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Chapter
[7]

Factors affecting watershed ecosystem: A case study of Mohand Rao watershed in Uttarakhand, India

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Abstract

Watershed is an area of land where all of the water that falls in it ends up in the same place. Water in the watershed comes from rainfall and stormwater runoff. The quality and magnitude of stormwater is affected by all the variations to the land use in mining, agriculture, roadways, urban expansion, and the activities of individuals within a watershed. Watershed health can be judged by the ecological environment of the watershed as well as the ecosystem services. Mohand Rao watershed, located in Haridwar district of Uttarakhand state in India, also faces ecological threat due to natural as well as anthropogenic processes which become root cause of watershed pollution. Main natural process in this watershed is the risk of seasonal flood and the major anthropogenic activity is mining of the riverbed material. Stormwater is contaminated by sanitary sewage, due to improper sewage lines in the villages. This leads to water contamination paving good environment for the pathogens to thrive. Thus contamination of water in the watershed is carried forward to the floodplain areas from highlands. Therefore, this book chapter emphasized on potential factors (especially water pollution) by which watershed ecosystem are getting deteriorated.

Keywords

Ecological threat, Pollution, Riverbed mining, Sewage, Watershed, Wastewater

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Introduction

A watershed can be defined as a geographical area of land that drains all the streams and rainfall down slope until it reaches a common point or an outlet such as the outflow of a reservoir, mouth of a bay, or any point along a stream channel (Kamboj *et al*., 2010) Basically, watershed is a land area through which water flows across the land and drains into a collective body of water, whether a stream, river, lake, or ocean. Each smaller watershed drains into a larger watershed that ultimately flows to the ocean. Water in the watershed comes from rainfall and stormwater runoff. The quality and magnitude of stormwater is affected by all the variations to the land use in mining, agriculture, roadways, urban expansion, and the activities of individuals within a watershed (Ako *et al*., 2014). During human development of landscapes, native vegetation is removed, soils are disturbed, impermeable surfaces are constructed, leading to increased, rapid runoff and flash floods during storms (Konrad and Booth, 2005; Walsh *et al*., 2005; Scott *et al*., 2013). Human impacts on landscapes often diminish the capabilities for ecosystems to provide essential services for people, including clean air, water and natural products (Scott *et al*., 2013).

Watershed is synonymous with other terms, such as "drainage basin" and "catchment area." Area". Watersheds are usually parted from other watersheds by naturally elevated regions. Watershed is not simply the hydrological unit but also socio-political-ecological entity which plays crucial role in determining food, social, and economical security and provides life support services to rural people (Wani *et al*., 2008). The movement of water leads to the connections between watersheds. Thus, water is important, as it carries nutrients, sediments, and pollutants from higher to lower elevations. Water also moves through the subsurface and creates a moisture gradient in the soil. This is why highlands tend to have drier soils than lowlands.

Surface waters are degraded by a combination of natural as well as anthropogenic activities. Increase in excavation of riverbed, degrade the natural ecosystem of the river (Kamboj *et al*., 2017). This disturbance was due to the loose soil resulting in soil erosion (Kamboj, 2013). The degradation of the river system is based on river bed material and environmental pollution such as wastewater, agricultural runoff, and also tourism activities. This causes the eutrophication condition due to the discharge of nutrients in excess amount (Kamboj *et al*., 2020). Such processes harm the use of surface water for drinking, industry, agriculture, restoration and other purposes (Simeonov *et al*., 2003). The sustainable development of resources is in threat as various regions of the world today, face several problems related to the occurrence, use and control of water resources. (Sohrab *et al*., 2012). Stormwater is contaminated by sanitary sewage too, due to improper sewage lines in the villages. This leads to water contamination paving good environment for the pathogens to thrive. Thus, contamination of water in the watershed is carried forward to the floodplain areas from highlands. When sewage is discharged into nearby rivers, it will gradually diffuse into normal water bodies and nearby soil with

the flow of river basins, resulting in pollution (Song *et al*., 2015). Stormwater contaminated by sanitary sewage from leaking sewer lines or cross connections can be a source of pathogens in urban areas (Sauer *et al*., 2011; Sercu *et al*., 2011, 2009) and has been associated with risks to human health (Gaffield *et al*., 2003). A significant association has been found between extreme rain events and gastrointestinal illness, which suggests that precipitation facilitates the delivery of waterborne pathogens from a variety of urban sources (Curriero *et al*., 2001; Drayna *et al*., 2010).

