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IRRIGATION VULNERABILITY ASSESSMENT REPORT

PANCHTHAR DISTRICT

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ACRONYMS

ADB	Asian Development Bank
AF	Adaptation Fund
AP	Adaptation Planning
CAM	Climate Assessment Matrix
CC	Climate Change
cm	Centimetre
^{0}C	Centigrade
CMIASP	Community Managed Irrigated Agriculture Sector Project
DDC	District Development Committee
DoI	Department of Irrigation
GON	Government of Nepal
ILO	International Labour Organization
IWRMP	Irrigated Water Resource Management Project
Km	Kilometre
LPS	Litres per Second
M	Meter
M&E	Monitoring & Evaluation
MIP	Medium Irrigation Project
MoSTE	Ministry of Science, Technology and Environment
NISP	Nepal Irrigation Sector Project
O&M	Operation & Maintenance
RCC	Reinforced Concrete Construction
RR	Random Rubble
TA	Technical Assistance
ToR	Terms of Reference
VA	Vulnerability assessment
VDC	Village District Committee
UNEP	United Nations Environment Programme
WB	World Bank
%	Percentage

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1 PANCHTHAR ASSETS/SYSTEM PRIORITIES

1.1 Panchthar District Irrigation Infrastructure

Panchthar is one of the hilly districts of Eastern Development Region and is located around 200 Km north of East West Highway. Tamor River is the main river of the district. It covers an area of about 139,766 Ha and Phidim is its district headquarters. The district is bounded by Taplejung in north, Sikkim and Darjelling (India) in east, Terathum and Dhankuta in west and Illam and Morang in south. It consists of 41 VDCs.

Panchthar Irrigation Development Division is one of the 26 irrigation development divisions of DoI and covers Panchthar and Taplejung districts. The main task of the division is the development of new irrigation schemes along with the rehabilitation and maintenance of running irrigation systems.

Records from the district development committee show that there is some 11,450ha of irrigated land commanded solely by systems built by the farmers. However since 1988 support has been given to the district in improving irrigation systems through a variety of donor assisted and government projects. From 1988 – 1992 the Irrigation Sector Project (ISP) funded by ADB constructed and rehabilitated 10 number projects covering 944ha. The follow up Second Irrigation Sector Project (SISP) from August 1996 – December 2002 constructed and rehabilitated a further 10 projects covering 849ha. A subsequent extension of ADB assistance through the Community Managed Irrigated Agriculture Sector Project (CMIASP) from March 2006 to June 2013 worked on 3 projects covering 979ha. Also from 1991-1997 under Mechi Hill Development Program Funded by (SNV) constructed and rehabilitated 13 projects covering 652ha

Through co-ordination with the Department of Irrigation Focal Point and the respective District Irrigation Officers a maximum of two irrigation systems were selected. A basis for choosing a particular irrigation system was based on one or more of the following criteria in the order of importance as shown below:

- The system to have suffered past damage due to an extreme event such as a flood, landslide, drought, etc.
- The system could be shown to be receptive to adaptive responses, i.e. the scheme was not totally defunct and rehabilitation works could be feasible undertaken to also include any climate change responses.
- To ensure that a representative sample of schemes was taken the selection process was to include where possible at least one government managed as well as one traditional farmer managed irrigation system.
- A newly planned irrigation system that will be constructed in the near future was also included.

Two systems were chosen for the baseline asset study embraced the above criteria and included an existing farmer managed system and a system rehabilitated some time ago.

1.2 Vulnerability Assessment Criteria for Priority Assets

1.2.1 *Vulnerability Assessment Criteria*

Climate change vulnerability in the irrigation context is a function of Irrigation system assets exposure to climate effects, sensitivity to climate effects, and adaptive capacity.

The exposure of the assets to climate threat was focused on its nature and extent and how it would affect the asset. Regarding temperature this concerned the overall increase and its magnitude throughout the year and how it would affect crop growth and irrigation water demand. For rainfall the timing of its increase and decrease at different times of the year was important on how much more or less water was required for irrigation. Rainfall intensity increases had a direct effect on possible crop damages and the likelihood of increased flash floods damaging irrigation infrastructure and generating landslides.

The sensitivity focused on the degree to which an asset would be affected by, or responsive to climate change exposure. Therefore for flash flood events the level of disruption and the length of time it took to return to normal flow conditions were considered. If damage was likely to irrigation infrastructure the degree to which the exposure to a threat would negatively affect the integrity or operation of the asset was evaluated looking at its design effectiveness, the materials used, construction quality, and the levels of maintenance and protective systems required.

The impacts were assessed through how the threats, or otherwise, would affect the operation and sustainability of the irrigation system and its ability to support agricultural production in the future.

Finally the adaptive capacity of the asset was assessed through consideration of the institutional capacity and access to technical and financial resources by the people or organizations directly responsible for the asset's management. Particular emphasis was given to the irrigation water user group's enthusiasm and commitment to the asset.

1.3 Priority Assets

Based on the VA criteria, 2 systems have been selected as priority assets in Panchthar District. The detailed information on each asset is outlined in the baseline report for Panchthar district. Brief discussion on the asset and its components are outlined below:

1.3.1 Subhang Khola Irrigation System

Subhang Khola Irrigation System is a farmers managed irrigation scheme commanding a net cultivable command area of 250 ha. The system was rehabilitated under the Irrigation Sector Project (ISP) in 1993/94.

The system is located in Subhang VDC-9 and constructed to irrigate ward number 3,4,5,6 and 7. The total length of the main canal is 6.12 km. The total benefitted household and population in the project area are 200 and 1,104 respectively. The major crops grown in the project area are paddy, wheat, maize and potato.

The main conveyance canal is both earthen and lined. The main structures built in the system are not in satisfactory condition. Further landslides and seepage problems in the canals were observed in several earthen and damaged lined sections. Due to these problems the system at present was not in operation and requires thorough rehabilitation work.

There have been reports of heavy rainfall causing landslides and damaging the canal system. In 1997 canal slipped down at various locations during the monsoon due to intense rainfalls. As a result canals were closed and not in operation to till date.

In view of the above, the above irrigation scheme has been considered to be vulnerable under severe rainfall events.

1.3.2 Lamichanedhar Irrigation System

Lamichanedhar Irrigation Project is a farmer managed system located in the Siwa VDC of Panchthar district requiring rehabilitation with a command area of 160 ha. The project area lies in the Siwa VDC that covers land of ward no. 2 to 8. The project was initiated and constructed 36 years by the farmers themselves with their own efforts. Then after, they are running the system with their own collective efforts. Most of the length of canal are in damaged condition and at present farmers are not getting water from the system.

The command area is terraced land and gently sloping with most of the command area lining towards the middle and tail reaches of the system. The source of water for this scheme is Siwa Khola located in Siwa VDC-4 and is perennial in nature. Farmers of this project again started to construct the canal with a few financial support of EIDSD in 2003/2004 and constructed 4.5 km length canal. The major crops grown in the project area are Rice, Wheat, Maize, Potato and Oilseeds.

The flow in the Siwa Khola is mainly contributed by sub surface flow during the dry season. This Khola originates from high hill mountains and its main tributary is the Nibu Khola. The catchment area is 12.5 km2 covered by 50% forest land, 30% cultivable land 30% and the remaining 20% by grazing land. There are very few inhabitants in the upstream parts of the watershed.

In general the condition of the assets of this system (mainly stone masonry lined canal) is damaged and not in operation. The masonry lined canal was damaged due to intense rainfall associated with landslide and seepage problems. The command area is terraced over gently sloping terrain. The terraces support paddy crops. The soils of the command area are characterized by loamy texture mixed with ordinary soil & gravel. The soil is moderately to excessively well drain and there are no water logging problems.

Landslides occurred several times at different locations along the main canal alignment in 2009/10. Past events have had more serious consequences with the main canal alignment being totally destroyed and requiring reconstruction. Most of the damages were due to landslides occurred due to intense rainfall.

2 VULNERABILITY ASSESSMENT METHOD

2.1 Overview

The vulnerability assessment process started with identifying the particular threat to the asset from potential climate change effects. This was considered under the principal headings of possible changes and shift in the regular climate and a combination of meteorological and hydrological events. Information on the future parameters of these threats was supplied from the mathematical modeling team for future events in 2050.

Having identified the particular threats the exposure of these climate stress on a particular asset was assessed. This was influenced by considering long-term changes in climate conditions and by changes in climate variability, including the duration, magnitude and frequency of possible future extreme events.

The sensitivity to which the asset could be affected by or responsive to climate change exposure was then evaluated. The variables considered covered the design, materials, sitting and levels of maintenance required by the asset.

Using the CAM matrix enabled the final projected impact level of the threats on an asset to be defined given the levels of exposure and sensitivity that had been assessed. Finally the adaptive capacity of the asset in terms of its ability to prepare for a future threat and in the process increase its resilience and ability to recover from the impact was evaluated. By considering the impact level and the adaptive capacity of the asset the CAM matrix enabled a final vulnerability score to be derived.

2.2 Climate Change Threat Profiles Considered

The climate change threat profiles for Paachthar District were prepared by the Hydrological Modeling teams. A preliminary draft of these was referred to by the experts during the field visit. A final detailed report on these threat profiles is presented in **Annex A**.

The principal climate change threat profiles considered were as follows:

2.2.1 Increase in temperature

Average monthly maximum temperatures were predicted in the summer by 1,6^{o}C. This was significant as it would raise the evapotranspiration rate from the crops and hence result in a larger irrigation demands. Minimum temperatures were also predicted to increase and this could assist the earlier harvesting of winter vegetable crops.

2.2.2 Increase and Decrease in Precipitation

Increasing number of dry days is predicted except in April and May, with the average number of dry days in June increasing from 6.3 to almost 6.9 days. This would increase the irrigation demand for the pre-monsoon land preparation stage for the rice crops. Precipitation vs annual recurrence interval curve shows an increase in precipitation occurs more frequently. More precipitation can be seen in the catchment than that was never experienced before. For example in the past 50mm of precipitation used to occur at every 25 years but in future it can be seen at every 2 years.

There will be an increasing number of extreme rainfall events with events that now occur every 20 years projected to occur every 2 years. This would generate more extreme flash floods in the rivers bringing down with them correspondingly larger volumes of sediment including large boulders. Landslide threats will be correspondingly increased. This would have an adverse impact on the irrigation diversion and headworks to the conveyance systems causing physical damage as well as blockages of the canals.

2.2.3 Increase in River Flows

Increasing wet season flows in the Subang and Siwa Kholas are predicted with the peak monthly average flow in the wet season increasing significantly due to the increase in rainfall expected. There will be an increasing risk and severity of flash floods and increase flood duration during the wet season. Increased river flows though will be beneficial in providing more water for irrigation.

3 VULNERABILITY ASSESSMENT RESULTS

The results of the vulnerability assessment are outlined in Annex B of this report. However, a brief vulnerability assessment of the two assets within the Panchthar District is outlined below:

3.1 Subhang Khola Irrigation System

3.1.1 Asset Description

The following table describes the important aspects of the Subhang Khola irrigation system. Below figures illustrate the condition of the asset and why it is vulnerable to climate change threats.

