

Effects of Eucalyptus Globulus on the Underground Water in Udigram, Swat, Pakistan

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Abstract: The plantation of Eucalyptus in hilly areas is not encouraging insight because it vanishes more than 50 liters of groundwater per day into the atmosphere and is gradually more dangerous to the water table and rock reservoirs. The rate of water evaporated by eucalyptus is higher than compared to the incoming showers in the area. This imbalance in the water cycle caused changes in the water table as well as the flow of water from the springs. On the other hand, its wood is of poor quality and having low market demand as well as domestic use. The precipitation shows -2 inches (-25.8 millimeters) decline per year in the winter season between 1995 and 2014, while the ratio of increase is 1.24 inches (31.5 millimeters) in the summer months. Generally, the major share of annual precipitation was from the winter season before 1995, but onward, it is in summer and the area dropped from humid to sub-humid climate. This seasonal fluctuation of rainfall and dryness of rock reservoirs has not only decreased the water table, but also caused changes in the flow of water from the springs and rivers. The dryness of the wells after reduction in precipitation, generally leads to the digging and intensive use of tube wells in the area. The study reveals that the dryness in spring has an aftereffect totally of cultivation of Eucalyptus on the *Raja Gira* hill slopes and required mitigation to overcome the issue of water availability for the locals.

Keywords: Eucalyptus, precipitation, temperature, climate change, water springs, water tunnels.

Introduction

The name eucalyptus normally refers to the little cap (operculum) covering the unopened flower. As with respect to its habits, it is described as an evergreen tree, shrub, and Mallee. According to Chippendale (1973), the average height of different types of Eucalyptus ranges from 4.6 to 97.5 meters. Furthermore, the Eucalyptus tree originally planted on the shoreline of the Botany garden, located on the eastern shore, Australia. The principal description of the tree was published in 1789 and a French Botanist, Heriter, proposed the name Eucalyptus.

Generally, twenty to twenty-five percent of forest covered area required for a balanced economy of a country. But in Pakistan, this percentage is less than four percent that is below the stable economic limits, which is continuously decreasing due to deforestation, urbanization, domestic and commercial use. The existing forests covered area can not fulfill the growing need for wood and other commercial products in Pakistan, which is the seventh most populated country in the World and fourth in the Asian continent having a 2.0 percent annual growth rate (GoP, 2017). To satisfy the wood utilization needs of the growing population, to build the forests covered area and to help the timber-based industries, forty genus of Eucalyptus were planted during 1995-2018 on the mountain and plain areas of the country for the purpose of the green evolution. About, 200 million trees (2.2 percent Eucalyptus) were planted in Punjab, particularly on the inundated lands. Essentially, in Khyber Pukhtunkhwa, about eighty million trees comprising 2.7% Eucalyptus

have been planted on the mountains and Ranchlands (Amjad, 1991).

The major issue of Eucalyptus is its negative effects on the physical environment, particularly on the surface as well as underground water in the existing climate change scenario in Pakistan. As it evaporates a lofty proportion of groundwater to fresh air and brings down the water table. The French scientists have planted the Eucalyptus tree in waterlogging and brackish areas. But in Pakistan, the Eucalyptus, predominantly, cultivated on hill slopes having the humid and sub-humid environment. The tree is exceptionally viable to rock reservoirs as well as groundwater. Subsequently, it is progressively critical to assess the effect of Eucalyptus on hill slopes, surface as well as sub-surface water and its obligation in bringing down the water table and flow of natural springs.

The research deal with the effect of Eucalyptus on the groundwater in *Udigram*, Swat Valley, Khyber Pukhtunkhwa, Pakistan. *Udigram*, a historical as well as a place of pleasant weather and greenery in the laps of *Hindu Raj* mountains is situated at 34°-47' North latitude and 72°-18' east longitude with an altitude of 961 meters above mean sea level. The village of *Balogram* limits the study area in the north, *Gogdara* in the south, *Raja Gira* mountain in the east and the *MurghazarKhwar* (stream) as well as Swat river in the west respectively. The Swat river flows from northeast to southwest and covers the discharge and irrigation system of the area (Figs. 1, 2).

