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Mainstreaming Climate Change Risk Management in Development

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Department of Local Development and Agricultural Roads, Kathmandu District

(DoLIDAR)

VULNERABILITY ASSESSMENT REPORT

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Prepared for	Ministry of Science, Technology and Environment, Government of Nepal Environment Natural Resources and Agriculture Department, South Asia Department, Asian Development Bank
Version	A

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1.1 Briefing on Sector in Kathmandu District

1.1.1 Rural Transport Network in Kathmandu District

Kathmandu District covers an area of 395 km^2 and is the most densely populated district of Nepal with a population of 1,740,977 in 2011. It is located in the valley and hills of Bagmati Zone, Central Development Region. The district consists of 57 VDC, 1 metropolitan city and one municipality.

The district's headquarters is Kathmandu Metropolitan City (KMC), also the capital of Nepal. KMC occupies 2592.7 hectares, or 48.88% of the total area of the district. The road area also occupies a significant land area (386.52 hectare). Being a capital city, KMC is also the major economic as well as education centre of the country.

In total 276 rural roads (village and core network) with a total length of 828.3 kilometres are completed or being upgraded in the district. Out of the total, 88.5 km is black topped, 627.8 km is gravel and 112 km is earthen. All the infrastructure works including rural roads of the district are being managed be District Technical Office (DTO).

1.1.2 District Technical Office

District Technical Office (DTO) of Kathmandu is responsible for planning, implementation and maintenance of all types of rural roads in the district. There are 35 nos. of staff currently working in the DTO with 1 DTO Chief (SDE), 8 Engineers, 9 Sub-engineers, 1 Section officer, 1 Account Officer and other support staff.

Kathmandu DTO has employed PARD (P) Ltd., a private local consulting firm to prepare district transport master plan (DTMP). The DTMP is in a draft form.

1.2 Criteria for Identifying Priority Assets/Systems for the Vulnerability Assessment

In the road sectors (both DoR and DoLIDAR) it is considered that the primary assets or systems are the road links joining important centres of population or production; for example a feeder road joining a national highway to a district centre is considered as a system. The priority assets in that system are the parts or sections of the link which, if affected by an extreme weather event, would cause serious disruption to the movement of traffic on the link.

The key criteria for prioritisation include:

- Infrastructure of national strategic importance
- Infrastructure of district strategic importance
- Infrastructure that has been impacted by past extreme events
- Infrastructure located in areas prone to past extreme events

In each district the consultant in consultation with the division chief prepared final lists of the priority structures of the district. The list was prepared following the criteria provided in District Office Report.

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1.3 Description of Priority System

In total two assets were covered in baseline report. Among them, Kageswori Chakrapth (Ring Road) is selected for vulnerability assessment and adaptation planning due to its importance and uniqueness.

The road starts from Danchhi VDC in Jorpati – Sankhu road and traverses through Bhadrabas, Alapot, Gagalphedi and Indrayani VDCs and finally joins Jorpati – Sankhu road. The total length of this road is 8.7 km, out of which 2.5 km is black topped and the remaining 6.2 km is gravelled. This road serves about 25,000 populations. The major section of the road still requires additional construction of retaining and cross drainage structures as well as grade correction

Construction of this road was initiated by Kathmandu DDC in FY 2001/02. After few years, the retaining walls and a section of the road collapsed in FY 2009/10 due to poor water management. After the collapse of road section, Kathmandu DDC decided to reconstruct it by carrying out detail engineering works.

The construction works of the road started on June 2011 and completed on March 2012. The total cost of the whole works including improvement works at Km 7+148 was 5.7 million rupees. The works comprised the followings:

- Construction of gabion walls
- Filling of road embankment
- Providing geotextile.
- Bio-engineering works
- Surface water management.

The unique aspect of the design of this road is the provision of geotextile and bio-engineering on rural roads which is rare in Nepal.