Canal	Stone masonry lined canal – 3.3 km
Drop Structures	5
Super-passage	11
Outlets	10
Condition of the System	Frequently threatened by the rainfall induced landslides
Past adaption success	Lining of the canals is on an ad-hoc basis but no robust measures

Figure 3-1 Subhang Khola Watershed and Free Intake

Figure 3-2 Stone masonry and silted lined canal with damaged canal replaced with HDPE Pipe

3.1.2 *Vulnerability assessment*

The following section outlines the decisions undertaken in setting the levels of threat, exposure, sensitivity and adaptive capacity for the above system.

3.1.2.1 *Threat: Increase in Temperature*

The average monthly maximum temperature is predicted to increase by $1.6^{o}C$.

- More intense temperatures occur more frequently and the duration of such intense temperatures will be longer. This means, a temperature of $25^{0}C$ will be spread throughout the year for longer durations, this in turn triggers longer summer period than before.
- Increasing number of dry days except in April and May- the average number of dry days in June is increasing from 6.3 to almost 6.9 days.

<u>Exposure: HIGH</u>

- Summer season get extended and beneficial to the rice crops especially in the colder area.
- Free Intake no RCC structures.
- Evapotranspiration rate will be slightly increased.

<u>Sensitivity (LOW)</u>

- No significant impact on irrigation infrastructures.
- Change in cropping pattern and calendar.
- Total agriculture productivity will be increased as the opportunity of increase number of crops
- The overall agriculture productivity will increase resulting low sensitivity.

<u>Impact: (MEDIUM)</u>

- As the temperature increases are relatively small and it would have medium impact on the crops within the command area.
- No significant impact on the design of irrigation infrastructures as it was designed for the maximum crop water requirement for the month of October/November

<u>Adaptive Capacity: (MEDIUM)</u>

- Easily farmers can adapt the change cropping pattern to match with increased irrigation water demand
- Technical advices are available from the district agriculture development office

<u>Vulnerability: (MEDIUM)</u>

As per the guiding matrix below, the vulnerability for the increased temperature is **MEDIUM.**

		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

3.1.2.2 *Threat: Increase in Rainfall*

The following threats have been identified as likely to impact on irrigation system and its components:

- Increased rainfall caused landslides events that damage the integrity of the entire system including intake and canal system
- Rainfall events occur more frequently and in larger volume that eventually triggers more landslides in the vicinity of the scheme area

Exposure: HIGH

- Longer duration rainfall events with high intensity will occur more frequently which in turn brings more surface flows that triggers greater landslide potential.
- Steep terrace slopes causes more rainfall runoff down the hill slopes creating the potential for more landslides
- Longer duration rainfall events occur more frequently saturating the soils on the hill slopes and creating the conditions for landslides along the canal alignment

Sensitivity: HIGH

- Materials used in the construction of intake and canal system are of poor quality and the design practices are not good.
- The design and construction of the system and its components including the main canal system are inadequate. Regular maintenance of the free intake and main canal are performed by the authorities on an ad-hoc basis.

Impact: HIGH

- Increased risk of landslides along the canal alignments.
- Need more frequent O&M tasks being undertaken which in turn raises the O&M costs creating a significant burden on the operators and the water users.
- Damage to the system and its components means, no flow reaches to the downstream farming land which eventually affects the crop production.
- Affects the livelihood of farmers if these events occur on regular basis and encourages the farmers to migrate to urban areas leaving their farming tradition. This eventually impacts on the food security as a whole.

Adaptive Capacity: LOW

- The local authority is supported by district level and community funds to provide support to O&M programs only.
- Minimal funds available to support or reinstate the existing damaged canal or intake points.
- Advanced technical capabilities are not readily available within the authorities to raise the existing system capacity to achieve more climate resilient designs.

Vulnerability Scoring: HIGH

As per the below guiding matrix, the vulnerability against increasing rainfall is **HIGH.**

		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*

3.1.2.3 *Threat:Landslide*

- As per the threat profile (See Annex A), on an average rainfall intensities will increase by 60%
- Rainfall events occur more frequently than before
- Increased number of landslides and damage to the canal system

Exposure: HIGH

- Longer duration rainfall events with high intensity will occur more frequently bringing more flows that trigger landslides.
- In addition to the landslides, the increased rainfall brings more sediments to the irrigation components thus damaging the canal structure
- The main canal is located just d/s of the wide catchment basin that could bring flash flows due to increased high-intensity rainfall that eventually produces more landslides and damages the asset components.
- Longer duration rainfall events will occur more frequently increasing the probability of landslides along the main canal alignment

Sensitivity: VERY HIGH

- Materials used in the construction of intake and canal system are of poor quality and design practices.
- The design and construction of the system and its components such as canal system are inadequate. Regular maintenance at the free intake and canal are performed by the authorities on an ad-hoc basis.
- Longer duration rainfall events will occur more frequently
- High intensity rainfall events will occur more frequently
- South facing slope brings more rainfall and runoff into the site

Impact: VERY HIGH

- Increased risk of landslides along the canal alignments.
- Need more frequent O&M tasks which in turn raise the O&M costs which is a significant burden on the water users.
- Damage to the system and its components means no flow reaches to the downstream farming land which eventually affects the crop production.
- Affects the livelihood of farmers if these events occur on regular basis and encourages the farmers to migrate to urban areas leaving their farming tradition. This eventually impacts on the local food security as a whole.

Adaptive Capacity: LOW

- The local authority is supported by district level and community funds to provide support to O&M programs only.
- Minimal funds available to support or reinstate the existing damaged canal or intake points.
- Advanced technical capabilities are not readily available within the authorities to raise the existing system capacity to achieve more climate resilient designs.

<u>Vulnerability Scoring: VERY HIGH</u>

As per the below guiding matrix, the vulnerability against landslides is **VERY HIGH**

		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

3.2 Lamichanedhar Irrigation System

3.2.1 Asset Description

The following table describes the important aspects of the Lamichanedhar irrigation system.

Canal	Stone masonry lined canal – 4.5 km
Condition of the System	Canal system is extensively damaged
Past adaption success	Farmers self-supported O&M works; no adaptation measures in the past
Command Area	160 ha

Figure 3-3: Damaged masonry lined main canal

3.2.2 Vulnerability assessment

The vulnerability assessment for the Lamichanedhar irrigation system has similar outcomes as for Subhang Khola as regards increased temperature and rainfall. This vulnerability assessment concentrates on the landslide threat

3.2.2.1 *Threat: Increase in Temperature*

The average monthly maximum temperature is predicted to increase by 1.6^{o}C .

- More intense temperatures occur more frequently and the duration of such intense temperatures will be longer. This means, a temperature of 25^{0}C will be spread throughout the year for longer durations, this in turn triggers longer summer period than before.
- Increasing number of dry days except in April and May- the average number of dry days in June is increasing from 6.3 to almost 6.9 days.

Exposure: HIGH

- Summer season get extended and beneficial to the rice crops especially in the colder area.
- Free Intake no RCC structures.
- Evapotranspiration rate will be slightly increased.

Sensitivity (LOW)

- No significant impact on irrigation infrastructures.
- Change in cropping pattern and calendar.
- Total agriculture productivity will be increased as the opportunity of increase number of crops
- The overall agriculture productivity will increase resulting low sensitivity.

Impact: (MEDIUM)

- As the temperature increases are relatively small and it would have medium impact on the crops within the command area.
- No significant impact on the design of irrigation infrastructures as it was designed for the maximum crop water requirement for the month of October/November

Adaptive Capacity: (MEDIUM)

- Easily farmers can adapt the change cropping pattern to match with increased irrigation water demand
- Technical advices are available from the district agriculture development office

Vulnerability: (MEDIUM)
As per the guiding matrix below, the vulnerability for the increased temperature is **MEDIUM.**

		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

3.2.2.2 *Threat: Increase in Rainfall*

The following threats have been identified as likely to impact on irrigation system and its components:

- Increased rainfall caused landslides events that damage the integrity of the entire system including intake and canal system
- Rainfall events occur more frequently and in larger volume that eventually triggers more landslides in the vicinity of the scheme area

Exposure: HIGH

- Longer duration rainfall events with high intensity will occur more frequently which in turn brings more surface flows that triggers greater landslide potential.
- Steep terrace slopes causes more rainfall runoff down the hill slopes creating the potential for more landslides
- Longer duration rainfall events occur more frequently saturating the soils on the hill slopes and creating the conditions for landslides along the canal alignment

Sensitivity: HIGH

- Materials used in the construction of intake and canal system are of poor quality and the design practices are not good.

- The design and construction of the system and its components including the main canal system are inadequate. Regular maintenance of the free intake and main canal are performed by the authorities on an ad-hoc basis.

Impact: HIGH

- Increased risk of landslides along the canal alignments.
- Need more frequent O&M tasks being undertaken which in turn raises the O&M costs creating a significant burden on the operators and the water users.
- Damage to the system and its components means, no flow reaches to the downstream farming land which eventually affects the crop production.
- Affects the livelihood of farmers if these events occur on regular basis and encourages the farmers to migrate to urban areas leaving their farming tradition. This eventually impacts on the food security as a whole.

Adaptive Capacity: LOW

- The local authority is supported by district level and community funds to provide support to O&M programs only.
- Minimal funds available to support or reinstate the existing damaged canal or intake points.
- Advanced technical capabilities are not readily available within the authorities to raise the existing system capacity to achieve more climate resilient designs.

Vulnerability Scoring: HIGH

As per the below guiding matrix, the vulnerability against increasing rainfall is **HIGH.**

		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*

3.2.2.3 *Threat: Landslides*

As per the threat profile (See Annex A), on an average rainfall intensities will increase by 60%

- Rainfall events occur more frequently than before
- Increased number of landslides and damage to the canal system

Exposure: HIGH

- Longer duration rainfall events with high intensity will occur more frequently which brings more flows that trigger landslides.
- In addition to the landslides, the increased rainfall brings more sediments to the irrigation components thus damaging the canal structure
- Longer duration rainfall events will occur more frequently and increase the probability of landslides along the canal alignment

Sensitivity: HIGH

- Materials used in the construction of intake and canal system are of poor quality and design practices.
- The design and construction of the system is based around stone lined canals. Regular maintenance at the free intake and canal are performed by the water users on an ad-hoc basis.
- High intensity rainfall occurs more frequently

Impact: HIGH

- Increased risk of landslides along the canal alignments.
- Need more frequent O&M which in turn raises the O&M costs being a significant burden on the operators and the water users.
- Damage to the system and its components means, no flow reaches to the downstream farming land which eventually affects the crop production.
- Affects the livelihood of farmers if these events occur on regular basis and encourages the farmers to migrate to urban areas leaving their farming tradition.

Adaptive Capacity: LOW

- The local authority is supported by district level and community funds to provide support to O&M programs only.
- Minimal funds available to support or reinstate the existing damaged canal or intake points.
- Advanced technical capabilities are not readily available within the authorities to raise the existing system capacity to achieve more climate resilient designs.

<u>Vulnerability Scoring: HIGH</u>

As per the below guiding matrix, the vulnerability against landslides is **HIGH**.