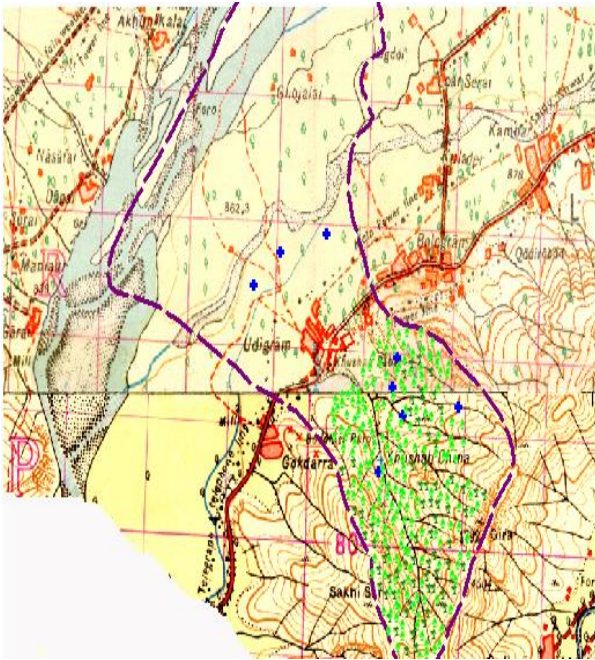


Fig.1 Topographic map of the study area, (Toposheet No. 43B/7).

As far as the Indo-Pakistan is concerned, the Capt. Dryas (1860) was the first, who planted the Eucalyptus tree in Punjab province, Pakistan. Hence, the Parker (1952) has introduced Eucalyptus plant throughout the plane and hill physiographies of Indo-Pakistan sub-continent. The other specific contributors consist of Khan (1955), Ahmad and Ruhullah (1982), Akbar and Tariq (1992), Akbar, et al. (1992), Rafique (1995), Boden (1968), Chippendale (1973), Parameswarappa, et al. (1997), Jackson, et al. (2005), Sohail and Sulaiman (1999), Aslam, et al. (2018), Zhang (2012), Tome and Barreiro (2012), Planisami and Joshi (2011), Ali, Bilal and Nisa (2014), etc.



Fig. 2 Areal view of Udigram village (Source: Field Photography).

Materials and Methods

The study is commonly based on three aspects of the physical environment that is declining and depth of the water table, the effect of Eucalyptus on the groundwater and rock reservoirs. Furthermore, the

contribution of precipitation, as well as temperature fluctuation in the decrease of underground water, seasonal streams and flow of water spring is cross-matched with the field observations. Mutually, the primary and secondary information has been utilized to appraise the effect of the Eucalyptus on mountains, water storage systems, particularly surface, sub-surface water and water table. The primary data have been gathered all the way through field questionnaires, individual meetings as well as field overviews, whereas, the secondary data regarding precipitation and temperature were collected from Pakistan Meteorological and Data Processing Center, Karachi (1986-2014). The questions are relevant to the effect of Eucalyptus on the water resources like wells, water springs, water table, groundwater, rock reservoirs along with the willingness of the locals for the plantation of Eucalyptus on the hill slopes in the Udigram village. Random sampling techniques have been used for the field observations and collection of primary data. For this purpose, the whole village classified into four-parts comprise Southern *Maira*, Northern *Maira* and Southwestern as well as the Northwestern part. The divisions of the village limited via roads, main streets and seasonal torrents, channels and topographic characteristics. A total of fifty questionnaires has been filled from each sample area along with other research tools like personal interviews, videos, observations and discussions with the locals as well as stakeholders. Furthermore, 1:50 K topographic maps and satellite images (Google Earth) have been used for the intention to map the area using a Geographical Information System (GIS) and Remote Sensing (Map Info and ERDAS). These maps have also been used for the purpose to analyze the slope of the water flow from springs during different seasons and to mark the Eucalyptus plantation area. A digital camera, as well as a global positioning system, has been used as a tool for the purpose to find out the exact location of springs using a geographic coordinate system and to take photos of the Eucalyptus trees and water springs on the spot. The information gathered during the field survey has arranged scientifically and examined by utilizing basic illustrative methods like averages, diagrams, maps, photos and graphs.

