Impacts of Climate Change on Water Availability and Reservoir Based Hydropower

A case study from Kulekhani Hydropower Reservoir, Nepal

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Abstract

The impacts of climate change (CC) are observed in several sectors, and water resource is one of them. This study explored the impacts of CC on water availability and reservoir based hydropower. It determined the impacts of CC in the reservoir water level and major watershed characteristics and has explored the perception of people on CC impacts in the reservoir. The primary data were collectedthrough questionnaire and field survey and secondary data were gathered from different literatures. The analysis of meteorological data generated from meteorological station. temperature and rainfall data, discharge of Kulekhani River, monthly data of reservoir level and annual energy generation revealed increasing pattern of temperature and decreasing seasonal and annual precipitation in the study area. Similarly, because of the increased sedimentation, the water level of the reservoir has been increasing though the precipitation has been observed declining. Consideration could be taken while designing such hydropowers to hold water year-round, resulting minimal power shortage. A clear institutional direction and strategies could make reservoir based hydropower climate resilient and enable sustainable generation of electricity.

Key words: Kulekhani hydro-electric reservoir, climate change impacts, water level

Introduction

In recent years, hydropower generation has got attention as it is a renewable, efficient, and reliable source of energy. Globally, hydropower accounts for close to 17% of the world's total power supply and dominates all renewable electricity by the share of 71% in the year 2016 (WEC, 2016). But, at the same time, hydropower is among the industries most vulnerable to climate change (CC), because water resources are closely linked to CC (Aronica and Bonaccorso, 2013). It is believed that the effects of CC on water availability are expected to affect hydropower generation (Bernstein et. al., 2007).

Hydropower comes from the damming of rivers and utilizing the potential energy stored in the water (Upadhaya, 2008). In Nepal approximately 83,000 MW of hydroelectric power potential is available, and about 280 MW of that have been developed. The electricity generation capability of reservoir based hydropower plants depends on the melting of snow and rainfall. In the recent years the installed reservoir based hydropower plants are not generating electricity of their capacity due to decrease in water availability (NEA, 2009).

Four months of monsoon season (June–September) with 80% rainfall and eight almost dry months are the characteristics of the Nepalese rainfall pattern. Due to this fact, river discharge also shows large seasonal fluctuations closely following the annual precipitation cycles hardly meeting the energy demands during dry months (Sharma and Awal, 2013). Therefore, the country is facing serious energy shortage leading to a crisis situation. The reservoir based hydropower plants would serve the gap as they tap the monsoon water in the storage to produce power during dry months or any other energy deficit situations. Any kind of impact on hydropower production would lead to serious disruptions in the energy infrastructure, as hydropower is the major source of electricity in Nepal.

Climate change and its impacts on river hydrology have been a major concern for hydropower development since fluctuations in river discharge can impact the production (Sharma and Awal, 2013). NEA in its twenty-fifth anniversary has declared that the organization would develop new regional storage projects (Dhakal, 2011). The government has decided to expedite the construction of storage-based hydropower projects in an effort to bridge the growing demand-supply gap in the nation's power sector. The projects include the 600 MW Budhi Gandaki and the 127-MW Upper Seti projects, both of which have been delayed several times due to unstable government.
Changes in precipitation and temperature brought by climate change could affect run-off resulting potential impact on water utilization and water resource projects (Shrestha and Aryal, 2011). Hydroelectric plants are highly dependent on predictable runoff patterns; moreover the reservoir based systems such as Kulekhani are sensible to this changing scenario. Therefore, increased climate variability that can affect frequency and intensity of flooding and droughts could also have similar impact on electricity generation (Dhakal, 2011).

As Kulekhani watershed area experiences intense monsoon rainfall events and it is only reservoir based hydropower in Nepal (Fig. 1), any kind of impact on hydropower production would lead to serious disruptions in the energy infrastructure. In order to identify the potential initiatives that the hydropower industry may undertake at the time when the government is in plan to install more reservoir based hydropower, it is important to determine the current state of knowledge of the impacts of CC on hydrological variables.

The Study Area

The study was carried out in the Kulekhani watershed (latitude 27041' 00"N to 27035' 04"N and longitude 85000' 32"E to 85012' 12" E) that lies in the western part of Indrasarowar Rural Municipality of Makawanpur district in the Province No 2, Nepal. Kulekhani Hydropower is the only reservoir type hydropower station in Nepal that represents general national scenario of reservoir type hydropower stations in present context (Dhakal, 2011). The reservoir of the hydropower is filled with water from the Kulekhani watershed, i.e. sub- watershed of the Bagmati Basin with approximately 126 sq. km catchment area. The elevation in the watershed ranges from 1,534 mean above sea level (masl) at the dam site to 2,621 masl at the peak of Simbhanjyang in the southern part of the watershed. Palung and Chitlang rivers are the major tributaries. The climate is subtropical at lower elevation and temperate at higher elevation. The average annual rainfall is 1,239 mm, with almost 80% of rain falling in the rainy season (June–September), which is the time of maximum seasonal flood. The temperature ranges from 20 to 27°C in summer and 10 to 15°C in winter (ICIMOD, 2015).

