2002). Pesticides, herbicides etc. are the most used chemical substances in rural areas. While pesticides are mostly used in agricultural areas, they are also used in forest and pasture (Görcelioğlu, 1993).

Studies on nitrogen and phosphorus fertilization used in forest areas have found very little in the water when controls are not taken. This value remained within the desired limits according to international drinking water standards and very rarely exceeded these values (Binkley et al., 1999). Another study revealed that fertilizer applied to plantation temporarily increased the amounts of ammonia, nitrogen, phosphate and orthophosphate in the stream. The amounts of these elements in the stream reached normal levels within 3 weeks (Campbell, 1989).

The insecticide, fungicide, herbicide and other chemicals are used for maintenance and conservation activities in forests can cause increase of concentration of pesticides in the stream. However, if they are not used riparian zone that protects the stream banks, there is no significant effect on the water resource (Gülcü et al., 2008). The adverse effects of the use of pesticides in forests on water quality remain in unremarkable levels if the necessary precautions are taken (Gülcü et al., 2008).

Aquatic organisms are adversely affected by exposure to pesticides, herbicides and fertilizers directly in water or indirectly by taking them into the water. Fishes fed on insects in the stream can be affected shortly by using insecticide (Reed, 1966). Herbicides can directly affect aquatic organisms by increasing the intake of organic matter into the streams and indirectly affect by remove the vegetation of the riparian zone (Wear and Greis, 2002).

3. Results and Discussion

The importance of water is increasing with the population increase, urbanization and industrialization in the world. The unconscious use of natural resources due to population growth and the increasing environmental pollution cause water resources to be adversely affected both in terms of quantity and quality of water day by day. The highest quantity and quality of water is produced in the forested areas which are located upstream of watershed. Inappropriate application of forestry activities in forests with hydrological functions adversely affect water quality and aquatic ecosystems. Interventions in watershed that is changed the quantity and quality of water concern with aquatic macro and micro fauna, stream vegetation, wildlife, people, and many living beings.

Removal of riparian vegetation during forestry practices, harvesting activities, road constructions, and use of fertilizers and chemicals are important activities affecting water quality and aquatic ecosystem. These activities cause events that adversely affect water quality such as altered water temperature, increased sediment and nutrient content, and reduced dissolved oxygen content in the stream (Li and Migliaccio, 2011; Gyawali et al., 2013). For this reason, forestry practices need to be planned in a way that does not damage the values and functions of the water resources in and around the forest.

Riparian zone has very important functions in terms of water quality as they are located in narrow areas along the rivers. Cutting or destroying riparian forests adversely affects water quality with a variety of ways. Riparian forests increase water quality by reducing the water temperature with shadow effect, decreasing sediment input, and filtering fertilizer and chemical substances. (Gyawali et al., 2013; Mello et al., 2017). In the studies where the soil erosion is evaluated on watershed, especially after wood production and thinning in the riparian zone, it was reported that the flow regime in the main stream changes and both the water temperature and the algal population increases. Moreover, the amount of sediment and organic matter transported to the main stream increase due to the decrease in vegetation cover (Molina and Cambo, 2011). Hence, riparian zones should be maintained in terms of not only soil erosion but also water quality and forestry applications that may cause soil erosion in watershed should be minimized by careful planning watershed management. Riparian zone should be protected regarding with preserving water quality and they should not be subject to wood production activities.

Owens and Walling (2001) examined the amount of phosphorus in the fluvial sediment in the watershed where the rural and industry dominate. They reported that the total amount of phosphorus in the sediment was between 500 and 1500 μg -1. They also emphasized that the increase in the total amount of phosphorus in the basin is due to the increase in rural and industrial areas. Very high amounts of nutrient input cause to explode the algal population in the area. Higher algal populations limit sunlight entry, increase turbidity, and increase biological oxygen demand, thereby reducing dissolved oxygen levels. Likens et al. (1970) conducted a study where the impact of timber harvest on soil and water resources was investigated. They found that nitrate concentrations in stream water from the treated watershed were 41 times higher than the undisturbed watershed the first year after cutting and 56 times higher in the second year. Nitrate value was always above the 40 ppm limit that is recommended for drinking water by the Public Health Service and it was about 85 ppm during the second year of complete vegetation destruction.

Roads are usually considered to be the major source of sediment to water bodies from harvested forest lands (Patric, 1976). Soil erosion and sedimentation caused by cutting and transporting trees in a stream watershed can be reduced to a minimum level by careful planning. The cause of soil erosion is not only the cutting of the trees but also the removal of cut trees from the area. According to the previous studies, this is mainly due to the skidding road, the construction of forest roads and the lack of adequate measures in these roads (Balcı, 1996). As long as the dead organic matter on the soil is not removed or destroyed, the mineral soil is protected from impact of forestry applications.

It is necessary to select the most suitable ground skidding area and to minimize the skidding distance between the stumps to the landing area at the side of the truck road during the wood production activities. So that, the tendency of the soil to suffer erosion can be reduced. Slope is an important factor in the selection of landing area where logs are sorted and loaded into the trucks. The slope should not be high to prevent the sorted logs rolling in the landing area while it should have enough slope to provide runoff drainage. The landing areas should be always kept clean from any obstacles to work safely and continuously. They should be well planned so that they do not cause any delay during the work and do not cause soil degradation and compaction. The ground skidding roads should not be along stream, high slopes or along long slopes because increasing both the length and steepness of slope will increase soil erosion. Transportation of timber should be carried out in a dry season and on days when the soil is not wet (Balcı, 1996).

4. Conclusions

Improperly implemented forestry activities can negatively affect surface water quality and aquatic ecosystem in a watershed. The conclusion is that these effects can be caused by unplanned harvesting, thinning and fertilization activities, degradation of riparian zones, and use of chemicals. Those impacts will cause increased erosion, habitat alterations, and changes of composition, type and amount of aquatic organisms, such as fish and invertebrates, which can shift the morphology of river. Thus, extensive researches can be conducted to determine how the aquatic ecosystem, especially fish and invertebrates and the riparian zone, water quality and soil erosion are affected in the forested areas. These studies can be a guide to new studies and provide an insight for environmentally friendly watershed management studies considering aquatic ecosystem, riparian zones, soil erosion risks, water quality and ecological catchment planning.

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