Watershed health can be judged by the ecological environment of the watershed as well as the ecosystem services. A healthy watershed is one that sustains ecosystem function and offers the human welfare and livelihood. Degraded watersheds cannot contribute quality water resources. Watersheds provide large benefits to our communities as well as to the environment. It is important to reflect on defending the integrity of our local watersheds. Maintaining the productivity and biodiversity of river systems is of utmost importance. The watershed intermediations increased the vegetative index, reduced the runoff, soil loss and land degradations. The biodiversity, thus improved in the delicate and fragile watersheds (Pathak *et al*., 2012). In India, watershed projects have matured recently, from mere technical involvements to restore degraded lands and vegetation to more precise poverty mitigation enterprises (Lodha and Gosain, 2008).

Status of Mohand Rao watershed ecosystems in Uttarakhand, India

Watersheds play a vital role in our ecosystem. These primarily serve the habitats based near them. Indian states have several watershed regions. Uttarakhand, being a hilly state is considered a hub of watersheds. Many watersheds take shape from the Himalayan range here and drain their water into the rivers in the floodplain areas. Mohand Rao watershed is located in Haridwar district of Uttarakhand state. It occupies part of the Rajaji National Park range and is therefore of utmost importance. This watershed also faces ecological threat due to natural as well as anthropogenic processes. The major anthropogenic activity here is mining of the riverbed material. This alters the watershed characteristics thus making a huge impact on the watershed ecosystem functions. So, the present study was carried out in Mohand Rao watershed from September 2016 to September 2018, to understand the impact of these activities on the watershed health. This study was carried out in Mohand Rao seasonal hill river watershed of Shiwalik foothill area in district Haridwar of Uttarakhand state. The Shiwalik foothills were formed by the erosion caused during the rise in the Himalayas, where Haridwar lies in the south western part of Uttarakhand state in the Indian subcontinent. The Mohand Rao watershed is located in between the latitude of 30°3′37 N″ to 30°15′ N and 77°E (Figure 1 and 2). Mohand Rao watershed is formed of Mohand Rao and its tributaries namely Sukh Rao and Chilla Rao. This watershed extends in an area of 30.5 sq. km approximately. This covers some portion of Rajaji National park forest area and nearby villages i.e. Shekhwala and Banjarewala.

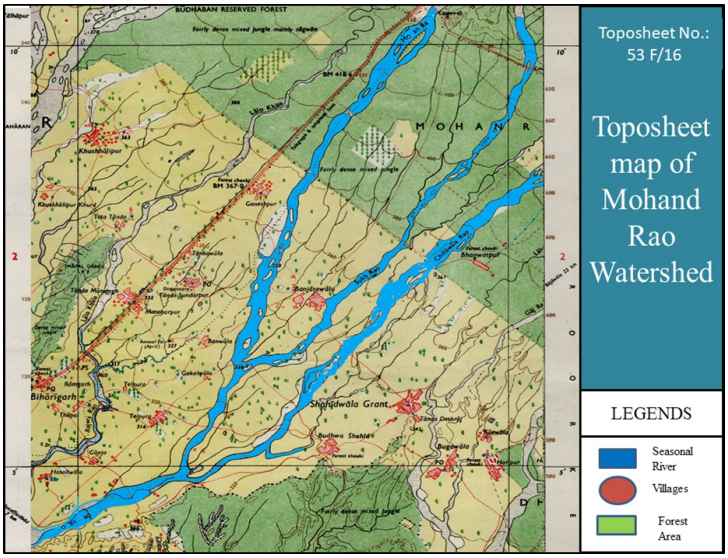

Figure 1. Toposheet map of Mohand Rao watershed in Uttarakhand, India.