Results and Discussion

Generally, water is an essential requisite for flora, fauna and human life. Its properties as a solid, liquid and gas make it more helpful among all chemical compounds. The source that keeps the water in balance is the hydrological cycle, A considerable amount of water received from rain or snow percolates downward into soil and rocks filling up joints, pore spaces and forms what is known as groundwater. Additionally, the water that seeps through the ground moves downward under the force of gravity until it reaches the impermeable layer of rocks through which it cannot pass. It is the key source that plays a vital role in the balancing of the water cycle and its fluctuation causes a change in the hydrological cycle of an area.

Table 1. Udigram, springs and flow of water, Source: Questionnaire survey

Name	Topography	Flow before plantation (Meters)	Flow after plantation (Meters)	Plantation Year	Fall in water flow	Evaporation (Liters)
Chinodog Spring	Hilly	800	200	1995	1996-97	50-60
Tehran Spring	Hilly	75	Dry	1995	1996-97	40-50
Attai Spring	Hilly	250	50	1995	1996-97	30-40
Serai Spring	Plain	No Change	No Change	1995	No Change	0
Jrando Spring	Plain	No Change	No Change	1995	No Change	0
Chinjan Spring	Plain	No Change	No Change	1995	No Change	0

With respect to Udigram, the most elevated peak towards the north is "Gira" with a height of 4792 meters (AMSL). The southern and northern Maira (dry land) situated in the piedmont plains at the base of Raja Gira hills covered by gravels and pebbles. The

1.5 meters (5 feet) to obtain water. It shows that the decrease in groundwater is 1.5 meters (5 feet) with 0.3 meter (1 foot) decline per year. Almost, five water wells considered in southern Maira, in which the only one is dry, while the remaining have been burrowed up

Table 2. Udigram Village, Swat district, Number and depth of wells and tube wells, Source: Field Survey.

Location	Depth of wells (Meters)	Depth of tubewell (Meters)	Closed	Stable/Active	Decrease (Meters)
Northern Maira	23.1	30.5	2	2	1.5
Southern Maira	21.9	30.5	1	1	1.2
NW Village	10.97	34.1	Nil	1	0.6
SW Village	12.8	36.57	2	1	0.9
Total/Mean	17.2	33	5	5	1.1

southwestern and northwestern portions of the village are nearer to the Jambil-Murghazar Khwar (Fig. 1). These topographic characteristics of the study area demonstrate that the surface as well as groundwater is absolutely inclining as from east to the southwest that is from the hills to the Swat river (Fig-3).

In the northern Maira part, the normal depth of the groundwater is 22.9 meters (25 yards), which reduced to 21.9 meters (24 yards) in the southern Maira part, 12.8 meters (14 yards) in the northwestern and 11 meters (12 yards) in the southwestern part of the study area (Table 2). The depth of groundwater attainments equal to the surface of the Swat river, where the agriculture activities are practicing in the open areas. Because of the nearness of Murghazar waterway, the northern part of the town demonstrates the lowest depth of the water wells that are 11 meters (12 yards), which increases towards the east with the rise in altitude of the area (Graph 1).

Decrease in Underground Water

With regard to the decrease in the water table, the participants have been suggested that the underground water diminished with the passage of time. The fall in underground water has been noted since winter 1995 when most of the wells dried in the area (Table 2). Beyond nine water wells in northern Maira, two newly established wells did not show change. Although, two water wells are forever closed and excluding burrowed

to 1.2 meters (4 feet) imminently to acquire groundwater. However, there has only one water well that remained stable. Consequently, the decline in the water table around is 1.2 meters or 4 feet. In the northwestern part of the village, almost five water wells have been considered for investigation, in which one water well has remained stable and the rest of the wells became useful after digging of 0.6 meter or two feet and reveals 0.6 meter or two feet declined in the water table. Among the six water wells in the southwestern part of the village, the two water wells have been closed due to decrease in the water table. Though, the remaining wells have been made usable after burrowing of 0.9 meter or 3 feet showing decline of 0.9 meter (3 feet) in the underground water level.