		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*

4 PANCHTHAR DISTRICT VULNERABILITY SUMMARY

4.1 Summary of Vulnerability Assessment Results

The vulnerability summaries for the irrigation systems studied in the Panchthar district are presented in the table below

PANCHTHAR DISTRICT VULNERABILITY SUMMARY

		VULNERABILITY	
Climate Threat	**Priority Assets Affected**	**Subang Khola**	**Lamichanedhar**
1. Increased Temperature	Intake and Command Area	M	M
2. Increased Rainfall	Intake and Command Area	H	H
3. Landslides	Intake and Main Canal	VH	H

The summary matrix highlights that the Subang Khola irrigation scheme was considered the most vulnerable out of the two case study systems analysed. This was principally due to threat from landslides being much greater as the main canal was not lined in a lot of places and frequently crossed quite steep fragile zones. These areas were also perennially wet due to water seeping from upstream areas and were in need of proper drainage facilities. The free intake site was also vulnerable to damage and blockage during flash floods.

4.2 Vulnerability Summary to Principal Climate Threats

Based on the vulnerability assessments performed within the Panchthar District, the following conclusions can be made on the vulnerabilities of the particular irrigation system assets to the principal climate threats.

CLIMATE THREAT	PRINCIPAL ASSET CONSIDERED	IMPACTS WITHIN IRRIGATION SYSTEMS	WHY VULNERABLE
Increase in Average Monthly Temperature	Command Area	1) For both systems the water required within the command area will be slightly increased particularly for paddy land preparation 2) There is scope for alternative cropping patterns to be introduced	Increased temperatures will raise the rate of crop evapotranspiration and higher water demands will ensue particularly during the pre-monsoon and monsoon periods
Increase in Rainfall Events	Intake and Command Area	1) For both systems will reduce water required from the river during the pre-monsoon period when water flows are reduced 2) Will cause more soil erosion from steep slopes and increase the likelihood of larger sediment flows passing down the kholas.	Increased rainfall is a benefit as reduces irrigation water demand
Decrease in Rainfall Events	Command Area	1) For both systems the slight decrease in rainfall during the post monsoon period will have little impact on irrigation water availability as river levels still high. 2) Small impact on irrigation infrastructures	Reduced rainfall will Increase irrigation water demand.
Increased in river flow	Intake Structure	1) Both systems have free intakes so little control on river inflows into the main canals 2) Both systems have no facilities for removing sediment entering the main canals at the intakes 3) Both systems could suffer from damage to the intake infrastructure due to increased river flows and sediment blockages 4) Both systems are vulnerable to debris brought down by flash floods blocking the intakes	Increases in river flows during the pre-monsoon and monsoon periods will bring more sediment which will enter the main canal system and Increase O&M costs Increased intensity short term rainfall events will increase sediment and debris flows carried by flash floods from the more vulnerable unprotected watershed areas
Landslides	Main Canal and Command Area	1) Both systems could be impacted by landslide events along the main canal alignment where they traverses steeply sloping terrain. 2) The vulnerability at the Subhang	Increase in high intensity rainfall events where there are step slopes along the main canal alignment or within the command area

CLIMATE THREAT	PRINCIPAL ASSET CONSIDERED	IMPACTS WITHIN IRRIGATION SYSTEMS	WHY VULNERABLE
		system is considered very high as the main canal traverses steep unstable soils that poorly drained and are already prone to landslips 3) If there is a landslide along the main canal there will be the loss of irrigation water to the downstream command areas 4) As some parts of the command areas in both systems are on steeply sloping terrain erosion of unprotected terrace slopes could encourage landslide events and loss of cropped areas	and there is inadequate upslope drainage and vegetative protection this will encourage landslide events.

4.3 Lessons and Application to Other Assets

The district has both farmers managed and agency managed irrigation system as well as non-conventional irrigation technology systems that gives an opportunity to understand the possible impacts of climate change threats on these type of assets. Assets within these systems have already suffered from past extreme events such as a floods, landslides and storm damage due to the existing variability in climate.

Since similar types of infrastructure can be seen across the district, this means, the same impacts, vulnerability and adaptation plans could well be applied to other irrigation projects within the district. Majority of the irrigation systems are experiencing similar sort of exposure, sensitivity towards the climate change threats and the adaptive capacity of the local authorities towards emergency management is more or less the same.

All the irrigation development divisions and sub-divisions are struggling with lack of funds and support to combat with climate change related threats and events. The problems associated with the ongoing operation and maintenance of the irrigation systems are the common issues.

4.4 Linkages to Other Sectors

The threats from climate change on the irrigation command areas should also be consider by the District Agricultural Development Office. The vulnerabilities, in particular to increased temperature and rainfall or alternatively drought, should instigate advice to farmers on any changes to cropping patterns, time of planting, or crop husbandry needs to overcome any problems. Similarly advice on what protection measures or change in crop varieties to withstand storm damage would be useful.

At the same time advice could be given to the farmers on how to maximize on any potential benefits that could be realized from future climate change projections.

ANNEX A: CLIMATE THREAT PROFILES

1 Summary of the Panchthar Climate Change Impacts

Panchthar district total catchment area is 5,504 km^2 of which the district area covers 1,235 km^2 (**Error! Reference source not found.**1).

The future projection window is 2040 to 2060. In other words downscaled climate projections are extracted for this period and the analysed changes used to project historical observation data into 2050.

According to the PRECIS climate projections the mean daily maximum temperature is expected to rise 1.7 to 2 °C depending on the area. Similar rise is expected for the annual maximum temperature. Minimum temperatures are also expected to rise about 2 to 3 °C on the average. Consequently there is slight expected rise in potential evapotranspiration 0.2 to 0.3 mm/d especially during the dry season.

Wet season average precipitation is expected to increase about 30%. Extreme event rainfall is expected to increase even more. Dry season is expected to become dryer especially in the already dryer Western part of the district.

Maximum pluvial (rainfed) flooding is expected to increase especially in the North-Eastern part of the district.

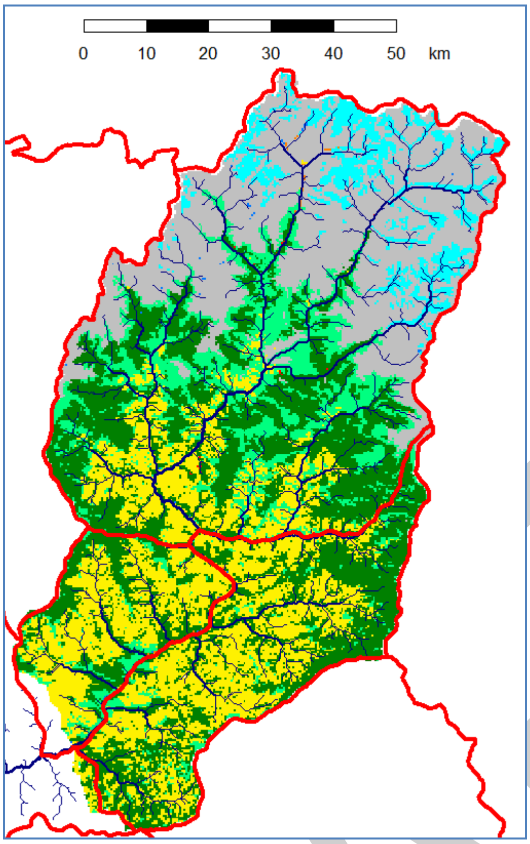
Erosion is expected to double over a large part of the district.

River flow is expected to increase significantly especially in July. Depending on the location the increase is about 30 to 80%.

2 Summary of the Panchthar Climate Change Impacts

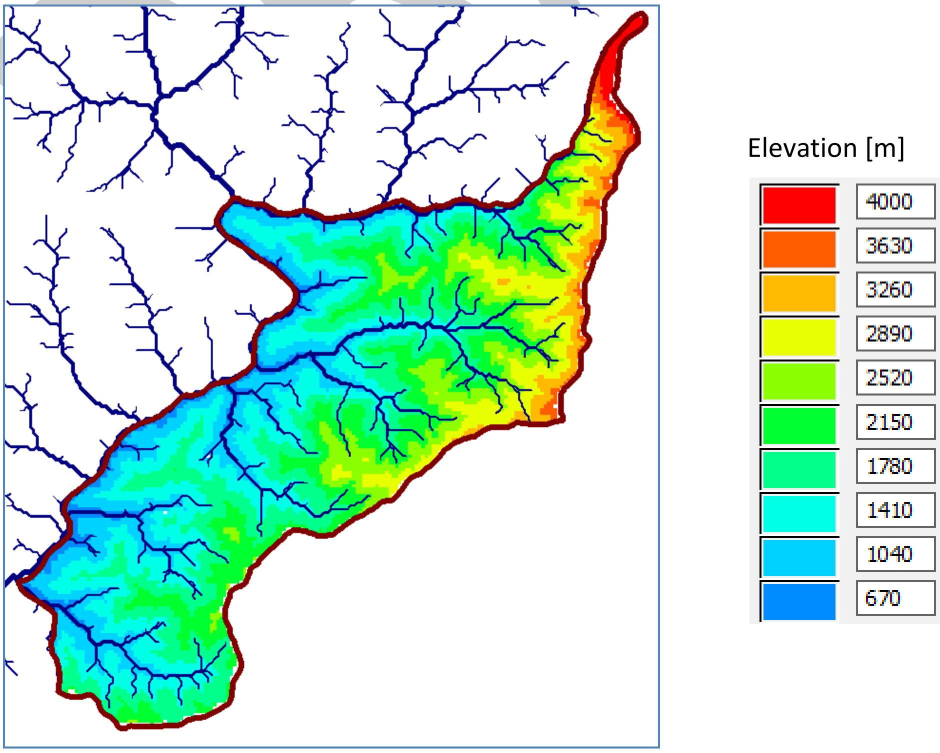
Panchthar model grid cell ("pixel") size is 300 m. Panchthar model area corresponding to the Panchthar district watershed is shown in Figure 1.

Figure 1. Watershed Model Area.