Figure 2. Visuals of Mohand Rao watershed in Uttarakhand, India.

Factors affecting Mohand Rao watershed ecosystem

Mohand Rao watershed, situated in Shivalik foothills of the Himalayas has a diversified ecosystem. Changes in its ecosystem can be seen due to some sensitive factors (Figure 3). These major factors

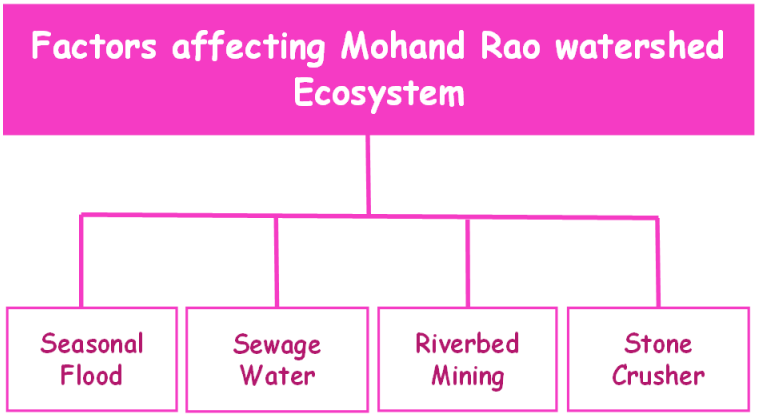

Figure 3. Factors affecting Mohand Rao watershed ecosystemin Uttarakhand, India.

affecting Mohand Rao ecosystem are:

***Seasonal flood*:** A flood is a condition when a river or stream overflows its banks. Seasonal floods are the norm in many rivers, for example when rains or snowmelt increase the flow. In flood condition, the river channel is totally filled and water travels on the floodplain and later decelerates. This water carries the runoff, cutting down the river banks and increases the bed load in the lower reaches of the river. The speed of the river carrying bed load is quite high due to excessive rainfall. Mohand Rao watershed receives heavy rainfall in monsoon season.

***Sewage water*:** Sewage water is wastewater from residents existing in a community. It is the water released from households after use for several purposes like washing dishes, laundry, and flushing the toilet. The term sewage is no longer frequently used and is now replaced with "wastewater". This wastewater due to improper sewerage lines is directly thrown into the rivers of the watershed. It is the main cause of watershed pollution as this wastewater carries pathogenic bacteria and later results in many diseases as in lowlands this untreated water may be further used by villagers.

***Mining of riverbed material*:** Extraction of riverbed material for minor minerals i.e., sand, gravel and boulders from the river is referred to as riverbed mining. Growth of urbanization, infrastructural and economic development activities all over the world have increased the demand of riverbed material for construction purposes (Kamboj and Kamboj, 2019). The environmental effect of sand and gravel mining on land and soil display the destruction of landscape, deforestation, water pollution, loss of farm and grazing lands and the collapse of river banks as the physical environmental impacts associated with mining of these materials. Kamboj *et al.* (2012) studied the positive and negative impact of illegal mining of Ganga River at Haridwar and found that it has very alarming impact on the environment. Mining of the riverbed material started for construction in the name of development. Rightly so, the riverbed material is highly in demand for the same purpose. Due to enormous rise in population, the

Figure 4. River bed mining and stone crashers at Mohand Rao watershed ecosystem in Uttarakhand, India.

demand of houses, buildings etc. is increasing, but the natural resources are not being replenished by the same rate (Figure 4a). Kamboj *et al.* (2018) examined the water quality of the active mining area and found the area severely affected.