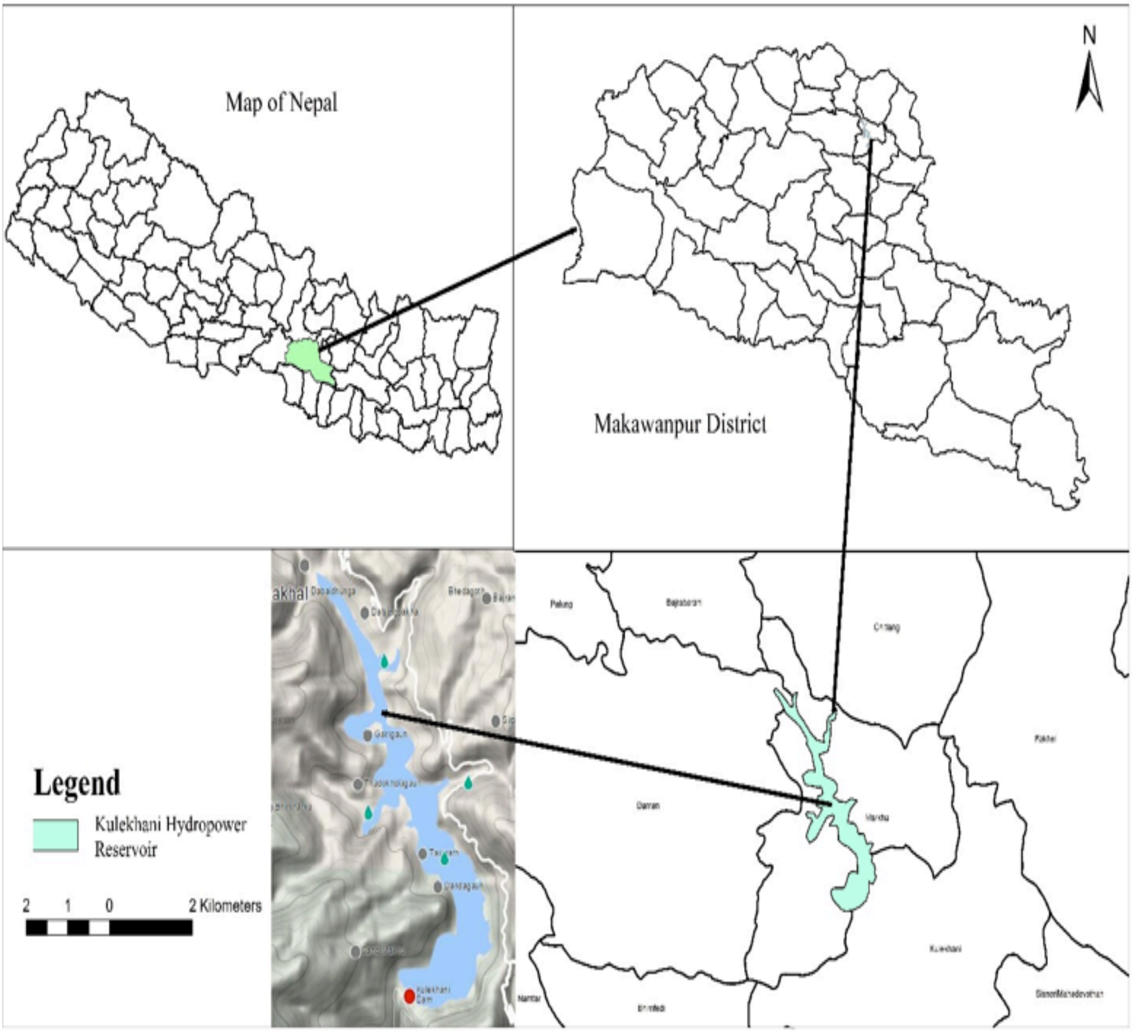


Figure 1: Map of study area

Materials and methods

The impact of CC was assessed in terms of different hydrological variables such as change in temperature, shift in weather pattern, rainfall distribution which have impacted on the intensity of discharge and water accumulation in reservoir (Dhakal, 2011). Primary data were collected through field observation, field survey, key informant interview (n = 40 respondent) and focus group discussions (n = 5 events with 62 participants). Secondary data were collected from published and unpublished literatures. The meteorological data on temperature (1975 to 2005) and rainfall data (1980 to 2010), annual discharge of Kulekhani River (1963 to 1977), reservoir level (1988 to 2013) and electricity generation data (1998 to 2013) were obtained from Department of Hydrology and Meteorology (DHM) and Kulekhani Hydropower Site Office. The obtained data were analyzed using SPSS and presented using summary statistics. Least square curve fitting technique was used to find linear trend in the data. The linear trend between the time series data (y) and time (t) is given in the equation below (Practical Action Nepal, 2010).

$$y = a + bt$$

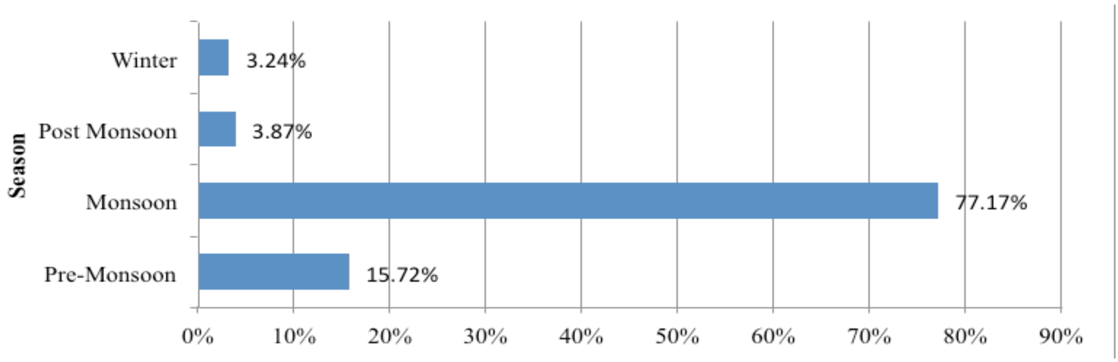
Where, y = temperature or rainfall,
t = time (year),
"a" and "b" are the constants estimated by the principle of least squares

Time series analysis was used to uncover the relationship between three important hydrological variables: discharge, precipitation and temperature. The time series model was developed considering rainfall distribution. Drought trend was analyzed combining the monthly values of precipitation expressed in millimeters (P) and temperatures in centigrade degrees (T), the biologically dry month is defined by the ratio P<2T (Bagnouls and Gaussen, 1953).

Result and Discussion

Rainfall Distribution

The total rainfall over the southern and northern parts of the Kulekhani watershed increases with elevation, whereas in the eastern part rainfall generally decreases with elevation. Makwanpur district receives major part of the annual rainfall in monsoon 81% followed by 4% in post monsoon, 3% in winter and 12% in pre monsoon season (Joshi G.R., 2008), whereas, the monthly data (1981-2010) of Kulekhani watershed analysis indicate that about 77.17% of the rainfall occurs in monsoon (June - September), 15.72% in pre-monsoon (March-May) and 3.87 % percent in winter (December-February) and 3.24% post monsoon season (October-November) (Fig. 2). This result shows that the reservoir level in Kulekhani Hydropower station rises during monsoon, and water accumulated during this time is used throughout the year for generation of electricity. Kulekhani Hydropower was initially designed as peaking power station, so that this hydropower could produce more electricity when the other run-off-river based hydropower operates on limited capacity during dry seasons. But it has been supporting as emergency stand by station and is forced to operate as and when required. This demand based operation system of Kulekhani may be helpful to meet the current demand but chaotic utilization of this valuable resource has raised question on its sustainability. The rainfall at watershed peaks up from June to August and is highest during July.



Average Annual Rainfall

The study by Shrestha et al. (2000) explains that rainfall data of Kulekhani watershed (1972 to 2009) have also changed in amount, intensity and frequency (Fig. 3). As rainfall and electricity generation is positively correlated, decrease in the annual average rainfall will have similar impact on electricity generation. So discharge and water level in the reservoir decline with rainfall which effect the energy generation in hydropower. Being nearest meteorological station from the study area, the Daman station's rainfall data was interpreted.