2. VULNERABILITY ASSESSMENT METHOD

2.1 Summary of method/process

The VA of the assets is carried out following the procedure as outlined below:

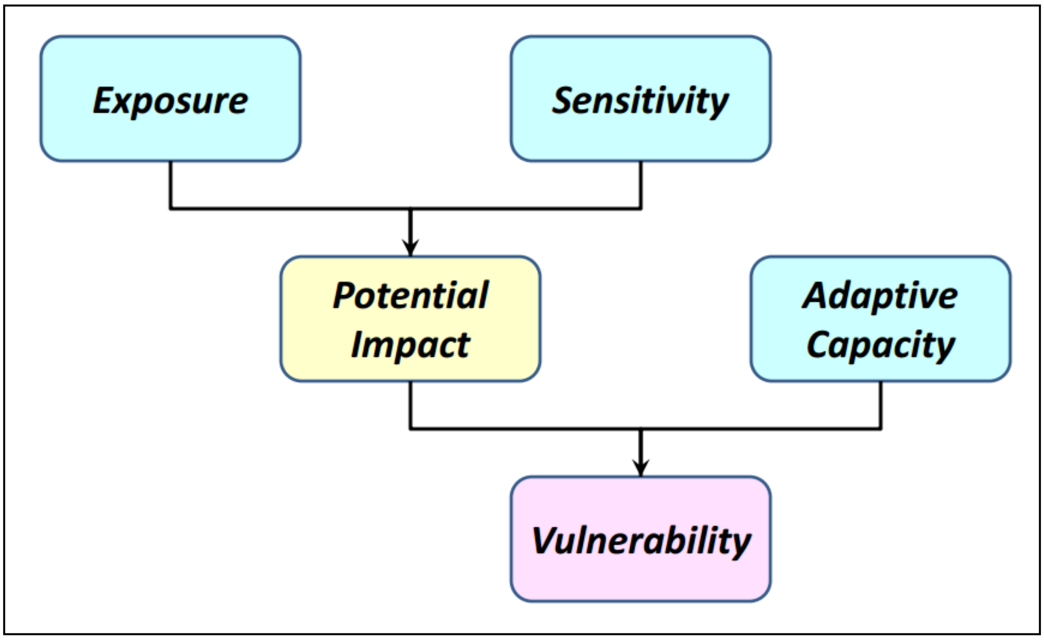

Fig 1: VA Process

There are two components in this phase

1. Assessing the impact of a climate threat on an asset and system; and
2. Defining the level of vulnerability of the asset and system to the projected threats.

2.1.1 Impact Assessment

The potential impact (or level of risk) is a function of the level of **exposure** to climate change induced threats and the **sensitivity** of the target asset or system to that exposure.

Exposure: exposure is the degree of climate stress on a particular asset. It is influenced by long-term changes in climate conditions and by changes in climate variability, including the magnitude and frequency of extreme events.

The following criteria influence exposure:

- Duration (e.g. hours or days of flooding)
- Location (e.g. distance from flood)
- Intensity (e.g. strength of rainfall, speed of flow)
- Magnitude (e.g. volume, flow or size of event)

Sensitivity: Sensitivity is the degree to which a system will be affected by, or be responsive to, climate change exposure.

The following variables affect infrastructure sensitivity:

i. Construction quality
ii. Levels of maintenance
iii. Protective system (e.g. river training wall to protect asset)
iv. Design (including safety margins)

A key tool in the process is the use of the **Climate Change Impacts Matrix** (Fig.2). The matrix is completed using descriptors for exposure and sensitivity, for example, 'very low' to 'very high'. If the exposure of a bridge to the threat of high flash floods is **High**(due to catchment area and topography) and its sensitivity to scour is **Very High** (due to soil type and foundation design) then the Matrix tells us that the **Impact** of the threat is **Very High**.

		Exposure of system to climate threat				
Sensitivity of system to climate threat		*Very Low*	*Low*	*Medium*	*High*	*Very High*
	Very High	*Medium*	*Medium*	*High*	*Very High*	*Very High*
	High	*Low*	*Medium*	*Medium*	*High*	*Very High*
	Medium	*Low*	*Medium*	*Medium*	*High*	*Very High*
	Low	*Low*	*Low*	*Medium*	*Medium*	*High*
	Very Low	*Very Low*	*Low*	*Low*	*Medium*	*High*

Fig.2: Impact Assessment Matrix

2.1.2 Vulnerability Assessment (VA)

A vulnerable system or asset is one that is sensitive to changes and extremes in climate and hydrology and one for which the ability to adapt is constrained. The vulnerability of an asset is therefore a function of the potential impact of changes in climate and the ability **(Adaptive Capacity)** of the responsible authority to respond to any possible impact.