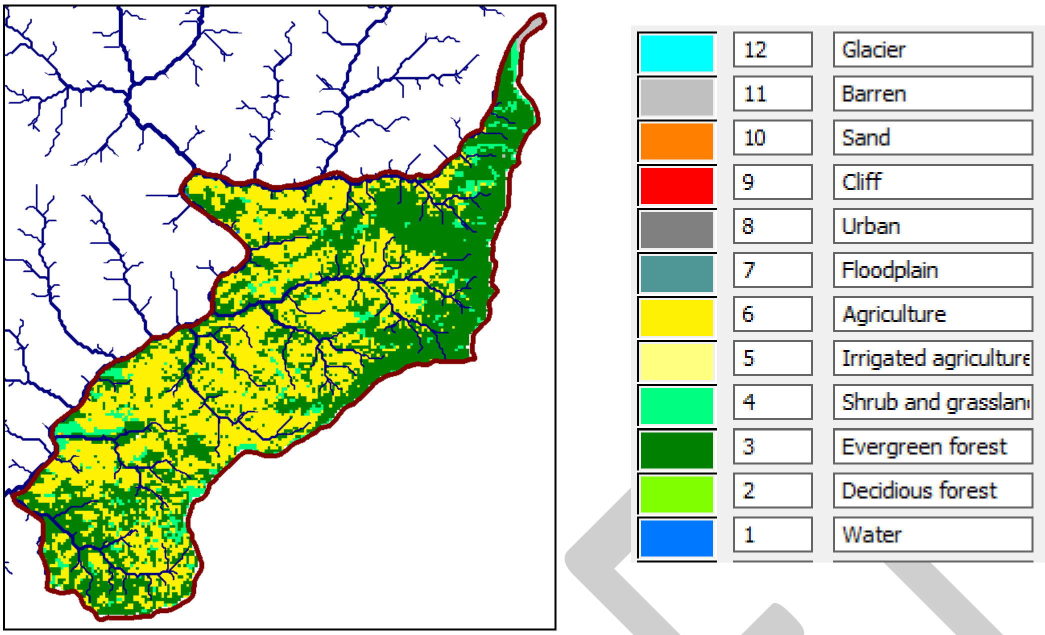
Panchthar district grid elevations reach from 400 m to 4’600 m:

Figure 2. Model grid elevations for the Panchthar district



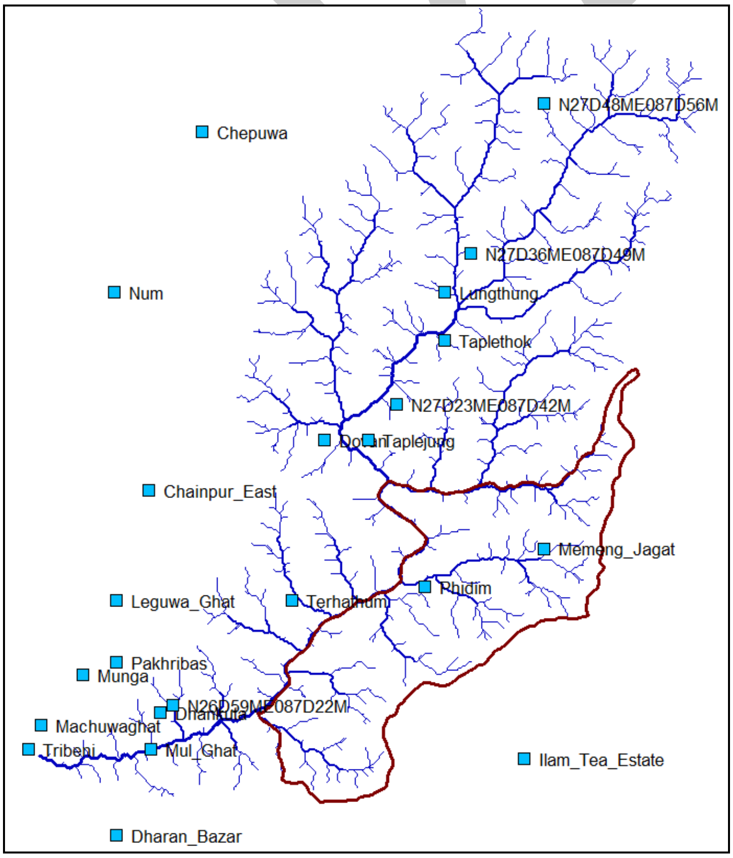
The land use is dominated by evergreen forest and agriculture:

Figure 3. Model grid land use classes for the Panchthar district.



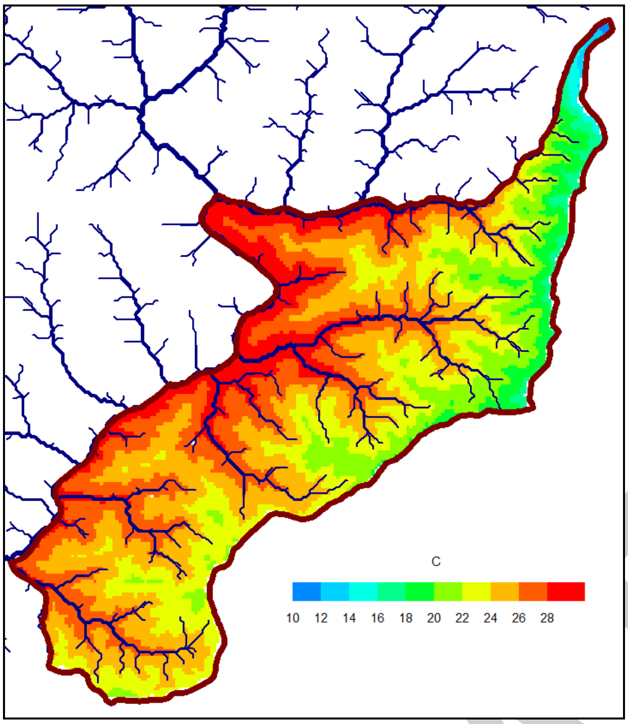
Panchthar model meteorological stations are presented in Figure4. Because temperature monitoring time series were not available re-analysis data was used instead for temperature.

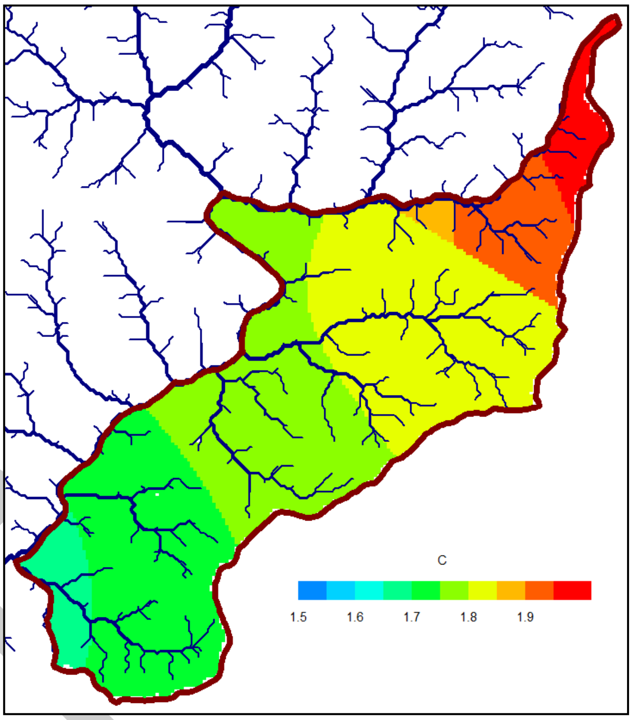
Figure 4. Model meteorological stations. "N2…"-stations are temperatures from re-analysis data, other stations are Nepal national precipitation monitoring stations.



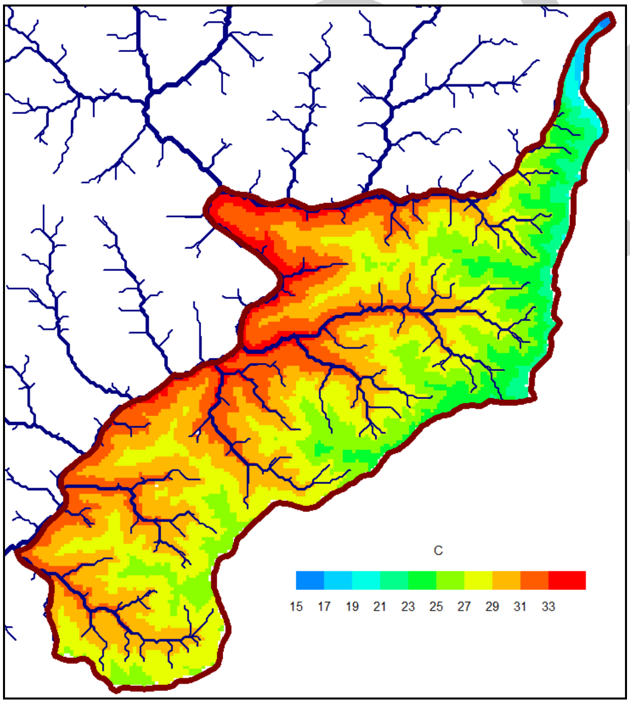
3 Maps for Hot spot Identification and Impact over view

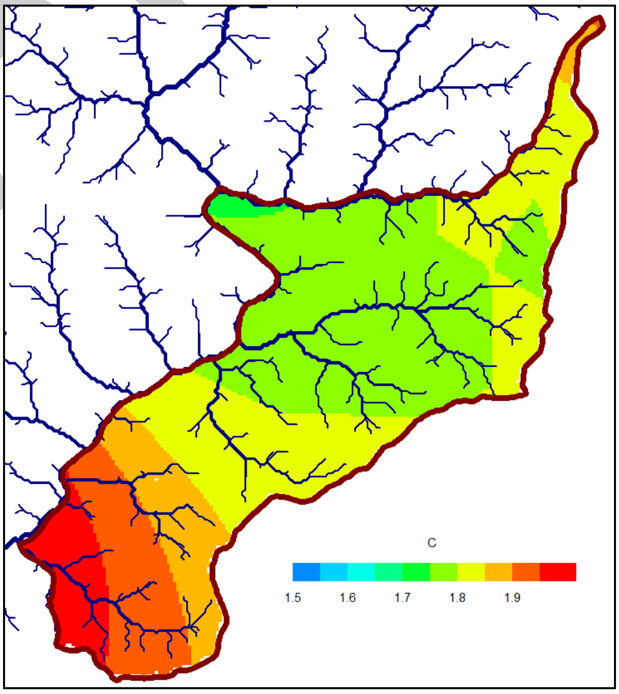
Wet season mean daily maximum temperature [°C] and change in 2050.



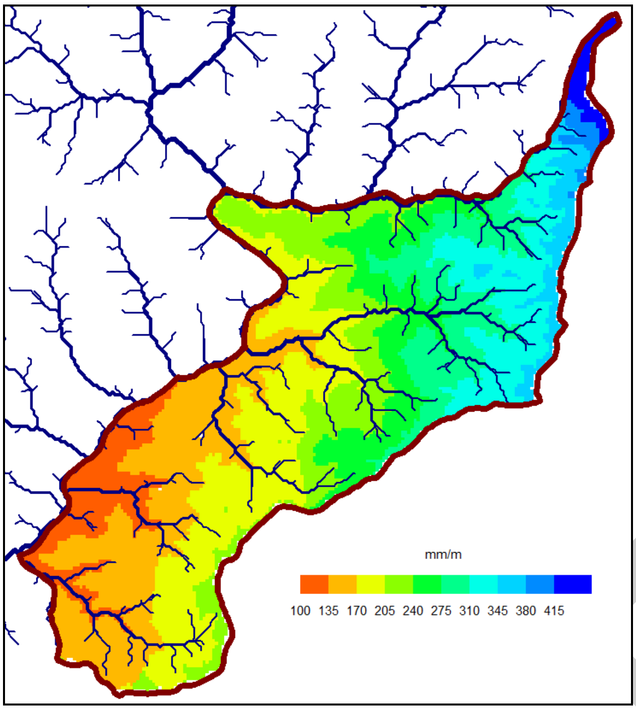


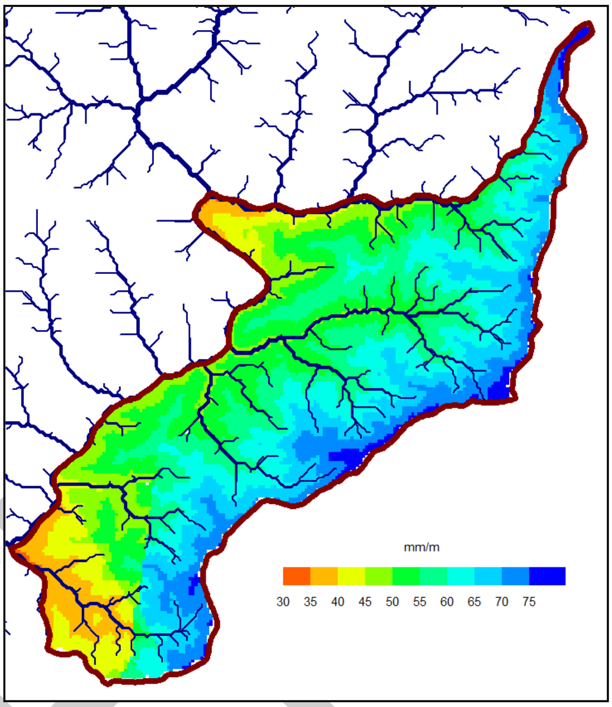
Wet season mean annual maximum temperature [°C] and change in 2050.