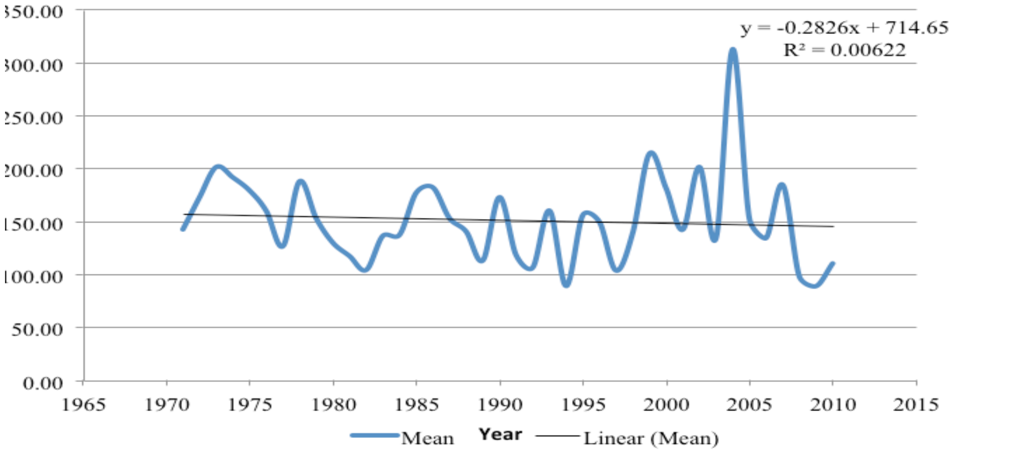


Figure 3: Mean Rainfall distribution at Kulekhani

Seasonal Rainfall Distribution

Pre monsoon

Pre-monsoon average annual rainfall occurs around 90 days from March to May and data show the trend of decrease in rainfall. Annual rainfall as well as the distribution of rainfall throughout the year is decreasing in pre-monsoon in Kulekhani (Fig. 4). This decreasing trend also suggests that Kulekhani receives less rain during pre-monsoon.

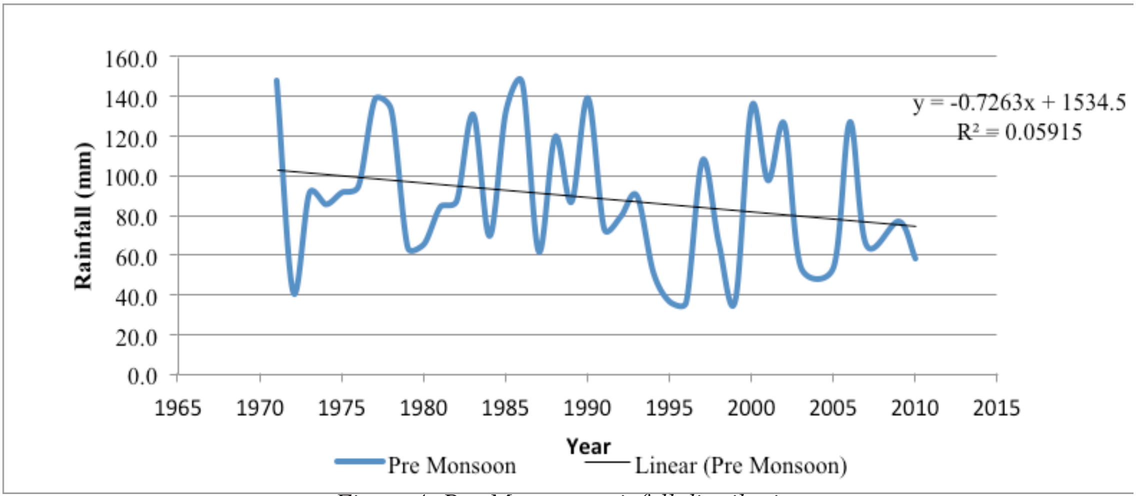


Figure 4: Pre-Monsoon rainfall distribution

Monsoon Rainfall

According to the study carried by NCVST (2009), monsoon rainfall in eastern and central Nepal is projected to increase more than in western Nepal. But, the trend of 30 years (1980-2009) shows that monsoon rainfall in Kulekhani is decreasing, though the decrease is very less significant, at around 1.2 mm per year. Annual report of Practical Action Nepal, 2007, states decrease in the number of annual rainy days during the last four decades. This national prediction is similar to the trend of rainfall days in Kulekhani (Practical Action Nepal, 2007).

The annual average monsoon rainfall and rainy days in Kulekhani are decreasing (Fig.5). This indicates that Kulekhani is getting the same amount of rainfall fewer days. If this trend goes on, it will have negative impact on Kulekhani reservoir. When there is heavy rainfall in short interval, the reservoir cannot replenish as water during monsoon will overflow from dam and there will be less water during dry season. Kulekhani hydropower cannot be operated as peak demand system in such condition. Kulekhani hydropower may have to increase the capacity of reservoir or make smaller check dams at upstream, which can hold water for some duration.

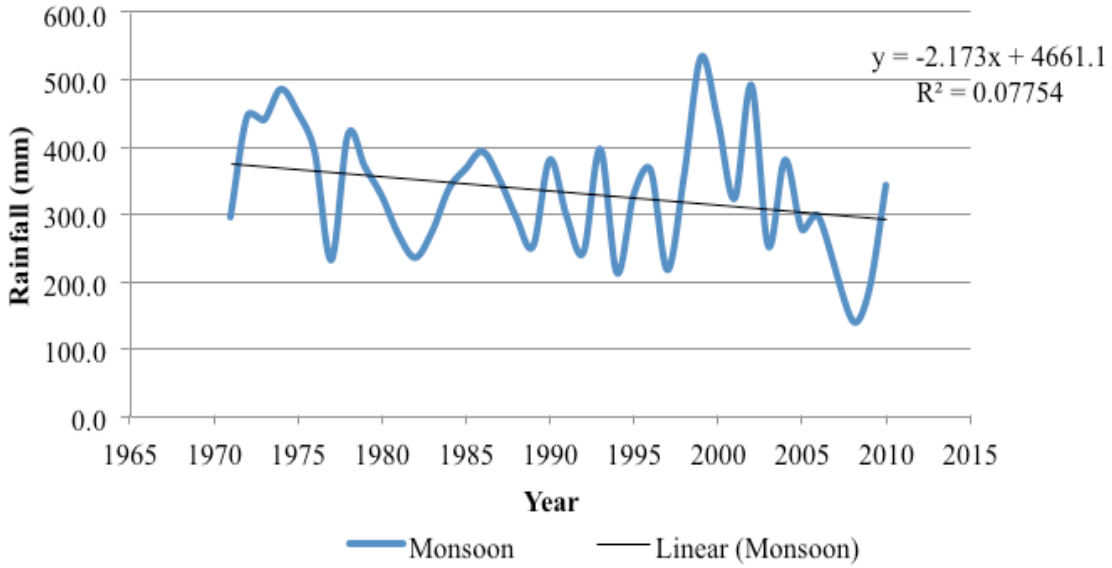


Figure 5: Monsoon Rainfall distribution

Post Monsoon Rainfall

The annual average and total post-monsoon rainfall is decreasing in Kulekhani watershed. Similarly, the non-rainfall days and rainy days receiving less than 10 mm rainfall in Kulekhani are also increasing, which shows that post-monsoon is getting less rainfall for fewer rainy days.