The following variables affect the **adaptive capacity** of the responsible institution:

i. Institutional Strengths/Weaknesses
ii. Financial Resources
iii. Technical Capacity
iv. Ability to respond effectively to extreme events in the District

The Vulnerability of an asset is determined by applying the Impact value given by the Impacts matrix and the assessed value of adaptive capacity to the **Vulnerability Assessment Matrix** (Fig. 3).

This value of **Vulnerability** obtained (from Very High to Very Low) is then carried forward to the Adaptation Planning phase of the Climate Change Risk Management methodology.

		Impact				
		Very Low *Inconvenience (days)*	*Low* *Short disruption to system function (weeks)*	*Medium* *Medium term disruption to system function (months)*	*High* *Long term damage to system property or function (years)*	*Very High* *Loss of life, livelihood or system integrity*
Adaptive Capacity	*Very Low* *Very limited institutional capacity and no access to technical or financial resources*	*Medium*	*Medium*	*High*	*Very High*	*Very High*
	Low *Limited institutional capacity and limited access to technical and financial resources*	*Low*	*Medium*	*Medium*	*High*	*Very High*
	Medium *Growing institutional capacity and access to technical or financial resources*	*Low*	*Medium*	*Medium*	*High*	*Very High*
	High *Sound institutional capacity and good access to technical and financial resources*	*Low*	*Low*	*Medium*	*Medium*	*High*
	Very High *Exceptional institutional capacity and abundant access to technical and financial resources*	*Very Low*	*Low*	*Low*	*Medium*	*High*

Fig 3: Vulnerability Assessment Matrix

1.4 Interpretation of the Climate Vulnerability Assessment Methodology Criteria for the Roads Sector

In the highways sectors there are two major elements which make up a road link:

1) Road Pavement & Side Drainage
2) Cross drainage structures

It is necessary to consider for both these elements their sensitivity and exposure to the various increased threats due to climate change.

2.2.1 Sensitivity

The following tables outline the sensitivity of the two road elements to various climate threats.

Table 1. Road pavement and side drains sensitivity to climate threats

CLIMATE THREAT	SENSITIVITY	IMPACT
Increased rainfall Increased intensity of rainfall	Depends on condition of existing pavement – a pavement in poor condition will have a High sensitivity	Damage to surface of pavement
Increased rainfall Increased intensity of rainfall	Side drains which are in good condition and well maintained will have a low sensitivity	Damage to side drains
Increased rainfall increases instability of hillside Increased intensity of rainfall increases instability of slope High flow in river scours base of hillside & causes landslide	A road across an hillside prone to landslides will have a Very High sensitivity A road above a river which is eroding the toe of the hillside will have a Very High Sensitivity	Landslide destroys road & side drains
Increased rainfall causes high monsoon flood Intense rainfall causes flash flood	A road constructed next to a river will have a Very High sensitivity	Road running along river valley damaged by adjacent river

Table 2. Cross road drainage sensitivity to climate threats

CLIMATE THREAT	SENSITIVITY	IMPACT
Increased rainfall causes riverine flooding	A road with adequate cross drainage structures for today's floods will have an increasing sensitivity as climate change takes effect	Road on embankment crossing flood plain washed out
Increased intensity of rainfall causes large flash flood	Design and condition of bridge foundations will cause sensitivity to vary from Medium to Very High	Bridge on river with small catchment area is damaged by flood
Increased intensity of rainfall increases size of flash flood	Design and condition of causeway slab and retaining walls will mean sensitivity will vary from Medium to Very High	Causeway for stream with small catchment area washed out by flood
Increased temperature variation from cold to hot season	The condition and design of the expansion joints & bearings will cause the sensitivity to vary from Low to High	Large Bridge over major river – damage to bearings & expansion joints
Increased rainfall causes high monsoon flood	The condition and design of the bridge piers and abutments will cause the sensitivity to vary from Low to Very High	Settlement or scour at pier or abutment

2.2.2 Exposure

The above tables illustrate examples of the sensitivity of various elements in the highway infrastructure to climate change. It shows that for both roads & bridges the major climate change threats are increased rainfall and intensity of rainfall which result in high monsoon floods, riverine floods and flash floods. For large bridges, very high temperature variations will be a threat to the viability of expansion joints and bearings.