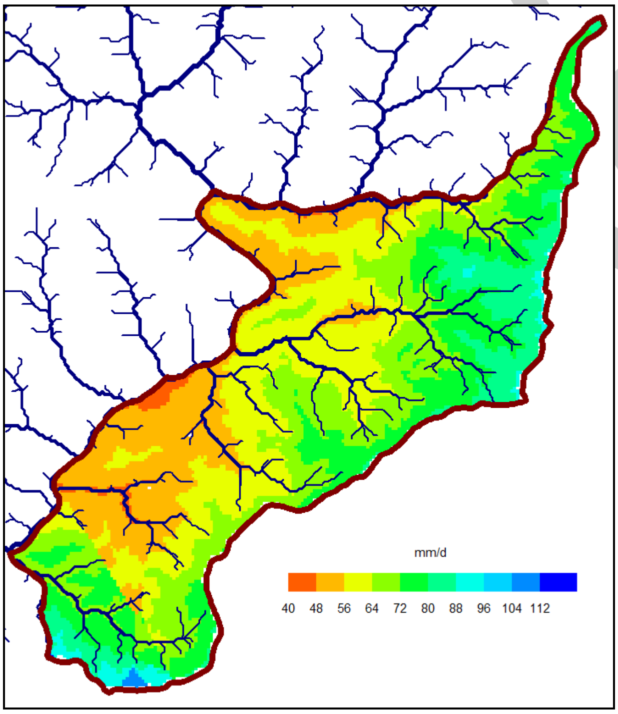


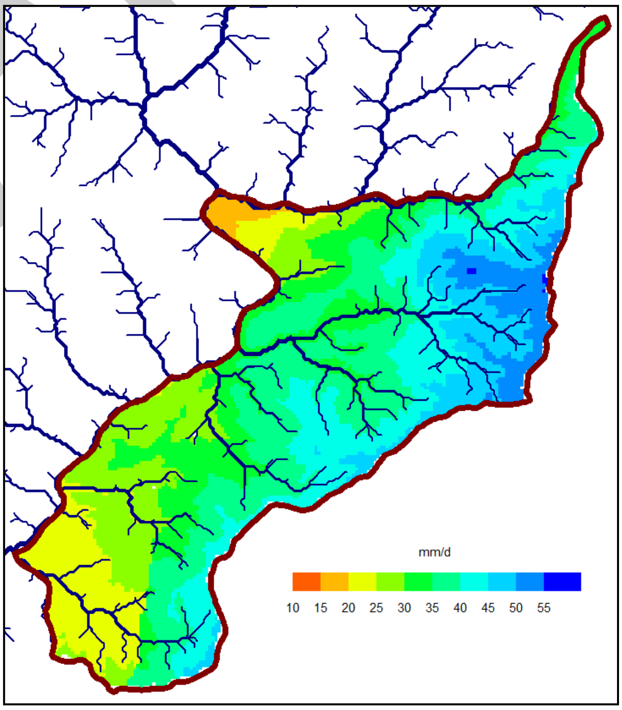
Wet season mean monthly precipitation [mm/m] and change in 2050.



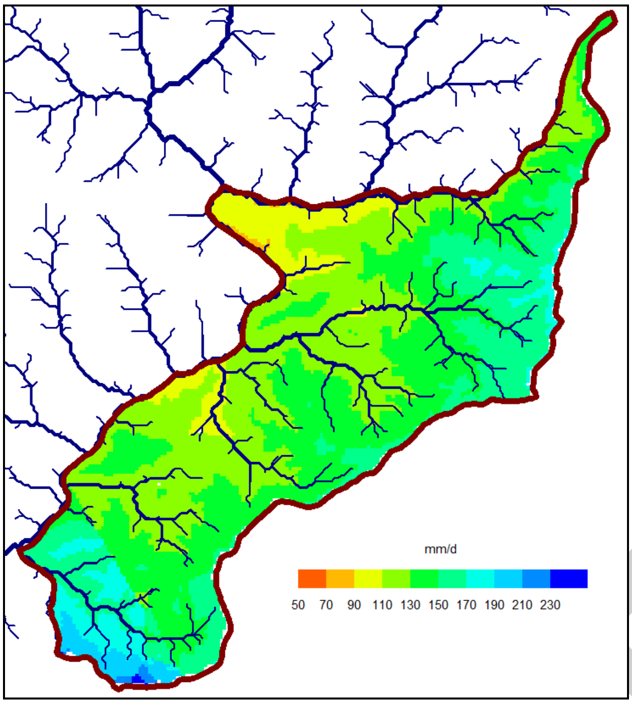


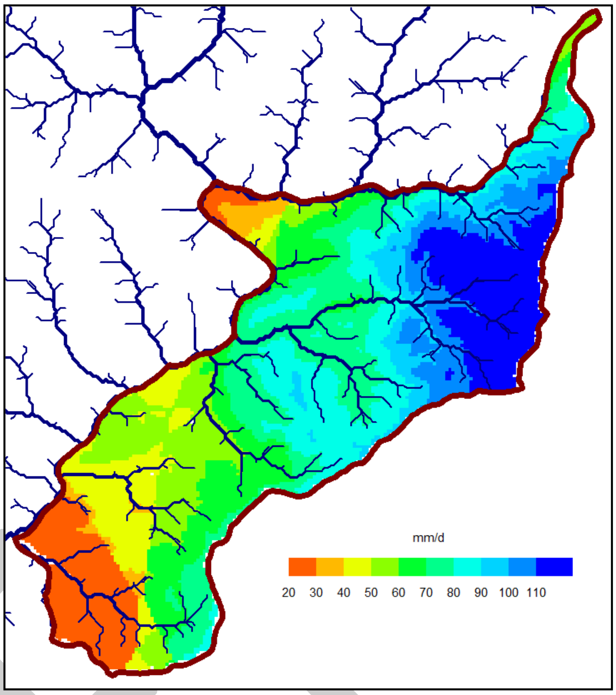
Wet season mean annual maximum precipitation [mm/d] and change in 2050.



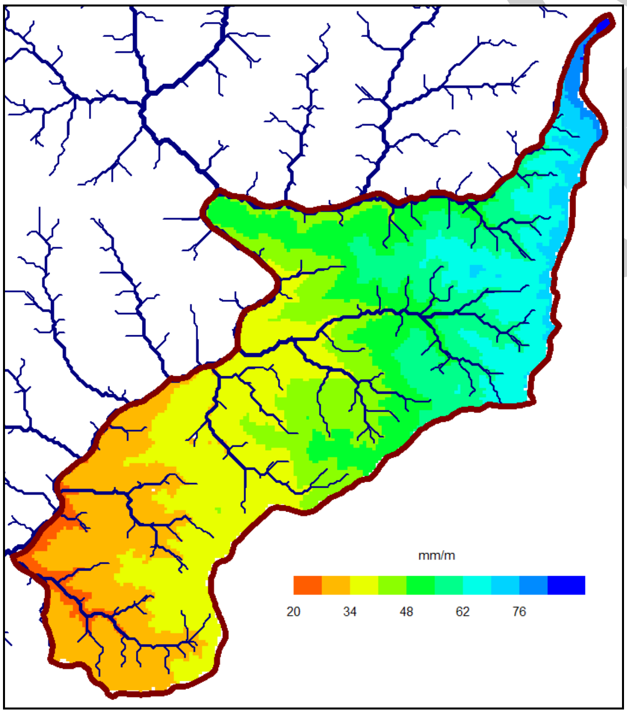


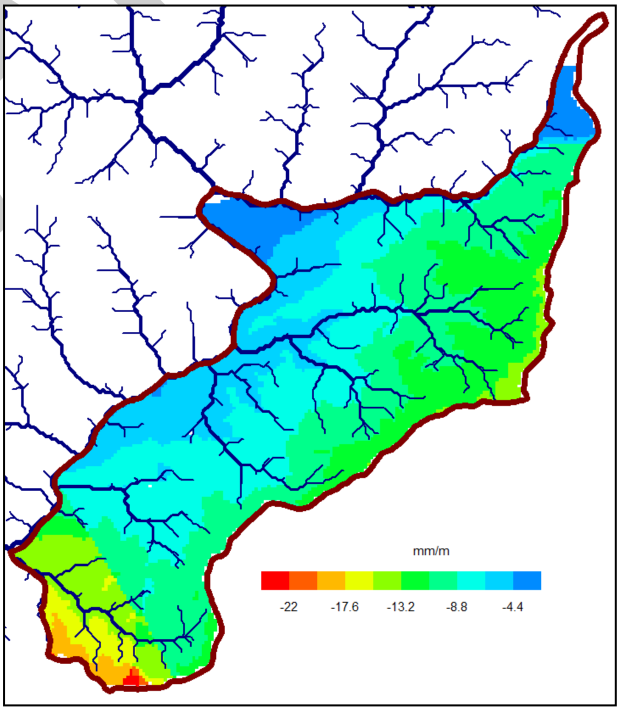
50 year precipitation event [mm/d] and change in 2050.