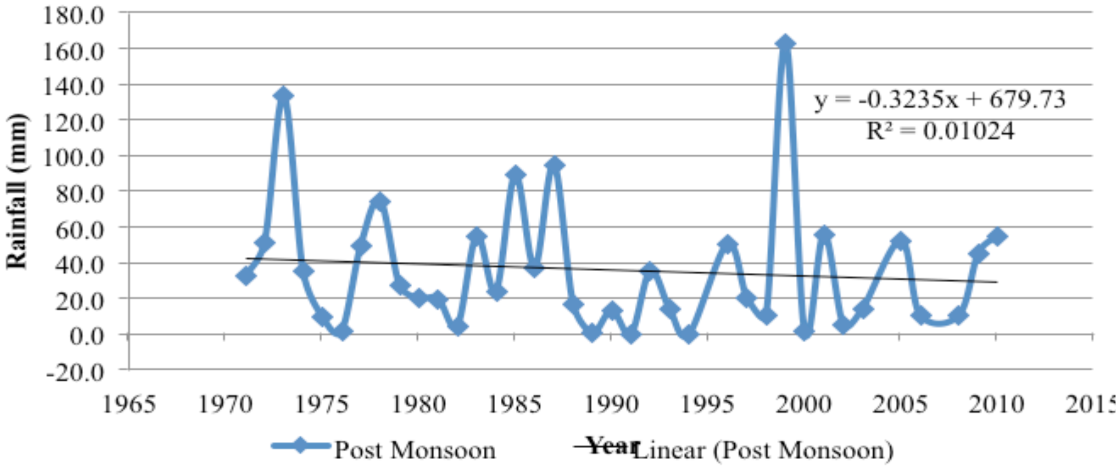


Figure 6: Post-Monsoon Rainfall distribution

The rainfall pattern shows post-monsoon period is getting dryer. It can also be predicted that post-monsoon is also shifting later towards winter. As the reservoir is replenished by the monsoon rainfall earlier, the changes in the rainfall distribution during the post-monsoon will not have much significant impact.

Winter Rainfall

Annual average winter rainfall and the amount of rainfall during winter in comparison to other season's annual average is decreasing in Kulekhani watershed. Winter also gets less rainfall as well as for smaller number of rainy days. No rainfall days and days with less than 10 mm rainfall are increasing as per analyzed data; thus, winter is getting drier.

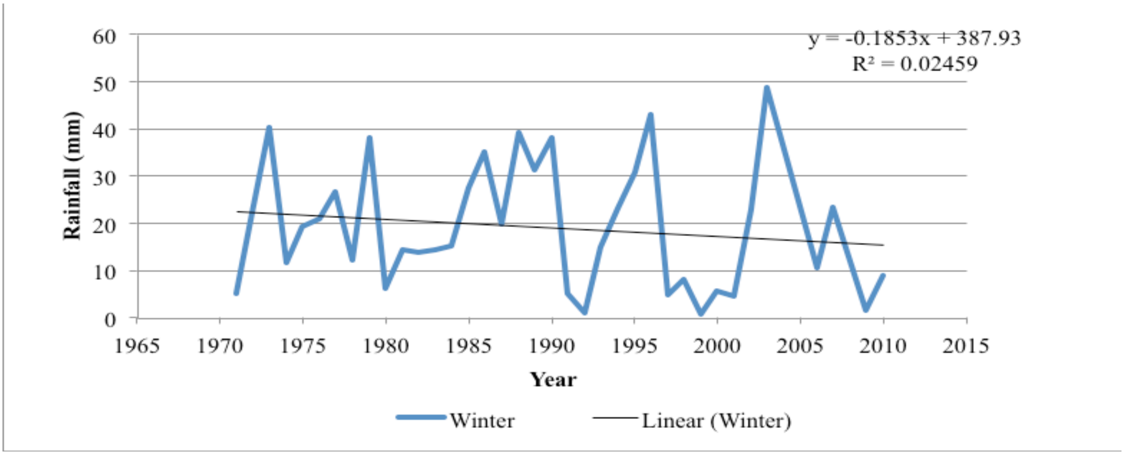


Figure 7: Winter rainfall distribution

Electricity generation is positively correlated with rainfall; less rainfall during winter means negative impact on electricity generation. With regards to decreasing rainfall period and amount, it can be predicted that electricity generation capacity of the hydropower is decreasing, which directly depends on water level in reservoir.

People's Perception on Precipitation

Analysis of catchment area people's perception shows that 50% of the people think that rainfall intensity is increased and 70% of the respondents think there is increase in drought problems (Fig. 8). Similarly 60% believed in the decrement of river water and 70% on the decrement of spring water (Fig. 9). The questionnaire survey in the catchment area reveals that increment of rainfall intensity resulted reduction of river and spring water and increment of drought problems.

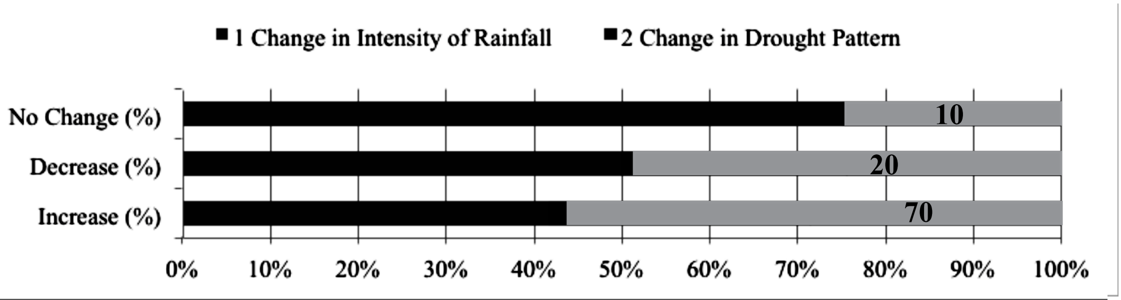


Figure 8: People's Perception on change in intensity of Rainfall

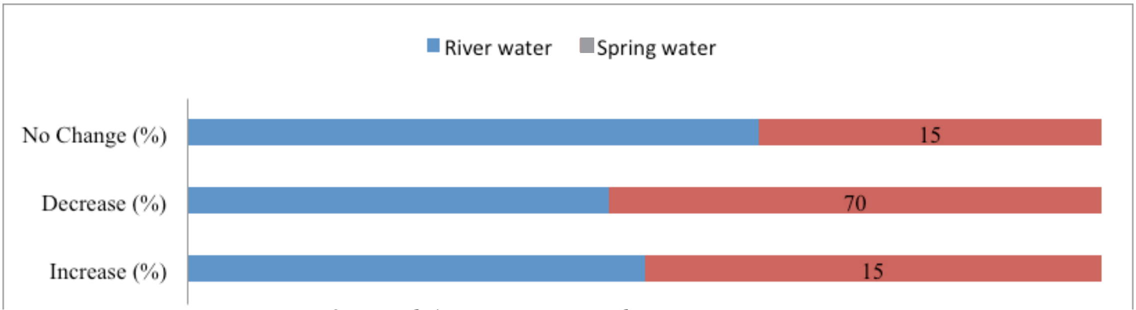


Figure 9: People's Perception on change in water resources

Temperature Analysis

MoE (2010) states that the mean temperature of Nepal is around 15°C, increasing from North to South with the exception of mountain valleys. Practical Action Nepal (2007) found that annual mean temperature in Nepal increased steadily at a linear rate of 0.4 °C per decade from 1975 to 2005. Alike ICIMOD, (2007) stated, the temperature rise in Nepal was within a range of 0.2-0.6 °C per decade between 1951 and 2001 particularly during autumn and winter. The study carried out by Practical Action Nepal in 2009 also showed that the annual mean temperature trend over Nepal ranged from -0.04 to 0.08 °C in central region during the period 1976 - 2005.