The Climate Change Threat Profile for Kathmandu District show that the flood magnitude will increase in the range of between 16-41 % in 2040 and 40-57 % in 2060 for different return periods.

The table below provides interpretation of exposure for different road and bridge assets to the climate threats identified for Kathmandu district. This general interpretation can be used along with consideration of the relative magnitude of the climate change threat at the target system site to assess the exposure of the assets of the target system.

The highway infrastructure in Kathmandu District will generally, depending also on upstream catchment area and topography, have a High or Very High Exposure to climate change.

Table 3. Interpretation of climate change threats and exposure for road and bridge assets

TYPE OF ASSET	CC THREAT	EFFECT OF THREAT	EXPOSURE
Large bridge on large river	Increase in max. temperature	Increase in expansion of deck – more stress on joints and bearings	Low to Medium
	Increase in wet season flow	Increased velocity of flow increases likelihood of scour to foundations	High to Very High

		Increased height of flood threatens stability of bridge deck and causes erosion of approach roads	Medium to Very High
		Increased sedimentation reducing clearance under bridge	Medium to Very High
Smaller bridge on smaller river	Increasing risk & severity of flash floods during wet season	Increased velocity of flow increases likelihood of scour to foundations	Medium to Very High
		Increased height of flood threatens stability of bridge deck and causes erosion of approach roads	Medium to Very High
Pipe culverts & causeways on roads crossing watershed	On hill roads - increasing risk & severity of flash floods during wet season	Increased velocity of flow threatens to wash out pipe/ causeway & headwalls	High to Very High
	On flood plain roads - increase in wet season flow	Increase volume of flow threatens to wash out pipe/ causeway & headwalls	High to Very High
Hill road crossing watershed on sloping ground	Increasing risk of landslides	Road blocked or totally destroyed	Medium to Very High
Hill road running along valley bottom adjacent to river	Increasing wet season flow	Road eroded by height & high velocity of flow	High to Very High
	Increasing risk & severity of flash floods		
	Increasing risk of landslides	Road destroyed as erosion to toe of hillside causes landslide	
Road crossing flood plain	Increasing wet season flow and water levels	Road overtopped by flood water and pavement/ embankment destroyed	Medium to Very High

2.2.3 Impact

The impact of an extreme weather event on an asset is a function of the Sensitivity and the Exposure and can be found by considering the Climate Change Impacts Matrix given in Fig. 2 and interpolating between the value of Sensitivity and the value of Exposure to give a value for Impact.

The value for Impact obtained by using the Impacts Matrix should be judged from a practical engineering point of view and if considered incorrect then the values used for Exposure and Sensitivity should be revisited. In particular, for road infrastructure, the value for sensitivity is very difficult to determine without carrying out detailed condition surveys for the particular asset under review. If sufficient design detail is unavailable, or the ground conditions difficult to judge, then an expert judgment of Sensitivity needs to be made and clear notes made justifying the decision.

2.2.4 Adaptive Capacity

Evaluating the Adaptive Capacity of DoLIDAR and DDC/DTO is not a simple task. Baseline assessments including consultations and site visits have shown that the DTO Kathmandu which is responsible for rural roads and bridges in the district has the following capacities:

- Sufficient experience in rural road and trail bridge construction;
- Do not have sufficient experience in design of roads and bridges
- Insufficient technical manpower in comparison to the number of projects;
- Inadequate financial resources;
- Inadequate management system; and
- Not very prompt in responding to disasters.

However, the efficiency and technical capability of DTO has increased in the last few years after the involvement of big donors such ADB, WB, DfID etc in the rural transport. Considering the above factors, it is deemed that the adaptive capacity of DoLIDAR/DDC/DTO as **'Medium'.**

Vulnerability Scoring: Based on the impact and adaptive capacity assessments, the vulnerability of the asset against the climate change threats is estimated using the guiding Vulnerability Assessment Matrix provided in Fig.3.

3. VULNERABILITY ASSESSMENT OF THE ASSET

3.1 Asset Description

The following table describes the important detail aspects of the asset

Table 4: Salient Features of the Asset

Name of the Road	**Kageswori Chkrapth (Ring Road); Indrayani-Gagalphedi Section**
Road Category	District Road Core Network (DRCN)
Service Provided by the Road	Provides motorable road service to Bhadrabas, Alapot, Gagalphedi and Indrayani VDCs in the eastern part of Kathmandu District..
Responsible Agency	DDC/DTO, Kathmandu
Location of Asset	Km 7+300
Major Aspects of the Asset	- The road section is blacktopped - Toe walls ar provided at the bottom to retain the slope - Bio-engineering along with geo-textiles are provided for slope protection
Existing Condition of different components	- Road pavement: good - Retaining walls: good - Gabion toe walls: good.