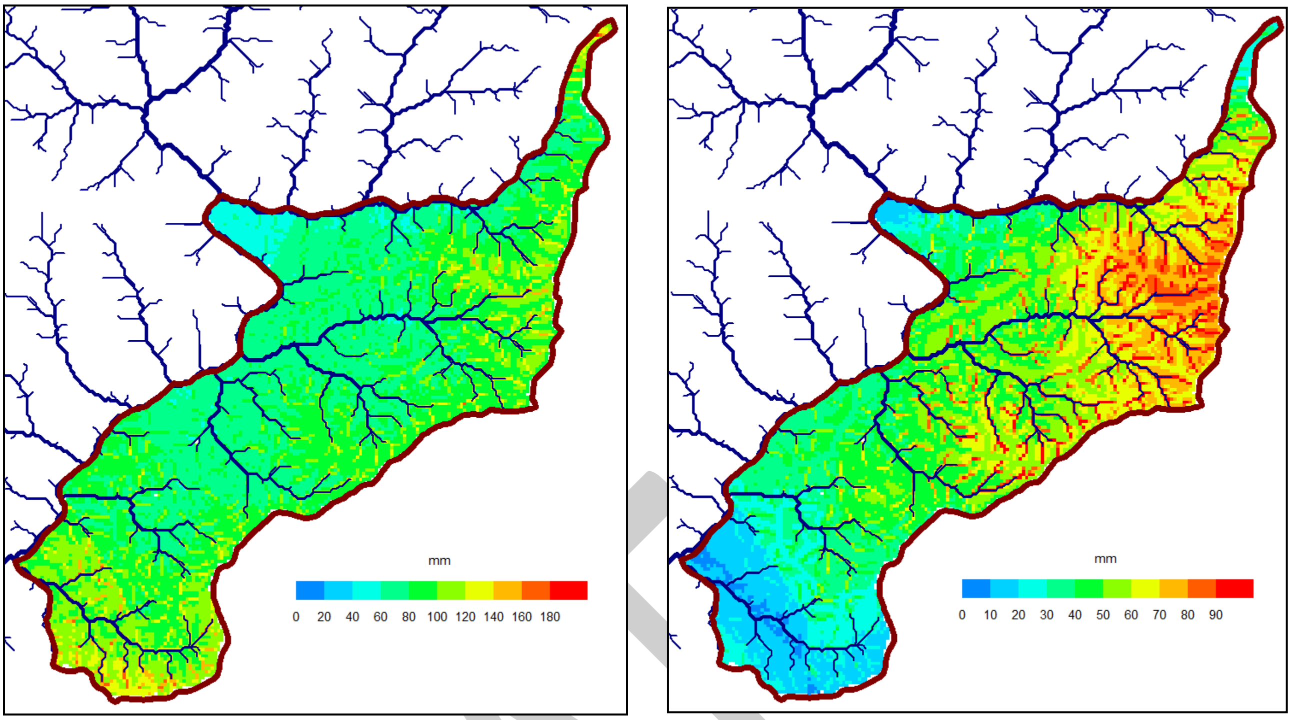


Dry season mean monthly precipitation [mm/m] and change in 2050.

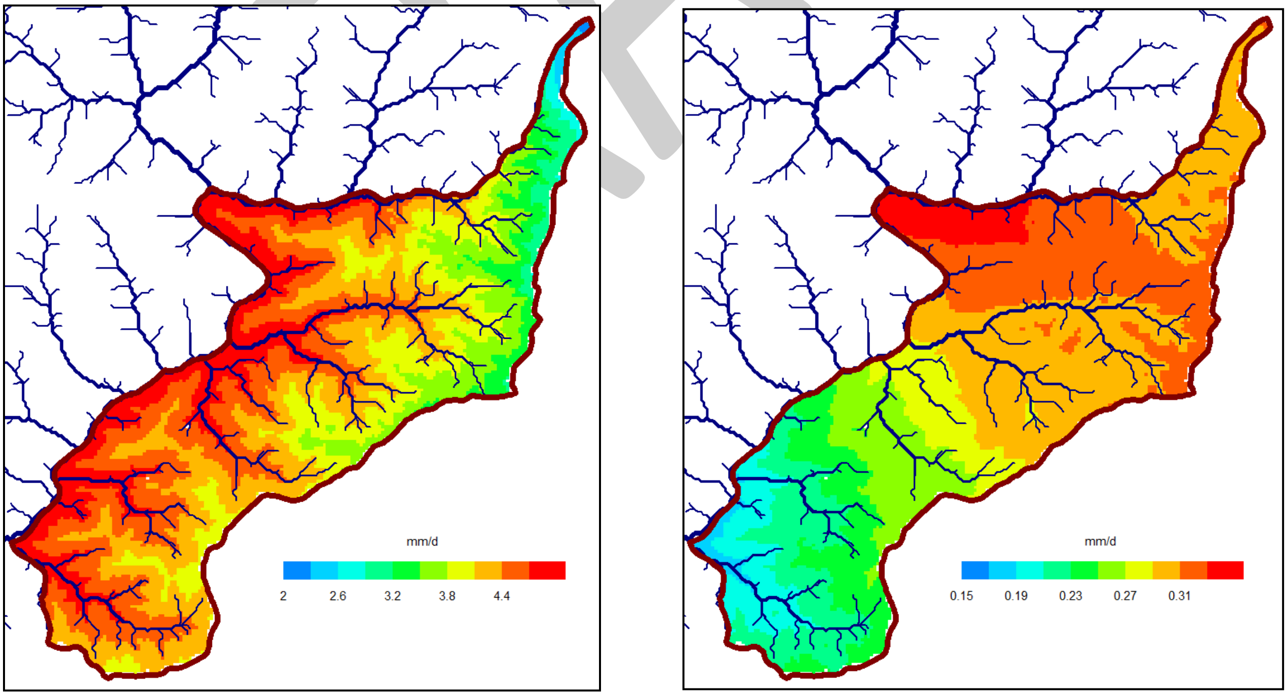




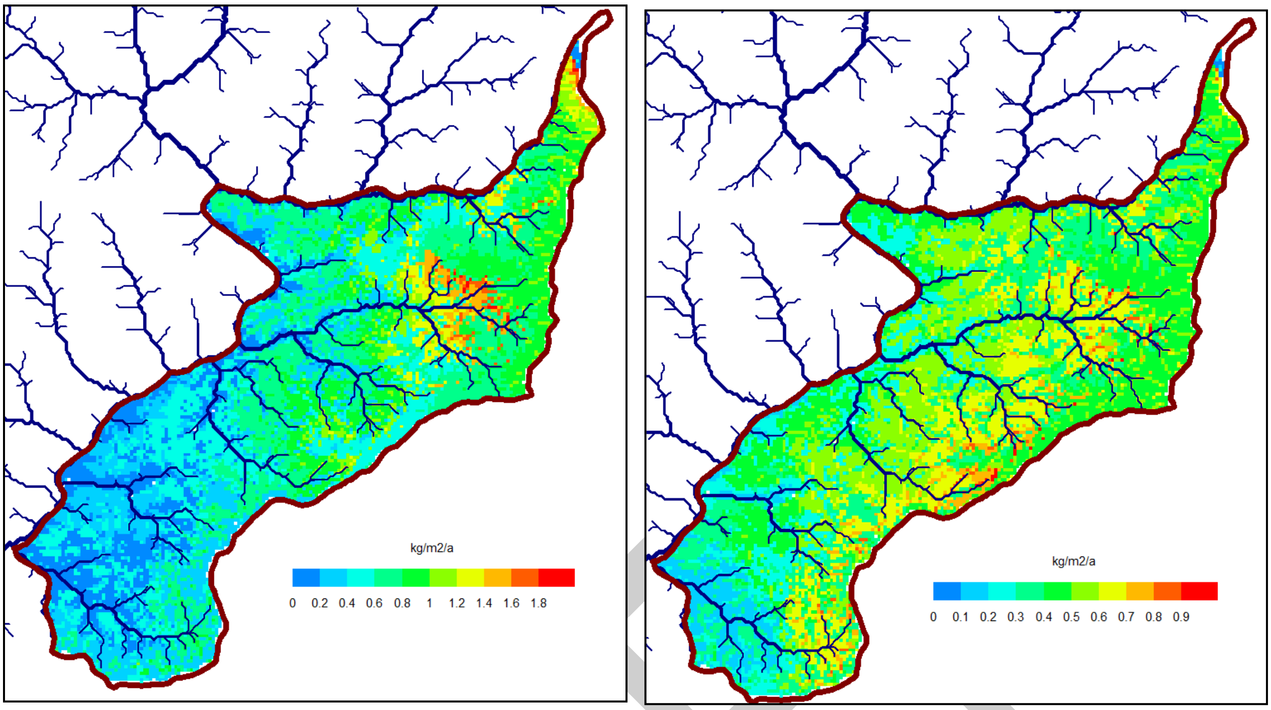
Maximum pluvial flooding [mm] and change in 2050.



Dry season potential evapotranspiration (PET) [mm/d] and change in 2050.



Average annual erosion rate [kg/m^2/a] and change in 2050.



4 Particular Site Specification information

Figure5 presents model output locations for time series. Three locations, Memeng Jaga, Phidim and Ts4, are selected for further processing and presentation in this document. The elevations of the stations are 1,758, 540 and 447 m. The corresponding upper catchment areas are indicated in Figure 6. The catchment areas are 22, 360 and 5’504 km^2.

Figure 5. Panchthar model output locations. Sites where profiles are output are indicated with red points.

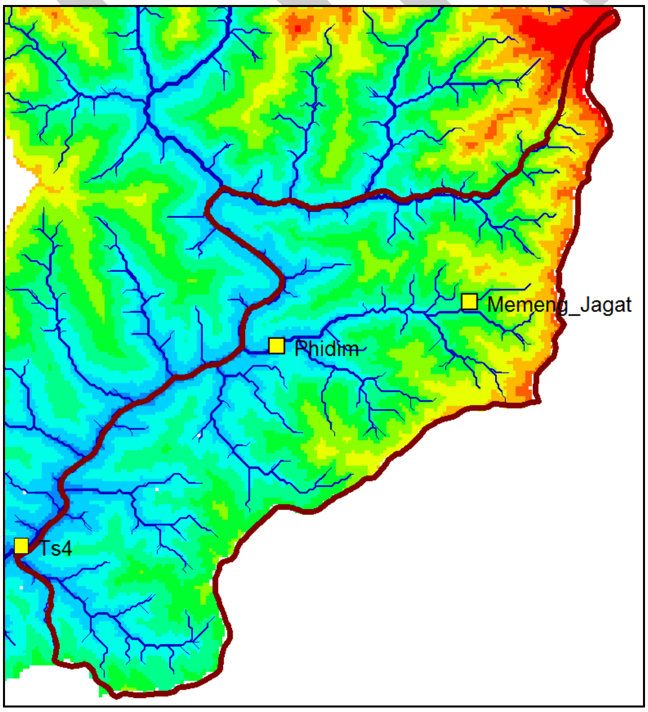
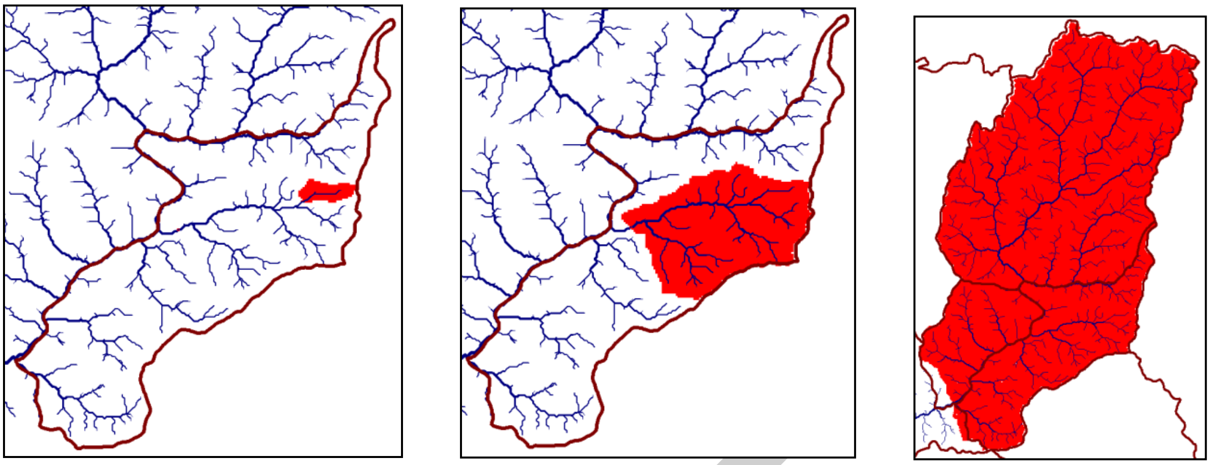
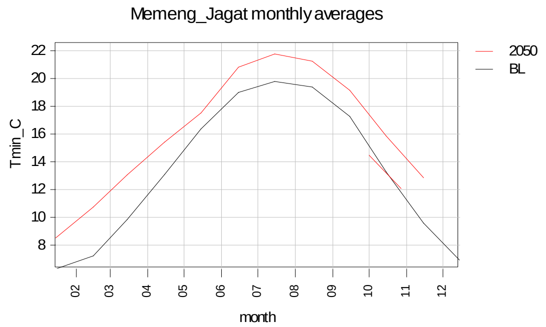
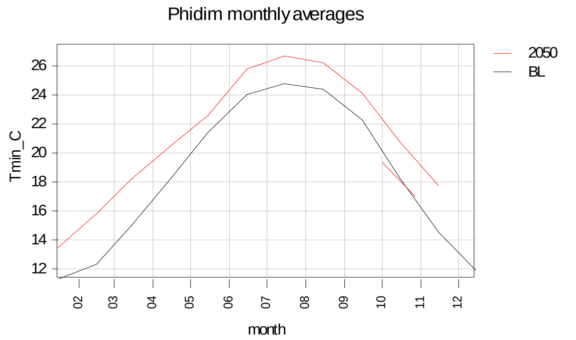