The temperature increase in Nepal is high compared to the global average temperature rise of 0.74 °C in the last 100 years (1906 to 2005) and 0.13 °C per decade in the last 50 years (1956 to 2005) (Parry et.al., 2007). Baidya et.al. (2008) found a general increasing trend in the extreme temperature events with a consistent higher magnitude in the mountains than in the plains. Practical Action Nepal, (2007) reported 13.2°C as an average mean annual temperature (1973 - 2005) of Daman. Temperature was above the usual after 1993. It also shows the rising trend of air temperature by 0.06°C , which depict some warming up from last 30 years, which falls within the range of annual mean temperature trend of central region (0.04 - 0.08), hills and mountain (0.038-0.128° C). These observations are showing consistency with the temperature analysis. The observed increasing trend (0.06° C) is also similar to the Nepal's annual mean temperature trend mentioned in Initial National Communication report submitted to UNFCCC by Nepal.

Mean Annual Temperature Trend

The temperature statistics for the station Daman (st905) near Kulekhani watershed as shown in Fig. 10 indicate that the mean annual temperature in increasing gradually.

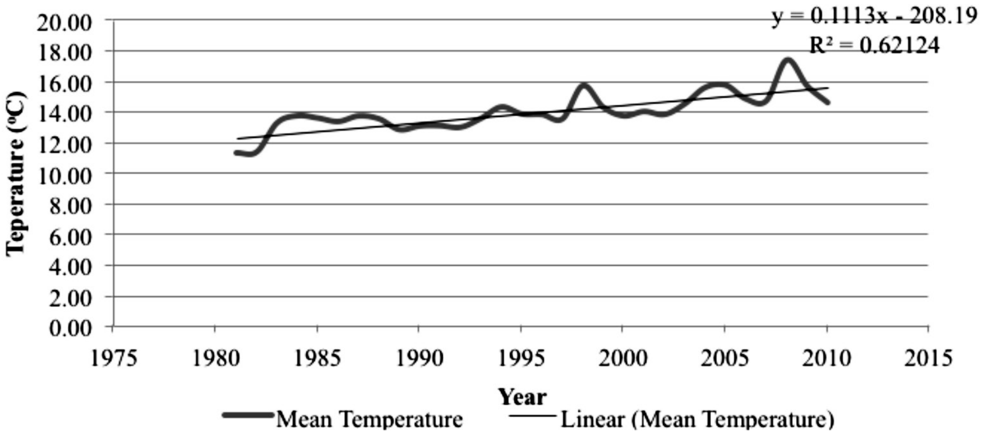


Figure 10: Mean Annual temperature trend

Mean Annual Maximum and Minimum Temperature Trend

The mean maximum temperature in Nepal increased by 0.060° C per year between 1977 and 2000 (ICIMOD, 2009). The result shows that the mean maximum temperature and mean minimum temperature is continuously increasing from 1981 to 2010. The maximum mean temperature was recorded highest (21.30° C) in 1998 and lowest (17.5°C) in 1989. Similarly, the minimum mean temperature was recorded highest (13.49° C) in 2008 and lowest (4.61°C) in 1982.

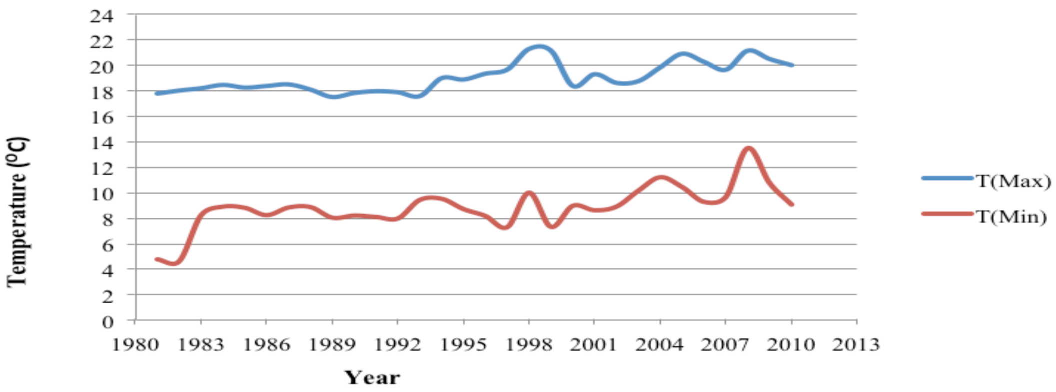


Figure 11: Mean maximum and minimum yearly temperature

People's Perception on Temperature

On the questionnaire survey analysis of people's perception of the catchment area on temperature showed agreement of 98% of the respondents on change in temperature with increasing patterns (Fig. 12).

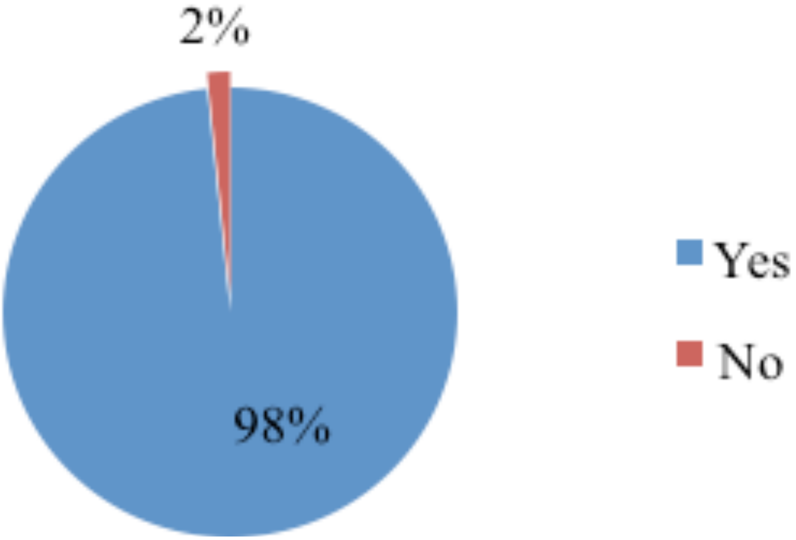


Figure12:People's perception on the change in temperature

Drought Trend

By combining the monthly values of precipitation expressed in millimeters (P) and temperatures in centigrade degrees (T), the biologically dry month is defined by the ratio P<2T (Bagnouls and Gaussen, 1953). An analysis of 30 years monthly data of precipitation and temperature shows that November and December are driest months since these months' temperature when assumed double the value exceeds the total precipitation received in these months. Of these two months, November is the driest month. The overall scenarios of precipitation and temperature are given in Table 3.