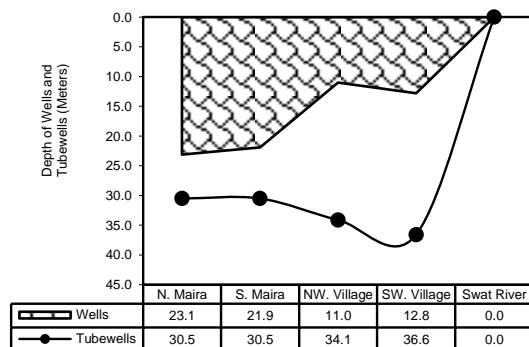


Fig. 3 Udigram, slope of watertable and depth of wells and tubewells (meters), field survey.

Table 3. Udigram Village, Swat district, Mean Monthly Precipitation (1986-2014), Source: PMDC, Karachi

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total (cm)	Deviation
1986-90	6.6	9.3	22.7	6.4	3.6	6.3	9.6	9.5	4.0	0.5	4.5	8.5	91.5	5.6
1991-95	7.7	8.4	17.5	13.2	5.7	5.9	19.3	6.8	6.6	5.1	2.2	3.8	102.2	16.3
1996-00	9.2	12.4	11.9	9.1	6.4	5.0	9.4	9.8	7.1	3.8	1.9	1.1	87.1	1.2
2000-05	6.8	2.4	6.1	5.6	1.6	3.1	5.3	4.6	6.6	3.0	4.6	4.4	53.9	-32.0
2006-10	6.1	10.7	7.5	11.5	4.9	8.1	15.4	12.0	6.5	2.4	2.0	4.2	91.3	5.4
2011-14	4.0	16.3	5.4	6.2	3.7	7.0	9.3	9.0	7.6	11.0	8.8	2.2	90.5	4.6
Average	6.8	9.7	12.1	8.7	4.3	5.8	11.5	8.6	6.4	4.1	3.8	4.1	85.9	1.2

Generally, there is a total of 11 tube wells in the study area which comprises three bored by government and eight by private sector (Table 2). The depth of tube wells in Maira is 30.2 meter (33 yards), although it is 33.8 meters (37 yards) in northwestern and 36.6 meters (40 yards) in the southwestern part of the village. It is evident that the depth of tube wells is ordinarily more when contrasted with water wells. Due to which, the underground water from wells flows towards tube wells. Resultantly, the wells in the vicinity of the village in the range of a half kilometers from tube wells have become dried (Fig. 3).

Drying of the Springs

Obviously, the six springs including three each in plain (Chinodog, Tehran and Attai spring) and mountains (Serai, Jrandi Dheri and Chinjan spring) have been selected for the current research (Fig. 5). The flow of water from *Chinodog* spring covered a distance of 800 meters in 1995, which reduced to 200 meters in 2014. As far as, the *Tehran spring* is concerned, the flow was 75 meters (1995) and currently, it is waterless (Table 1). Besides, the flow of water from the Attai spring ranges up to 250 meters during 1995 that dropped to 50 meters in 2010 and currently is completely dry. The water springs in plain areas of the village demonstrate no change in the flow of water because of a well-created irrigation system. As per the occupants of the village, the mountain springs were become dormant because of the plantation of Eucalyptus in the surroundings of the water springs and decrease in winter precipitation.