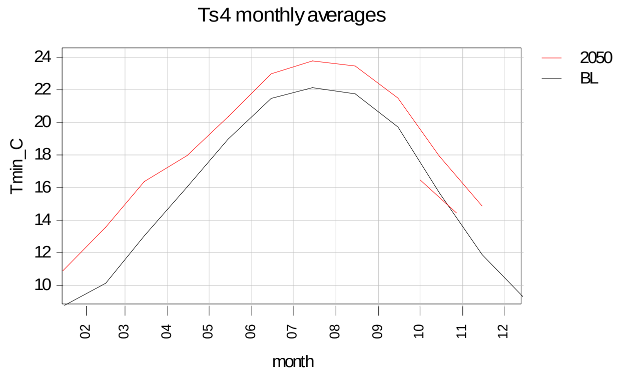
Figure 6. Upper catchment areas for the Memeng Jagat, Phidim and Ts4 output locations.



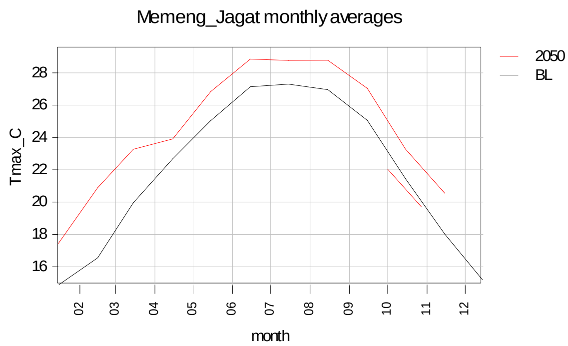
Minimum Temperature (⁰C)

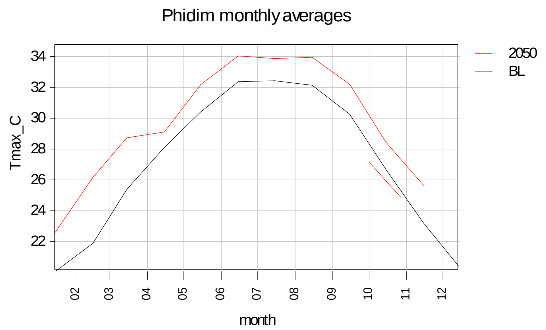


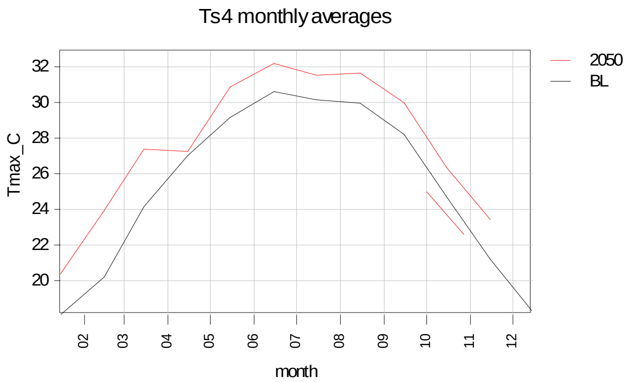




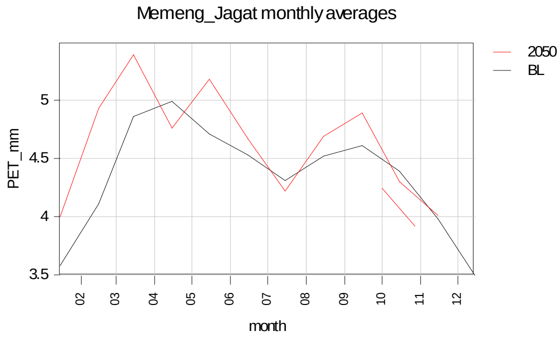
Maximum Temperature (⁰C)

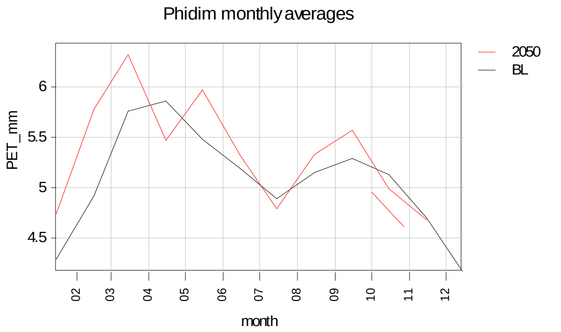


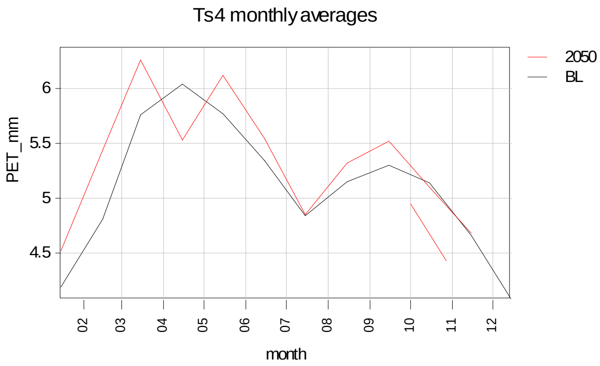




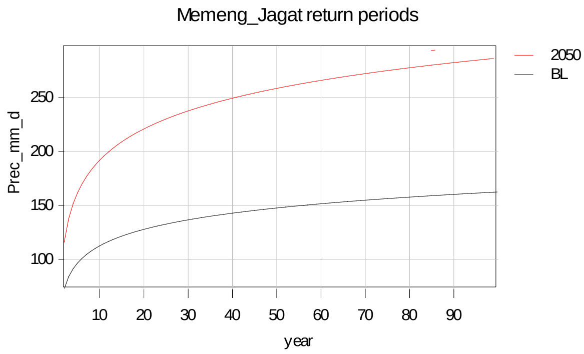
Potential Evapotranspiration (PET) (mm)

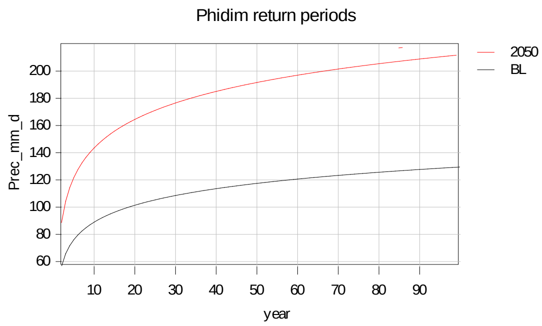


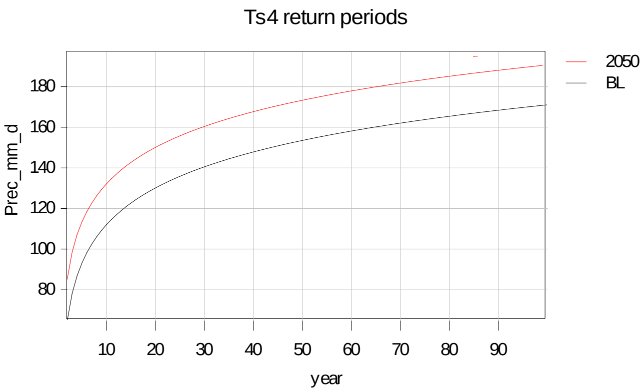




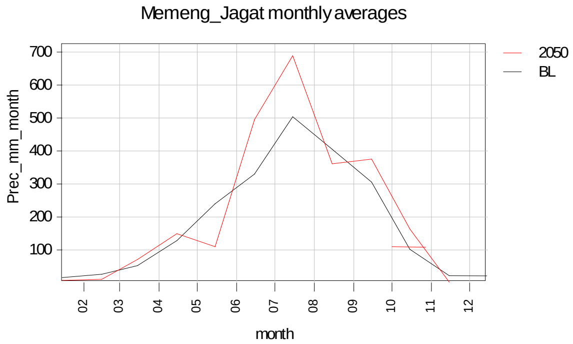
Precipitation Return Period (mm/day)

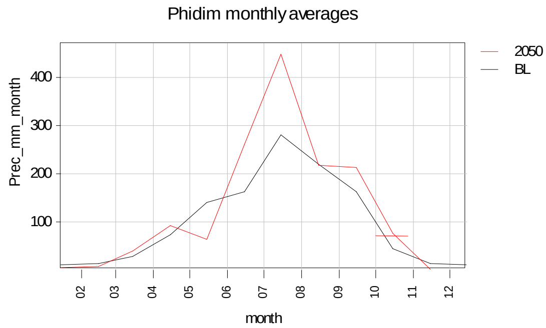


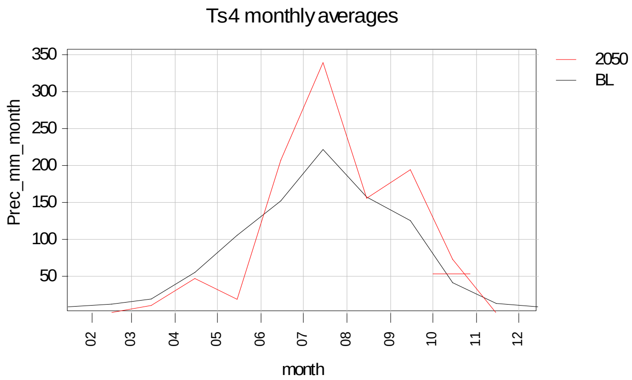




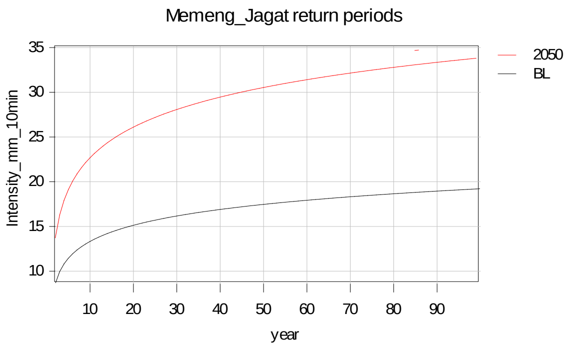
Preccipitation (mm/month)