Table1: Monthly mean precipitation and mean temperature of 30 years

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation	15.33	26.79	38.81	71.91	171.16	264.13	467.88	361.28	222.00	61.69	6.46	14.50
Temperature	7.14	8.21	11.79	14.55	16.31	17.58	18.09	18.21	17.55	15.39	11.35	8.20
TA	14.29	16.42	23.59	29.10	32.63	35.16	36.17	36.41	35.10	30.79	22.71	16.40
	P>2T	P>2T	P>2T	P>2T	P>2T	P>2T	P>2T	P>2T	P>2T	P>2T	P<2T	P<2T
	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	D	D

ND-Not Drought, D- Drought, TA- Theory Applied

Discharge of Kulekhani River

The Kulekhani River (river), also known as Palung River, is the main stream of the watershed. The discharge data were taken from Kulekhani site office that was established by the Department of Hydrology and Meteorology in 1962. But, the station was closed in 1978 during the operation phase of Kulekhani dam. The summary of the mean monthly and annual discharge (m^3/s) for Kulekhani River for year 1963 to 1977 is given in the table.

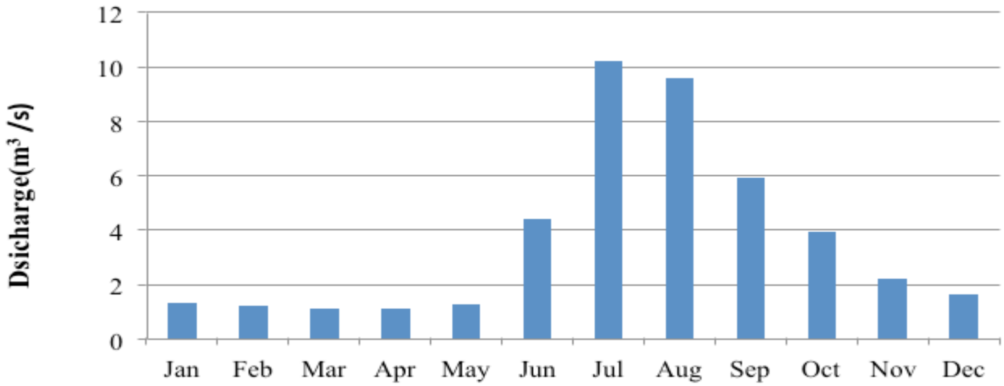


Figure 13: Mean monthly discharge (m3 /s) of Kulekhani River

Table2: Mean monthly and annual discharge for Kulekhani River

Mean Monthly and Annual Discharge (m3/s) for Kulekhani River

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1963	1.17	1.06	1.13	1.15	1.65	1.13	6.61	7.64	5.75	3.52	2.16	1.75	35
1964	1.47	1.39	1.17	0.91	1.26	2.21	7.24	12.1	15.2	4.49	1.84	1.5	51
1965	1.32	1.3	1.22	1.76	1.47	3.73	17.2	18.4	5.71	3.16	2.85	1.77	60
1966	1.6	1.47	1.17	0.74	1.12	1.14	10.4	20.8	10.3	3.33	2.2	1.73	56
1967	1.09	0.93	0.86	1.02	0.65	4.53	11.8	6.92	5.65	3.36	2.32	1.7	41
1968	1.66	1.46	1.63	1.21	1.1	2.52	5.72	6.33	2.62	7.12	2.25	1.47	35
1969	1.18	0.89	0.87	0.92	0.95	0.88	3.1	6.89	4.18	1.91	1.1	0.83	24
1970	0.82	0.72	0.64	0.6	0.64	3.42	21.5	8.96	5.26	3.3	2.19	1.46	50
1971	1.15	1.11	1.1	1.98	2.13	21.6	5.17	7.68	4.27	3.82	2.22	1.86	54
1972	1.72	1.78	1.62	1.41	1.38	1.45	26.3	5.6	7.92	3.51	1.15	1.58	55
1973	1.38	1.24	1.58	0.96	1.29	10.2	7.34	7.95	9.51	9.51	5.14	2.74	59
1974	1.59	1.33	1.14	1.16	1.26	1.66	7.15	15.6	3.5	3.5	1.96	1.5	41
1975	1.28	1.18	0.88	0.76	1.07	2.11	14.8	11	4.7	4.7	2.35	1.67	47
1976	1.46	1.25	1.02	1.09	1.44	7.96	6.04	4.75	2.3	2.3	1.75	1.45	33
1977	1.28	1.22	1.07	1.39	1.64	1.57	3.16	3.47	1.8	1.8	1.6	1.63	22
mean	1.345	1.222	1.140	1.137	1.270	4.407	10.235	9.606	5.911	3.955	2.205	1.643	3.67

Source: Department of Hydrology and Meteorology (1963 to 1977)

Kulekhani River is the main river that feeds the reservoir; therefore any changes in discharge rate of it will affect water level in the reservoir and finally electricity generation. Considering monthly discharge data from 1963 to 1977, discharge level in Kulekhani River increases from June to August, during the rainy season. The water accumulated during this time can be used to generate electricity throughout the whole year.

The melting of glaciers and snow in the mountains has affected the major river discharge in Nepal during dry season. Parry et.al. (2007) has predicted that the annual river discharge increases until around 2030 and then decreases because of rapid melting of snow and glacier in the beginning, and then significant decrease of available snow and glacier mass thereafter. Likewise Practical Action Nepal (2009) has suggested further studies for individual glaciers and rivers, since the change in temperature and precipitation vary from one region to another the river discharge will also be affected accordingly. The same study has further suggested the need of assessment of the impacts of CC on discharge of major river systems to understand the specific changes as the varied regional CC will have varied impacts on river discharges over the regions and over the seasons. The discharge data of Kulekhani river remained unknown after the station was closed down in 1978 during the operation phase of Kulekhani dam,.This study has limitation to show latest temporal variation on discharge.

The analysis of the discharge of Kulekhani River of 11 years (1963 to 1977) shows that the discharge level is in decreasing trend. As the amount of rainfall and its intensity is decreasing, this could be one of the main reasons affecting the discharge level.

Water Level of Kulekhani Reservoir

Data analysis from 2003 to 2012 shows that the water in the reservoir rises from July, peaks at September and starts decreasing from October to June (Fig. 14). When discharge in the river falls, the level of water also decreases, because of high demand of electricity in nation grid or Central Nepal Power System (CNPS).

