State of the Kamala River Basin, Nepal

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Contents

Summary

The Kamala Basin in the south-east of Nepal has been chosen by the Government of Nepal as a pilot basin to develop capacity in basin planning. The Kamala Basin Initiative is jointly supported by the Government of Nepal and Government of Australia to further scientific cooperation around water resources management.

The Kamala Basin is important in terms of agricultural production, but has complex issues related to high levels of poverty, flooding, sediment erosion, and water resources distribution and availability during the year.

The Kamala Basin is a densely populated part of Nepal intersecting three provinces, four districts, 15 municipalities and eight rural municipalities. The mix of castes, ethnicities, and religions varies from the Middle Mountains, to Chure and the Terai region.

The workforce is transitioning from agricultural subsistence to non-agricultural occupations, with 33% of the households having a member who has migrated for employment opportunities outside the region or overseas.

More than 70% of the population work in the agriculture sector, mainly producing rice, wheat and maize. The Terai region, with its flat plains, is extensively used for food production through the Kamala Irrigation schemes; in the fertile valleys there are farmer-managed irrigation systems; while the Middle Mountains and Chure areas are predominantly used for terraced agriculture and forestry.

Agricultural production is strongly tied to water availability through irrigation using surface water and groundwater, but surface water is only adequately available during the monsoon, even in the large irrigation systems.

Flooding of the region causes significant damage during monsoon season. The districts of Siraha and Dhanusha were particularly affected in Nepal's 2017 flood. The National Planning Commission estimated that Nepal's recovery would cost USD 705.1 million (NPC, 2017). Monsoon floods are predicted to increase under a changing climate (Scott et al, 2019).

Studies are showing that under likely future climate conditions, monsoonal precipitation is projected to increase by 4–12% in the near future in the region. Intensification of extreme precipitation events is inconclusive between studies but increased air temperature is already evident (MoFE, 2019, Wester et al, 2019), which may demand adaptation actions to traditional agriculture.

Damage from floodwaters is compounded by landslides, mainly in the Chure region, produced by high level of soil erosion causing accumulation of sediment in irrigation infrastructure. Additional to a natural phenomena, human activities are exacerbating the impacts of floods and landslides.

As part of the ongoing process of developing strategies that will improve the welfare of communities in Nepal, this state of the basin provides information of the current condition of water resources in the Kamala Basin, including how water is used, water quality and trends in how the water resource is changing.

Synthesis of main issues in the Kamala Basin

Monsoonal floods are impacting communities and infrastructure

High sediment loads in the river system are increasing flood risk and damaging infrastructure

Water availability is constraining agricultural production

Infrastructure design, construction and maintenance are not meeting current needs

Labour is scarce, land per household is limited and agricultural profitability is low

Institutions need stronger integration

Potable water for domestic purposes is not uniformly accessible

Knowledge about key issues and available primary data are limited

1 Introduction

1.1 Outline and objectives

The local and regional economy of the Kamala Basin has a high dependence on water. Water availability is dependent on monsoon climatic patterns, where heavy rainfall mainly concentrates in four months (June to September).

Much of the rainfall becomes runoff, with streamflow and water availability in the basin varying substantially during the year, ranging from floods to drought. These conditions limit water access during the dry season (around the months of November to March). An effective integrated water resources management is needed in order to support water access for agricultural and industrial activities, environmental sustainability and human consumption.

This document presents up to date water resources related data and trends for the Kamala Basin. The document intends to support the development of the Kamala Basin Water Resources Development Strategy, which seeks to support effective actions to obtain the most feasible and effective use of water resources, considering present and future demands, stakeholders' needs, and potential limitations to provide water across the basin.

The main objectives of the State of the Kamala River Basin are to:

- make water resources data available to a broad audience
- describe local characteristics related to water resources management and their influence on the development of the region
- identify issues and limitations of water resources management to be addressed in the strategy in order to improve economic, environmental and social conditions
- collate the necessary information to support the Kamala Basin Water Resources Development Strategy.

1.2 Basin planning in Nepal

Internationally, basin planning has emerged as a key tool in water resources management, especially where the benefits from water resources need to be shared among different economic sectors and the environment, or shared between user groups, such as those upstream and downstream in a basin.

By considering all impacts of development, basin planning provides a useful tool for supporting sustainable development.

The Government of Nepal is supporting basin planning initiatives across every Basin in Nepal. Through these initiatives, and subsequent activities, the Government aims to harness Nepal's rich water resources to improve water distribution in the country and support social, economic and environmental benefits.