***Stone crushers*:** These are the machines installed near the riverbed mining area to crush the big boulders into different sized pebbles, gravel and sand. Crushing of boulders produces large quantity of dust, which further floats in air and spreads in the surrounding area of the stone crusher. Inhalation of the fine dust leads to severe respiratory health problems (Figure 4b). Pebbles are further differentiated into various sizes and are sold at different rates accordingly to the contractors for construction purposes. Trucks in large numbers carry the bedload to the crusher units. The condition of the road is

Figure 5. Trucks carrying riverbed load and Cutting of riverbank changing channel morphology at Mohand Rao watershed ecosystem in Uttarakhand, India.

thus very pitiable. Ponds and ditches can be seen (Figure 5a and 5b).

Impact of major factors on health of Mohand Rao watershed

All the above factors laid their major impact on the ecology of the Mohand Rao watershed as follows.

***Channel morphological changes*:** Seasonal flood plays a major role in changing the channel morphology. The morphology of the Calora River in Italy changed from transitional to single-thread (Magliulo *et al.*, 2013). In monsoon, the water brings heavy load of substrate material or the runoff with it to the lower reaches (Figure 5b). This results in flood like condition. Due to this, major soil erosion takes place (Kamboj, 2013) and the banks of the rivers are cut off at varied angles which further increase the river width as well as the bank height at several areas of the watershed. In Mohand Rao watershed channel morphological parameters as depth, bank height, river width, drainage area, slope, substrate

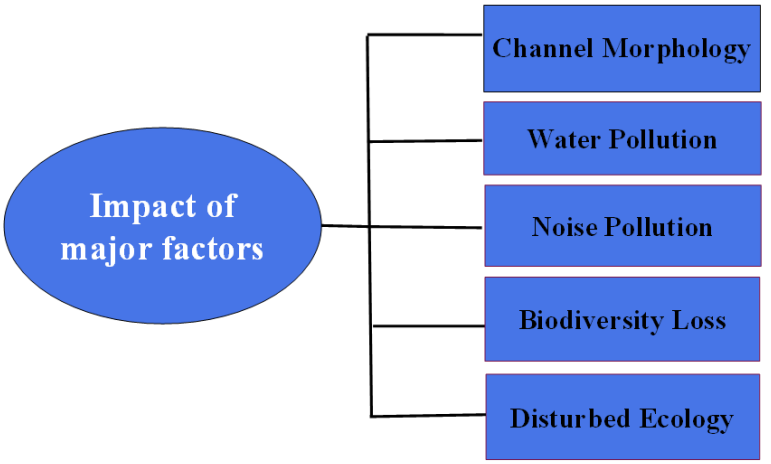

Figure 6. Impact of major factors on Mohand Rao watershed ecosystem in Uttarakhand, India.

structure at different sites were studied.

During the study period from 2016-2018 river depth, bank height, river width and slope were increased in the region where more mining occurred. The drainage area was increased in Mohand Rao and Sukh Rao river due to excessive mining in these rivers. The enlargement was more in Mohand Rao than Sukh Rao as Mohand Rao is the main river used for mining activities (Figure 6). The substrate characteristics were differentiated on the basis of size into boulders, cobbles, pebbles, gravels and sand (Kamboj *et al*., 2017). These characteristics showed that huge amount of substrate was brought down by the rainwater in the monsoon as runoff. Thus, all these parameters changed the overall morphology of the rivers forming the watershed. Instream mining causes instability to the river channel. It disturbs the existing stability of the channel form and causes undercutting of the river banks by incision (Kamboj *et al*., 2020)

***Water pollution*:** Water pollution in the rural watersheds mainly occurs due to two reasons. The wastewater or sewage discharged from the household in the form of faeces and urine, carrying bodily waste, washing dishes, laundry and food preparation are classed as domestic or sanitary sewage. Surface runoff also known as storm flow, is the share of rainfall that runs hastily over the ground surface to a defined channel. Precipitation absorbs gases and particulates from the atmosphere, dissolves and leaches materials from vegetation and soil, suspends matter from the land, washes spills and debris from urban streets and highways, and carries all these pollutants as wastes in its flow to a collection point. The Mohand Rao watershed during the study revealed that the villages Banjarewala and Shekhwala were lacking proper sewage lines and thus this domestic wastewater ultimately reached the rivers.