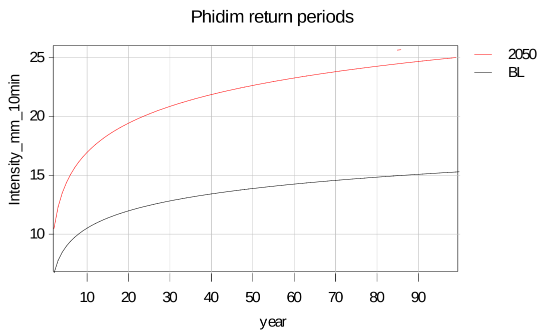


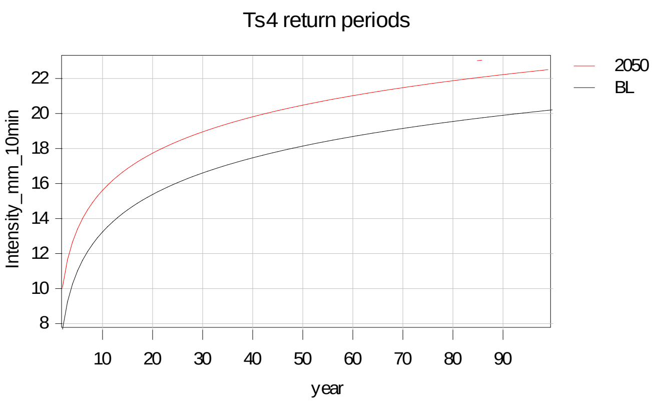




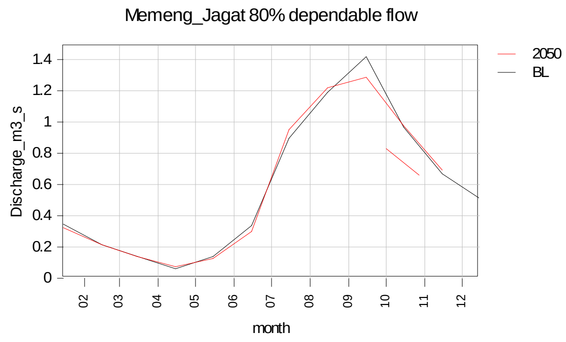
Rainfall Intensity Return Period (mm/10min)

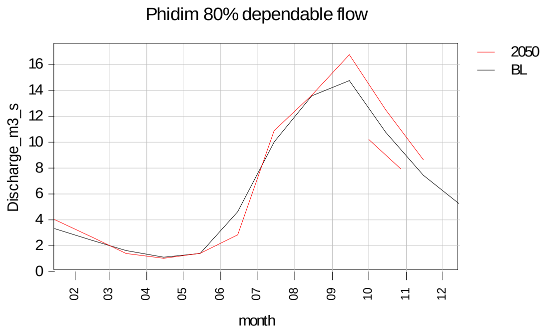


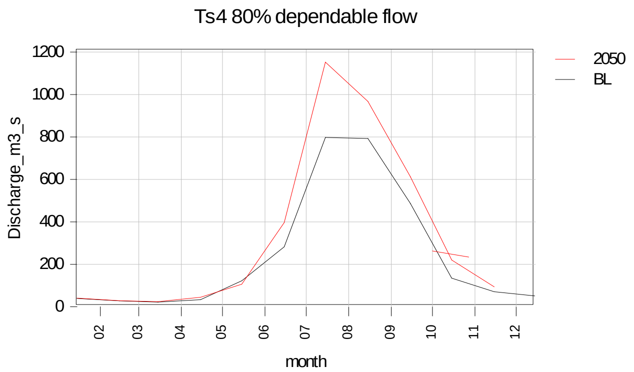




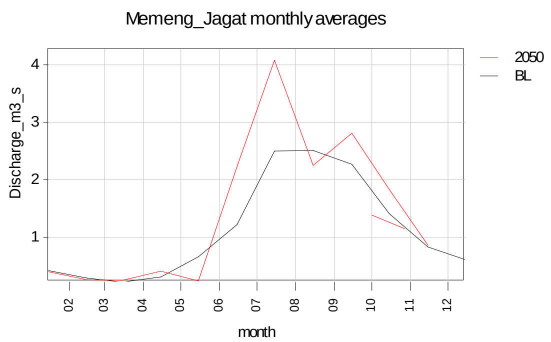
80% Dependable River Flow (m^3/s)

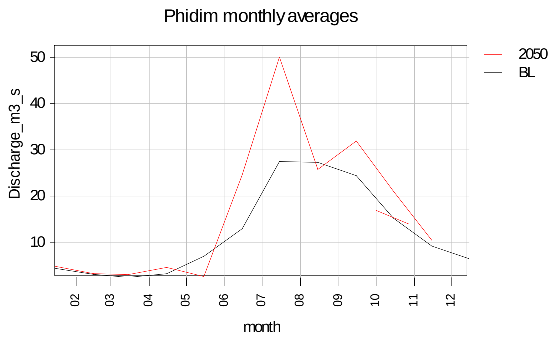


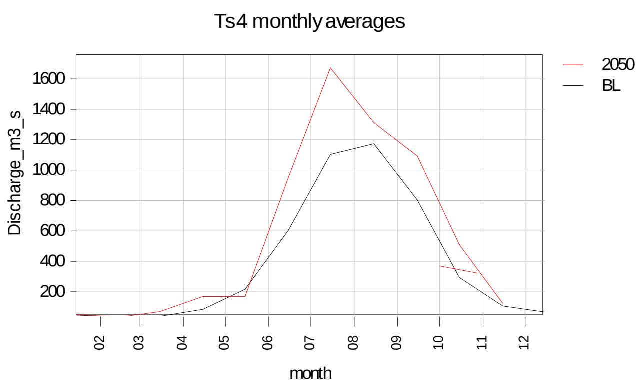




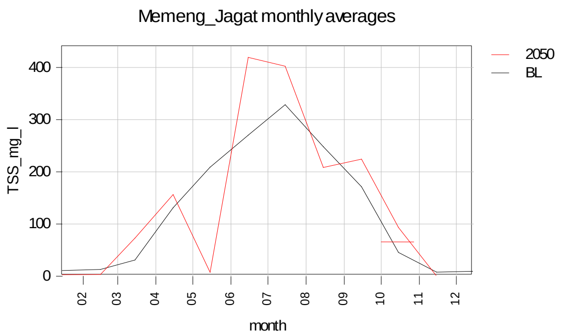
River Discharge m^3/s

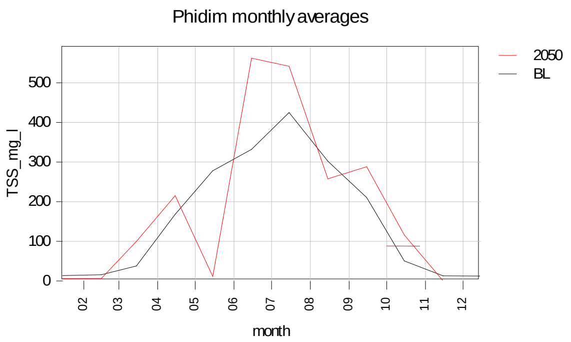


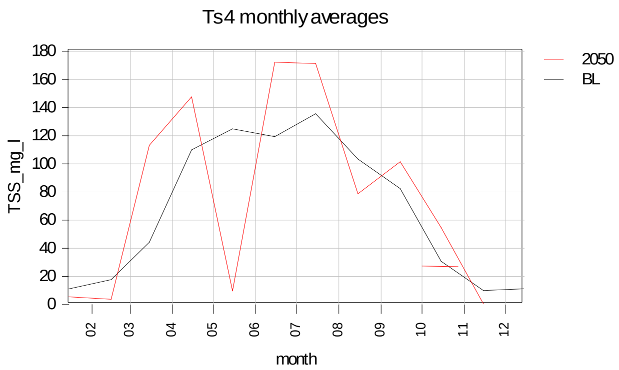




Total Suspended Solids (TSS) in the Rivers (mg/litre)







ANNEX B: VULNERABILITY ASSESSMENT MATRICES

Asset – Subhang Khola Irrigation System with 250ha command area. Major elements are:

- Free intake structure
- Main Canal lined and unlined with length of 3.3km
- 10 no of superpassages and 8 No of outlets

Threat	Interpretation of threat	Exposure	Sensitivity	Impact Level	Impact Summary	Adaptive capacity	Vulnerability
Increase in Max. temperature and evapotranspiration	▪ The average monthly maximum temperature is to increase by 1.6°C throughout the year	[1]H	L	M	• Water required at intake slightly increased particularly for paddy land preparation • More chance of disease to winter vegetable crops	M	M
Increased Rainfall	▪ Precipitation increase during early and mid-monsoon period	[2]H	H	H	• Could reduce water demand during the monsoon period	L	H
Landslides	▪ High intensity rainfall events increase during monsoon	[3]H	VH[4] [5]	VH	• Damage to main canal alignment • Loss of irrigation supply to command area	L[6]	**VH**

1 Linkages with other sectors

DADO not active in the area to provide farmers with extension services

[1] Average monthly maximum temperature increase by 1.8°C throughout the year and average monthly ETo increases during monsoon
[2] Monthly average daily rainfall increases slightly during early monsoon period
[3] Intensity of high rainfall increases causing soil erosion and saturation of steep hill slopes
[4] Main Canal infrastructure in poor condition
[5] Main canal crosses steep slopes with fragile soils and poor drainage facilities and already experienced landslide events
[6] Repair or rehabilitation of any landslide induced damages beyond the capacity and financial resources of farmers to cope with

Asset – Lamichanedhar Irrigation System, Major elements are:

- Free intake structure
- Main Canal lined with stone Masonry 4.5km
- Canal system is extensively damaged
- Command Area is 160 ha.

Threat	Interpretation of threat	Exposure	Sensitivity	Impact Level	Impact Summary	Adaptive capacity	Vulnerability
Increase in Max. temperature and evapotranspiration	▪ The average monthly maximum temperature is to increase by 1.6°C throughout the year	[1]H	L	M	• Water required at intake slightly increased particularly for paddy land preparation • More chance of disease to winter vegetable crops	M	M
Increased Rainfall	▪ Precipitation increase during early and mid-monsoon period	[23]H	H	H	• Could reduce water demand during the monsoon period	L	H
Landslides	▪ High intensity rainfall events increase during monsoon ▪ Increased number of landslides	[4]H	[5]H	H	• Damage to main canal alignment • Loss of irrigation supply to command area	L[6]	**H**

1 Linkages with other sectors

DADO not active in the area to provide farmers with extension services

[1] Average monthly maximum temperature increase by 1.8°C throughout the year and average monthly ETo increases during monsoon
[2]Monthly average daily rainfall increases slightly during early monsoon period
[3] Rainfall events occur more frequently than before
[4]Intensity of high rainfall increases causing soil erosion and saturation of steep hill slopes
[5] Main Canal infrastructure in poor condition
[6] Repair or rehabilitation of any landslide induced damages beyond the capacity and financial resources of farmers to cope with