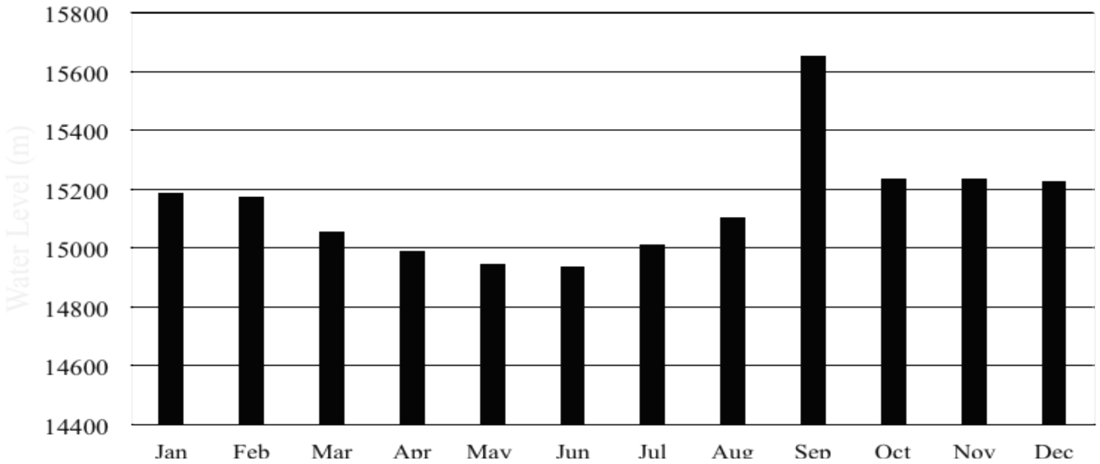


Figure 14: Monthly water level in Reservoir

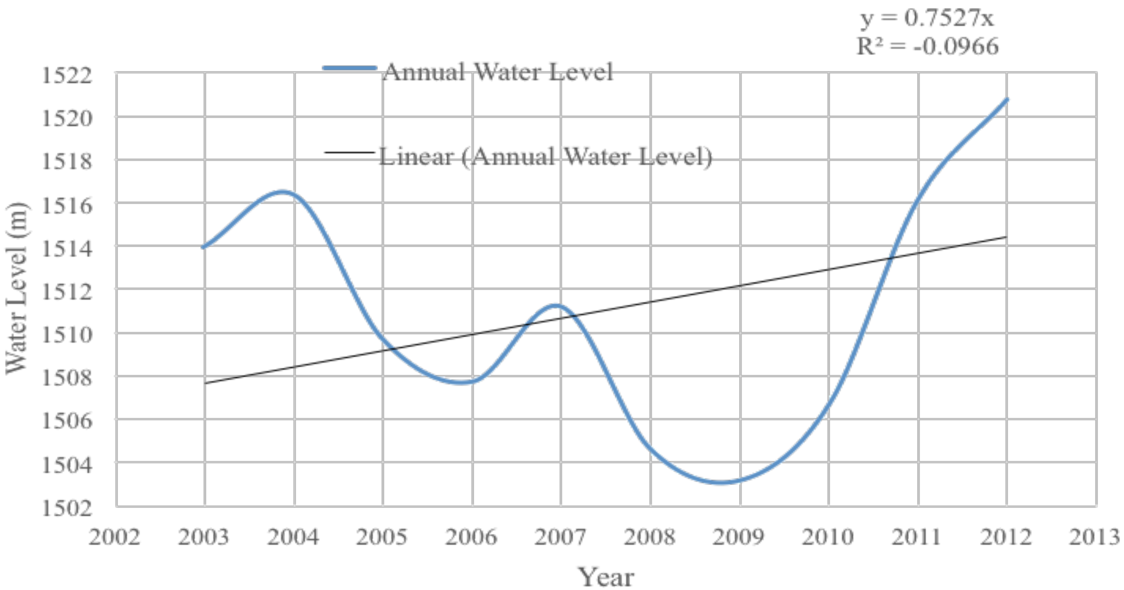


Figure 15: Annual water level in Kulekhani reservoir

The earlier studies indicate that sedimentation in the reservoir as a serious threat on the life span of Kulekhani Reservoir and demands urgent environmental solution. The past record of about 10 years demonstrates that the amount of water in the reservoir is decreasing (Dhakal, 2011). Decrease in water level results from: decrease in total amount of rainfall in the watershed, decrease in discharge level of Kulekhani River, sedimentation, high demand of electricity. Continuity of the same trend will have similar negative impacts on electricity generation in long run.

Electricity Generation

Monthly Electricity Generation Energy generation data analysis from 2003 to 2012 shows that from March the amount of electricity generation decreases till June and increases slowly when there is high discharge in the river from July. During the dry seasons, the Central Nepal Power System (CNPS) is fed mostly with the energy generated from the Kulekhani Hydropower Stations.

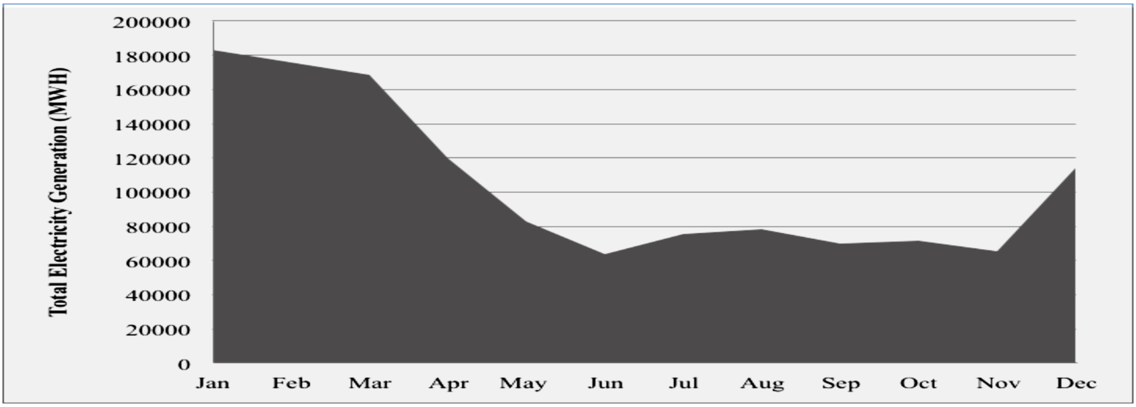


Figure 16: Monthly discharge of Energy generation (MWH)

4.6.2 Annual Electricity Generation

As Kulekhani Hydropower Project is demand-based hydropower, it is very difficult to make any assumption or define the trend on the basis of its past records. However, decreasing discharge rate and amount of water will probably decrease the generation of hydroelectricity in Kulekhani. During the year 1993 A.D. the amount of energy generation was very low, it may be because of damage occurred due to the heavy rainfall, which was recorded as one of the devastating disaster in Nepal's history. According to the officials at Kulekhani dam, the damage could be minimized by the use of efficient early warning system installed at the project site, even though they were very less efficient. Likewise, in the year 1999 there was highest amount of annual rainfall ever recorded (about 2400 mm) in Kulekhani watershed area. This may be the reason that energy generation was highest in this year.