***Noise pollution*:** Noise pollution is the regular exposure to raised sound levels that may lead to adverse

effects in humans or other living organisms. Mohand Rao watershed, in the study period of 2016-2018 due to riverbed mining activity has total of twenty-eight stone crusher units throughout. These stone crushers work day and night in crushing big boulders extracted from river into smaller ones. Later, these are transported through different modes of transport using trucks, tractors, bullock carts etc. Thus, these roads have ditches which are filled with water in rainy season and experience casualties. They produce a lot of noise in the area. It affects the fauna of that area. Study reveals that the faunal diversity reduced with increase in the number of these units. The birds and mammals avoid these areas because of the loud noise made by the stone crusher. The noise pollution affects the birds in many ways such as damages of ears, changing in reproductive and vocal communication, disturbance in ability to hear the predators and important sounds.

***Loss of biodiversity*:** The changes in the biodiversity of the watershed were also evident after an extensive study of the flora and fauna (Tables 1-3). The floral diversity included the study of trees, herbs and shrubs. Herbs and shrubs were much disturbed in the mining zone of the watershed in comparison to the Rajaji forest area (Sharma and Kamboj, 2019).

This disturbance was due to the loose soil resulting in soil erosion (Kamboj, 2013). Very few species of

Table 1. Status of trees diversity in Mohand Rao watershed (+ present; - absent).

Botanical name	Common name	Family name	Forest area	Active mining area
Dalbergia sisso	Shisham	Fabaceae	+	+
Tectona grandis	Teak	Verbenaceae	+	-
Butea monosperma	Dhak	Fabaceae	+	+
Pithecellobium dulce	Jungle Jalebi	Mimosaceae	+	-
Odina wodier	Mohin	Anacardiaceae	+	-
Ficus virens	White Figure	Moraceae	+	-
Koenigii	Sweet neem	Rutaceae	+	+
Acacia nilotica	Babool	Mimosaceae	+	-
Bombax ceiba	Simbal	Bombeaceae	+	-
Syzygium cumini	Jamun	Myrtaceae	+	+
Tamarindus indicus	Imli	Caesalpiniaceae	+	-
Eucalyptus globulus	Blue-gum (Safeda)	Myrtaceae	-	+
Populus nigra	Black Poplar	Salicaceae	-	+
Phoenix dactylifera	Khajur	Arecaceae	+	-
Azadirachta indica	Neem	Meliaceae	+	-
Ficus religiosa	Peepal	Moraceae	+	-
Ficus benghalensis	Banyan	Moraceae	+	-
Aegle marmelos	Bael	Rutaceae	+	-
Shorea robusta	Sal	Dipterocarpaceae	+	-
Cassia fistula	Amaltas	Fabaceae	+	-
Holoptelea integrifolia	Papri	Ulmaceae	+	-
Mallotus philippensis	Rohini	Euphorbiaceae	+	-

Table 2. Status of shrubs diversity in Mohand Rao watershed (+ present; - absent).

Botanical name	Common name	Family name	Forest area	Active mining area
Ricinus communis	Castor	Euphorbiaceae	+	-
Lantana camara	Raimuniya	Verbenaceae	+	+
Smilax aspera	Salsa	Smilacaceae	+	-
Ipomoea carnea	Morning Glory	Convolvulaceae	+	-
Clerodendrum viscosum	Bhant	Lamiaceae	+	-
Ziziphus ziziphus	Jungli Ber	Rhamnaceae	+	-
Solanum torvum	Bhurat	Solanaceae	+	-

Table 3. Status of herbs diversity in Mohand Rao watershed (+ present; - absent).