Precipitation Fluctuation

The annual precipitation noted at Udigram from 1986 to 2014 was 86 cm (33.9 inches) and was falling in sub-humid climates, which was 108 cm (43 inches) during 1931-1985 (normal data) with humid climates. The area is highly moist in March and July, while the driest months are June and November. Commencing from 1931 to 1990, the maximum share of the annual precipitation was from the winter season, but currently, it was observed during summer months. The winter season of the village varies from October to April, while the summer season is from May to September. These main rainy seasons are additionally classified into four sub-seasons, namely winter (mid-November to mid-April), pre-Monsoon (mid-April to June), Monsoon (July to mid-September) and Post Monsoon (Mid-September to mid-November).

The annual precipitation of the village demonstrates a decreasing pattern throughout the series (1986-2014). The valley has been recorded 117 cm (45.9 inches) precipitation during 1998, which declined to 94 cm (37 inches) during 1990. From 1991 to 1995, it has been exceeded to 102 cm (16 inches) for a second time and afterward dropped to 87 cm (34 inches) within 1996-2000 having a negative deviation in the last five years. The precipitation of the village further declined to 54 cm (21 inches) during 2001-05 and rose up into 91 cm (37 inches) in 2006-10 with a little decrease of 90.5 cm (36 inches) during 2010-14 (Table 3). The data reveal that the precipitation of the area increased up to 1.2 cm (0.45 inch) having a severe decline of -32 cm (12.5 inches) during 2000-2005 and heavy rains of 16.3 cm (6.2 inches) in 1991-95. Furthermore, the village has humid climate during 1991-95 and falls into sub-humid climate in the excluding years of the series. Before 1995, the area recorded heavy rains during the winter season, but currently, it is from the summer season and showed a drastic change in the precipitation condition of the area.

Groundwater and eucalyptus

Eucalyptus vanishes a lofty quantity of groundwater into the atmosphere. Therefore, it has been introduced for the waterlogged as well as river seepage areas. Due to its high rate of evaporation, it affected rocks as well as water reservoirs. As indicated by Meinzer (1959), the rocks consist of several open spaces called interstices. In which water can be put away and through which water can move and is known as subsurface water. Even as a quantity of which totally saturated with water is named as groundwater. The subsurface water above the zone of immersion and in the zone of aeration is known as vadose water. The aeration zone is subdivided into the soil, water, the intermediate and the capillary zone. The soil water zone is comprised of soil and different materials close to the surface, which released water into the air by evapotranspiration. The capillary zone extends immediately above the zone of saturation to the limit of capillary rise water. The intermediate region is deception among the soil water and capillary zone and maintains the previous two zones (Walton, 1970).

The most significant variables which belong to the water table are an aquifer, aquitard, and aquiclude. These all are the sources that yield appreciable quantities of water to drain, wells, and springs. In these sources, an aquifer serves as a transmission conduct and storage reservoir. It transports water from recharge

areas to surface bodies of water wetlands and springs areas of evapotranspiration and other water-collection devices.



Fig. 4 Plantation of Eucalyptus on Raja Gira Mountain.

According to the people's responses the water table of the study area revealed above three feet (0.85 meter) decreasing from 1995 to 2014. Some of the respondents have of the feeling that the decline in the groundwater, as well as spring channels have, mostly, brought about by the plantation of Eucalyptus on mountain slopes. Noticeably, the Eucalyptus tree is termed as the sun based tube well and released the vast volume of the groundwater into the air from rock reservoirs as well as water logging areas. Thus, it is more dangerous to all those sources which serve as storage of incoming water particularly into the rock reservoirs. As the water table declines, the water stored in the interstices and rocks comes-out in the shape of springs and flows towards the intermediate zone of aeration subsequent to assimilation by the surface of the earth and help in the recharging of the water table. The forest department of Pakistan did the plantation of Eucalyptus on hill slopes in 1995, which started to evaporate 45 to 52 liters of the groundwater per day into the atmosphere through evapotranspiration and made the mountain reservoirs dried (Table 2 and Fig. 4).

The change in mountain reservoirs did not only influence the flow of spring water, but it also caused a change in the water table as well as in the level of running water (Figure 1). The three water springs of the town located in a sloping area are totally covered with Eucalyptus and in the light of this, one of them has been totally dried, while the remaining shows a 80% decrease in the flow of water. However, the water spring situated in Shandala mountain having no Eucalyptus tree in the surrounding remained stable.