Fig. 4a: Overall view of the road. The road is blacktopped and its condition is good. The gabion walls and bio-engineering works are located at the right side.

Fig. 4b: Road slope seen from the valley side. The condition of the toe wall and bio-engineering works is good. The whole slope is in stable condition

Fig. 4c: Photo of the stabilized slope. Although the newly constructed road section is stable, the adjacent areas have started to slide. The local people covered the area with plastic sheet to protect it from rain water in order to prevent further landslide.

3.2 Climate Change Threat to Infrastructures in Kathmandu District

The climate change threat profiles for Kathmandu District were prepared by the hydrological modelling teams. The threat profile is provided in Annex 3. The effects of climate change to the road and bridge sector as implied by the threat profiles is outlined below.

3.2.1 Threat due to Temperature Increase

As per the threat profiles, the average temperature increase in Kathmandu District by 2060 will be up to 1.85^0.

Adverse effect on the asset due to above temperature rise will be nominal.

3.2.2 Threat due to Precipitation and Flood Increase

The threat profile findings are as follows:

- Increasing number of extreme rainfall events – events that now occur every 5 years are projected to occur every 2 years;
- Increasing wet season flow on the Bagmati River – peak monthly average flow in wet season will increase by up to 68%

The above findings show that there will substantial increase in frequency and magnitude of extreme discharge. Hence following aspects need serious consideration while designing road and bridge structures:

<u>Design life</u>: At present the important bridges are designed for 100 years return period and rural road bridges for 50 years return period. The drainage structures, in general are designed for 10, 20 or 25 years depending upon the importance of the roads. In order to accommodate the increased flood volumes, bridges as well as drainage structures should be designed for higher return periods. For example there may be a need to design important bridges for 200 years return period (instead of 100), rural road bridges for 100 years return period (instead of 50) and drainage structures for 50 years return period (instead of 25) to accommodate the increasing flood volumes.

<u>Invert level of bridges/culverts</u>: Due to increase in discharge, the high flood level (HFL) will increase. This will require increasing the invert level of bridges/culverts.

<u>Foundation depth of bridges/culverts</u>: The increased discharge will cause more scouring requiring more foundation depth.

<u>Size of drainage structures</u>: Sizes of both side drainage and cross drainage structures should be increased to accommodate increased flood volumes.

<u>Road pavement</u>: Roads lying in low land and adjacent to rivers will be highly affected by increased flood. The wetting of subgrade for longer duration will decrease its strength (CBR) requiring thicker road pavement.

<u>Landslides</u>: The events and scale of landslide will be higher with the increase in precipitation.

3.3 Vulnerability Assessment Results

The table below presents the vulnerability assessment for the different components of the asset. The analysis found that the most vulnerable components are he road section and breast wall.

Table 5. Vulnerability assessment for Kageswori Chkrapth (Ring Road); Indrayani-Gagalphedi Section

Climate change threats	Interpretation of threat	Exposure	Sensitivity	Impact Level	Impact Summary	Adaptive capacity	Vulnerability
Component 1: Road pavement							
Increasing intensity and duration of rainfall Increasing number of extreme rainfall events	Increase in intensity and duration of rainfall will weaken the sub grade consequently accelerating the pavement damage	H[1]	L[2]	M	The road would be closed for a considerable time. But the road has very little traffic. Hence the impact of the slope failure will be medium to high for both cases.	M[3]	M
Component 2: Gabion retaining walls							
Increasing intensity and duration of rainfall Increasing number of extreme rainfall events	Increase in pore water pressure and damage to wall.	M[4]	L[5]	M	The road will be closed for short duration. But the road has very little traffic. Hence the impact of the slope failure will be highas per matrix but in actual the impact will medium.	M[3]	M
Component 3: Fill slope and bio-engineering							

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Increase in precipitation Increasing risk of road slips	Increase in accumulation of surface and sub-surface water will damage bio-engineering works and will cause slope failure.	H[6]	L[7]	M		M[3]	M