Botanical name	Common name	Family name	Forest area	Active mining area
Ageratum conyzoides	Chick weed	Asteraceae	+	+
Alternanthera sessilis	Garundi	Amaranthaceae	+	-
Malvastrum coromandelianum	Kharenti	Malvaceae	+	-
Anagallis arvensis	Biliputi	Primulaceae	+	-
Cyperus rotundus	Nut Grass	Cyperaceae	+	+
Parthenium hysterophorus	Congress grass	Asteraceae	+	+
Melilotus indicus	Yellow sweet clover	Fabaceae	+	-
Oxalis latiforia	Khatmithi	Oxallidaceae	+	+
Oxalis corniculata	Amrul	Oxallidaceae	+	+
Achyranthes aspera	Latjira	Amaranthaceae	+	-
Mecardonia procumbens	Makardana	Plantaginaceae	+	-
Chenopodium album	Bathua	Amaranthaceae	-	-
Cannabis sativa	Bhang	Cannabaceae	+	+
Vetiveria zizanoides	Khas khas	Poaceae	+	-
Tinospora cordifolia	Amrita/giloy	Menispermaceae	+	-
Imperata cylindrica	Cogon grass	Poaceae	+	-
Eulaliopsis binata	Sabaigrass	Poaceae	+	-
Rauwolfia serpentina	Sarpgandha	Apocynaceae	+	-
Solanum villosum	Kovidaraha	Solanaceae	+	-
Solanum nigrum	Mokoi	Solanaceae	+	+
Saccharum spontaneum	Kaans	Poaceae	+	+
Eclipta alba	Bhringaraj	Asteraceae	+	-
Juncus tenuis	Poverty rush	Juncaceae	+	+
Sacchrum munja	Munja	Poaceae	+	+
Malva sylvestrus	Gurchanti	Malvaceae	-	-
Rumax dentatus	Toothed dock	Polygonaceae	+	-
Acalypha indica	Kuppi	Euphorbiaceae	+	-
Euphorbia hirta	Asthma weed	Euphorbiaceae	+	+
Cynodon dactylon	Dub grsass	Poaceae	+	+
Euphorbia prostrata	Red euphorbia	Euphorbiaceae	+	+
Ischaemum rugosum	Ribbed murain-grass	Poaceae	+	-

shrubs and herbs could be found here. Similarly, the avian and mammalian fauna under study was affected due to mining in the riverbed mining prone area of the watershed. Sharma *et al*. (2019) studied the effect of riverbed mining on floral diversity of Mohand Rao watershed and concluded loss of floral diversity in the active mining area as compared to the forest.

***Disturbed ecological equilibrium*:** Ecological equilibrium of a watershed is to sustain a state of dynamic stability within a community of organisms so that the ecosystem diversity remains relatively stable, subject to gradual changes through natural succession. A stable balance is needed in the numbers of each species. Increase in excavation of riverbed, degrade the natural ecosystem of the river (Kamboj *et al*., 2017). The study showed a disturbed ecological equilibrium throughout the watershed.

Conclusion and recommendations

Unscientific riverbed mining practices have proven to be harmful for the ecological equilibrium of the watershed ecosystem. The watershed health is at high risk. The changing morphology of channels results in degradation of water quality. In Flood-plain mining area, the riparian vegetation has also degraded due to the transportation of the riverbed materials. The transportation and mining activity reduced the floral and faunal biodiversity. Sewage water running in the channels shows improper functioning and causes diseases. From the above conclusion, it is recommended that the mining activity should be banned near the ecologically sensitive area and should be allowed in those rivers only where replacement rate of material is high. The extraction should be performed in a sustainable manner. Proper facilities for sanitation and wastewater should be practiced. General awareness campaigns for the people involved in mining activity as well as wastewater should be carried out time to time.

Conflict of Interest: The author declares that there is no conflict of interest.

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