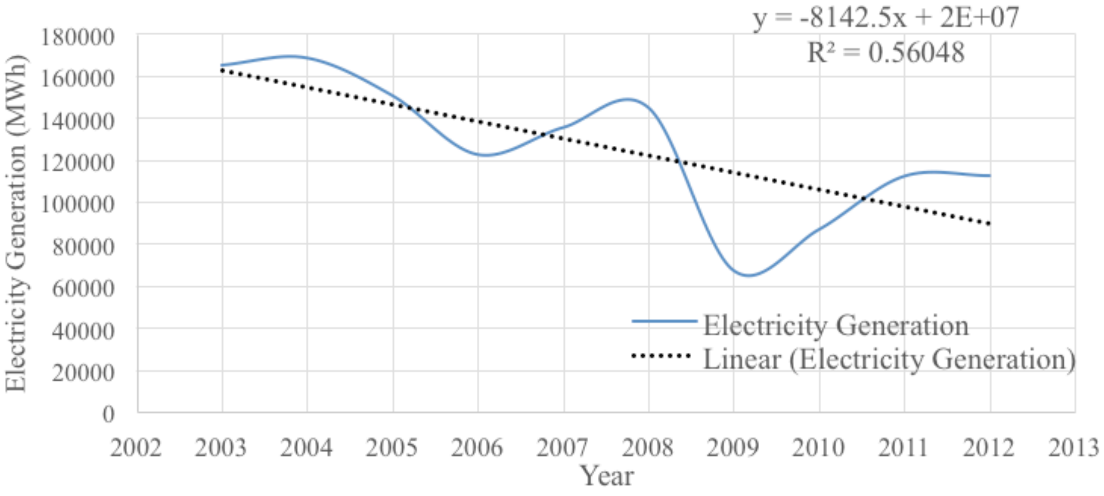


Figure 17: Total electricity generation (MWH) from Kulekhani-I

Sedimentation Status

Winrock International (2004) states that the erosion processes in the Kulekhani watershed transport an enormous amount of sediment to the reservoir. Sediment deposited in the reservoir reduces the life of the reservoir. A monitoring survey conducted by the Department of Soil Conservation and Watershed Management (March 1993) concluded that a total of 2.2 million cubic meters sediment has been deposited in the reservoir in 10 to 11 years.

The same study by Winrock International further states that sedimentation measurement done in the reservoir shows that excessive sediment was deposited in the years 1993 to 1995 and heavy rainfall is one of the factors to accelerate the process. Fig. 18 illustrates the sedimentation status of Kulekhani reservoir from the report of Kulekhani Reservoir Sedimentation Study conducted by NEA in 2011.

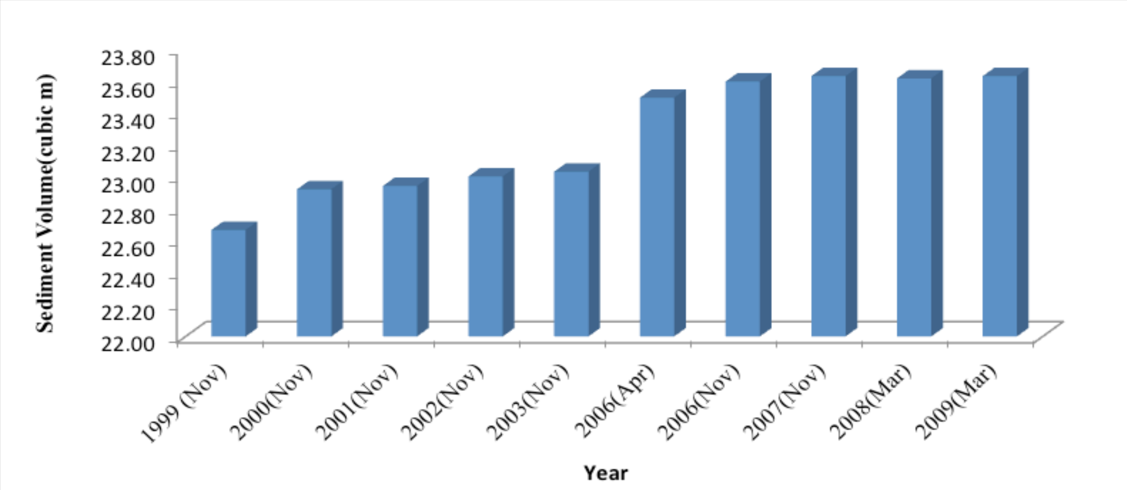


Figure 18: Total sediment volume status of Kulekhani-I in cubic meter

Land Use

Forest occupies about 44% of the entire watershed and the sloping agricultural land is about 34%. The remaining 22% of watershed consists of grazing lands, rock fields, landslides, reservoirs and others (DOSC). After the establishment of Kulekhani Hydro-Electric Project, forest protection activities, and total cover of the forest also has increased whereas soil erosion and landslides problem are decreasing in the catchment area. These changes occurring in the Kulekhani watershed area could affect the discharge of the feeder streams, on the water level of the reservoir and the electricity production of overall country. Table 3 based on the social survey in the settlement of the catchment area shows the effect on the water level of the reservoir.

Table 3: Status of Forest and Soil condition of the catchment area

	Community responses		
	Increase	Decrease	No change
Status of landslides	20	70	10
Status of soil erosion	15	75	10
Status of forest protection activities	60	15	25
Plantation in private land	50	15	35

In the questionnaire survey, 70% of the respondents agreed on the decrement of the landslides problems and 75% believed in the decrement of soil erosion in the catchment area. Similarly 60% people said that forest protection activity has been increased in the area and in the same line 50% agreed on the fact that plantation of trees on the private land has been increased.

Conclusion

Nepal Climate Vulnerability Study (2009) has projected that more extremely high rainfall events occur during monsoon and decrease slightly in the winter. This implies that the watershed will have less rechargeable rainfall and higher rates of sediment production. This signifies higher costs of construction and maintenance of reservoir-based hydro-electricity plant. The past record of 30 years shows that the mean annual temperature as well as temperature minimum and maximum is continuously increasing. Similarly the past 30 years precipitation data analysis shows annual amount of rainfall is also decreasing. The seasonal analysis also shows decline in pre-monsoon, monsoon, post-monsoon and winter precipitation, which has ultimate effect on the water storage in the reservoir. The study of sedimentation status of the Kulekhani reservoir from different reports has shown that the sedimentation has been gradually increasing in the reservoir. This is the main reason behind increasing trend of water level of the reservoir. Kulekhani River is the main feeder stream of Kulekhani reservoir.The annual discharge data analysis of Kulekhani River from 1963 to 1977 shows that the discharge of the river is gradually decreasing which directly affects the water level of the reservoir. The analysis of energy generation data for last 15 years shows that annual production of electricity of the Kulekhani hydro-power project is declining due to increment of annual temperature, decline in annual and seasonal rainfall, decline in discharge of Kulekhani River and increment of the sedimentation status of the reservoir.

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