The comparison of these springs shows that the dryness of water springs along with the decline in the amount of annual precipitation is also due to the plantation of Eucalyptus trees in the area. The mountainous region of Pakistan, especially the northern territory is the source of the water resources. The melting of glaciers, the flow of water springs and

share of precipitation are served as a source of running water. Due to the high rate of evapotranspiration by eucalyptus from rock reservoirs, the springs have become dry and the area has lost the share of spring water in the river. It shows that the Eucalyptus tree is more dangerous to the water table, groundwater, rock reservoirs, and springs. Therefore, serious consideration must be given to the fact that the plantation of Eucalyptus is stopped on the mountain slopes as well as in the lowlands of Pakistan.



Fig. 5 Photograph of Chinodog (left side) and Tehran water spring (right side).

Willingness to Plant Eucalyptus

Above 20 thousand trees were planted on the hill slopes, graveyard and piedmont plains of the village from 1994 to 1995. These forests comprised of 80% Eucalyptus, 10% *Bakyane* (*Melia Azedarach*) and 10% Acacia and Pine trees. The majority of the Eucalyptus trees planted at a normal distance of about 1.2 to 1.83 square meters (4 to 6 square feet) over hills and 1.52 to 3.05 square meters (five to 10 square feet) in the piedmont plains. Eighty percent of the people surveyed are not agreed to plant Eucalyptus forests on the hills, although 15 percent of the occupants were willing for the plantation of the Eucalyptus trees and 5 percent have did not show any reaction in this regard.

Reasons for not Planting Eucalyptus Trees

The essential aim behind the plantation of Eucalyptus is to save the hill slopes from intensive soil erosion, while the landlords of the area provided land for the purpose to keep the mountains in their own hands. Against the involvement of landlords, the common inhabitants resisted not only the plantation of Eucalyptus but also of the other trees to reduce the hold of the landlords in the area. Another reason for the unwillingness is the high rate of evapotranspiration of groundwater into the atmosphere. The tree has also poor market demand, low domestic use and having dispersed shade as well. Moreover, the majority of the locals exposed their willingness to plant Deodar (*Cedrus Deodara*), Shisham (*Dalbergia Sissoo*), Bakyan (*Melia Azedarach*) and Pine (*Pinus Sabiniana*)

trees, which are suitable to the weather of the entire area and less affecting the hydrological cycle.

Impact on Agricultural Production

Prior to 1995, the individuals of the valley cultivated different crops having harvests of above 100 tons per acre on the Ghazibaba Serai (cultivated land), water springs and rain-fed territories. Because of a decrease in the water table and a decline in the flow of water springs, the area totally becomes dry because of which the yield of Rabi and Kharif harvests has diminished. Resultantly, the agriculture production of the village decreased to more than 1500 tons throughout Rabi and Kharif seasons.

Conclusion

The raising of Eucalyptus as either compact or linear plantation on mountain slopes is not profitable. It has a very poor market demand, low domestic use and evaporates a high ratio of the groundwater into the atmosphere. Due to high rates of evapotranspiration, it also causes dryness of the rock reservoirs, change in the flow of water from the springs and a decline in the water table.

The winter rainfall of the area has decreased at the rate of 5 cm (2 inches) per year from 1995 to 2014. It reveals that the rate of incoming water to rock reservoirs is less than the water evaporated by eucalyptus. This imbalance in the incoming and outgoing water from the mountains has affected the recharging sources of the water table and caused a problem of water availability in the area.

Eucalyptus is strongly recommended for growing along riverbanks (10 meters away) and waterlogged areas. The tree is generally known as the solar tube well, which evaporates an average of about 50 liters of groundwater per day into the atmosphere and results in the lowering of the water table from 3.05 to 7.6 meters (10 to 25 feet) in marshy lands and 1.52 to 3.05 meters (five to 10 feet) in the drylands.

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