1. *The exposure is high because the area is located where the rainfall intensity will have significant effect*
2. *The road is blacktopped; probability of penetration of surface water to the subgrade is nominal.*
3. *Refer to section 2.2.4.*
4. *The exposure is medium because the surface water management is satisfactory. It will not be highly affected by rainfall.*
5. *The quality of wall is good. Development of more pore water pressure will be low as the slope is covered with bio-engineering.*
6. *The exposure is high because the area is located in the where the rainfall intensity will have significant effect*
7. *The sensitivity is low because the slope is designed and constructed with the provision of bio-engineering and the quality of bio-engineering works is good;*

1.4 Asset Vulnerability Summary

The table below provides a summary of the vulnerability assessment for different components of the asset.

Table 6. Summary of vulnerability assessment of Kageswori Chakrapth (Ring Road); Indrayani-Gagalphedi Section

THREAT	IMPACT	EXPOSURE	SENSITIVITY	IMPACT	ADAPTIVE CAPACITY	VULN.	COMMENTS
Increasing intensity and frequency of extreme rainfall events	Damage to road pavement	**H**	**L**	**M**	**M**	**M**	The sensitivity is low because the road section is black topped and the surface water management is satisfactory.
Increasing intensity and frequency of extreme rainfall events	Damage to gabion retaining wall.	**H**	**L**	**M**	**M**	**M**	The sensitivity is low because the increase in pore water pressure will be nominal due to bio-engineering. The quality of wall is also good.

Increasing intensity and frequency of extreme rainfall events	Damage to bio-engineering works and failure of slope.	**H**	**L**	**H**	**M**	**H**	The slope is protected by retaining wall and bio-engineering works. The quality of walls and bio-engineering is good.

ANNEX 1

ANNEX 2

SAME AS FOR DOLAKHA DISTRICT

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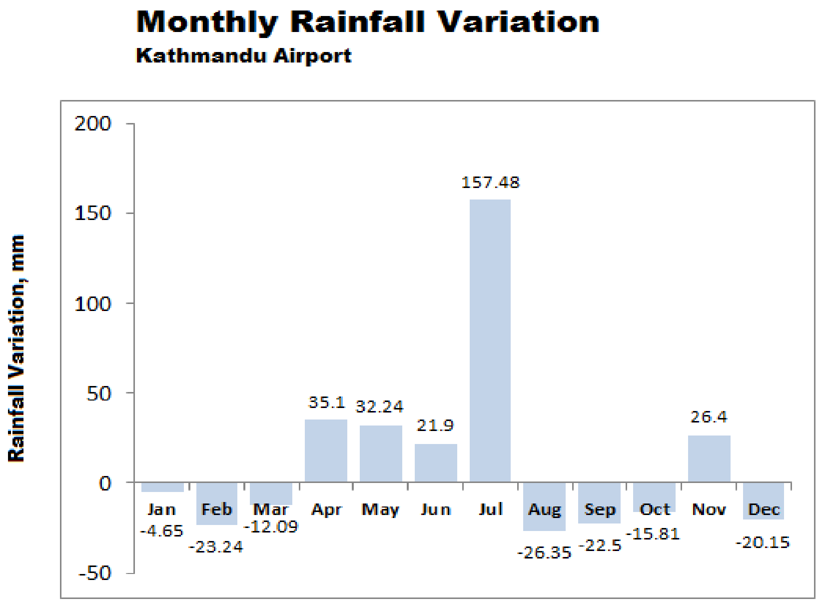
ANNEX 3: KEY CLIMATE CHANGE THREATS

Seasonal changes in rainfall



Kathmandu Airport

Month	Monthly rainfall,mm BL	Projected Rainfall 2060, mm	Change in Rainfall, mm	% change
Jan	34	29	-5	-14
Feb	47	24	-23	-49
Mar	57	45	-12	-21
Apr	72	107	35	49
May	211	243	32	15
Jun	344	366	22	6
Jul	326	484	157	48
Aug	337	311	-26	-8
Sep	305	282	-23	-7
Oct	148	132	-16	-11
Nov	56	83	26	47
Dec	65	45	-20	-31

- Greatest increase end of dry/start of wet season
- Decrease end of wet season/start of dry

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