In the Kamala Basin, the Government of Nepal, in collaboration with the Government of Australia, is supporting the development of the 'Kamala Basin Water Resources Development Strategy'. This strategy is being developed with the participation of key stakeholders of the Kamala Basin to ultimately improve the welfare of people and communities across the basin in a sustainable way.

The vision of the 'Kamala Basin Water Resources Development Strategy'

- Improve the welfare of the communities in the basin through changes to the way water is managed and distributed.
- Build a new road away from the business as usual with challenges of ageing infrastructure towards improved water and food security in the long term (Figure 1).

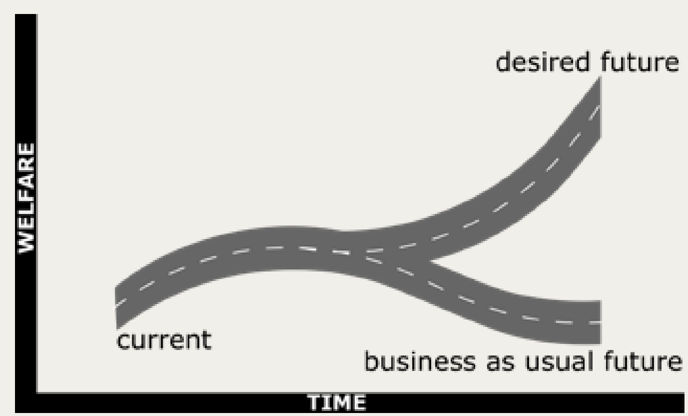


Figure 1 The vision of the Kamala Basin Initiative

The Strategy will not identify specific detailed projects, but will provide high-level guidance and evaluate development pathways.

The Strategy is a key step in developing the Basin Plan which is being established under Nepal's National Water Resources Policy and the National Water Act – Water Resources Legislation, which are under development.

While the plans anticipate increasing certainty for people and organisations who might invest in Nepal, they also aim to be adaptable to new knowledge and changing circumstances, especially in the face of the potential effects of climate change in the region (Wester et al, 2019).

The State of the Basin collates the relevant information to examine the current situation and dependency of water resources. In consultation with stakeholders, a range of preferred future pathways are identified and compared in order to assess different development options.

These are discussed and agreed to establish a desired development strategy that provides elements and directions for the basin plan and respective changes to improve welfare (Figure 2), (Foran et al, 2018).

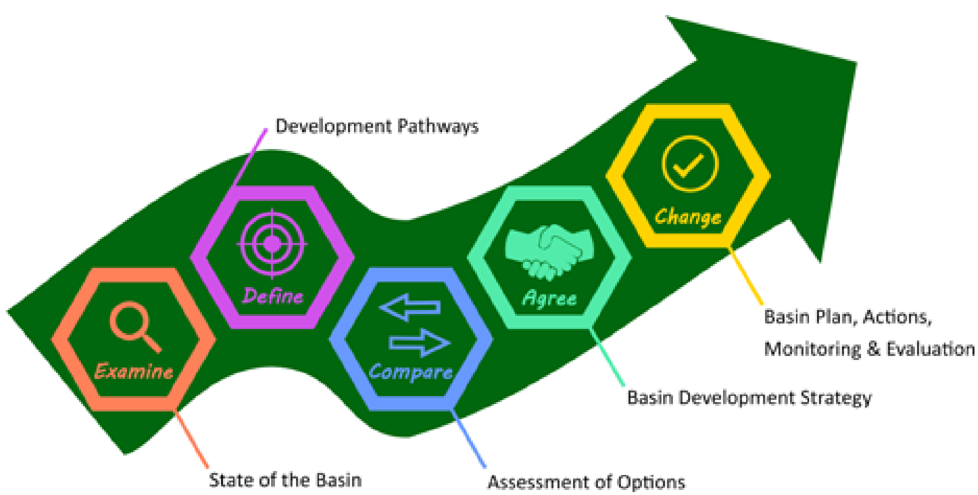


Figure 2 The State of the Basin in the context of the Basin Plan

1.3 Water Resources Management background

The welfare of people in the Kamala Basin is strongly tied to the availability of water. The water resources of the basin support environmental health, industrial activity and household needs such as drinking water for people and livestock, and irrigation for crops and pasture. The water requirements are growing due to the need for water for irrigation. This becomes more critical considering the variability in precipitation and increase in groundwater use.

The first major irrigation infrastructure constructed in the Kamala Basin was the Kamala Irrigation Project (KIP) in the 1970s. The Kamala River surface water supported canal systems and irrigation expansion across 25,000 ha of the districts of Dhanusha and Siraha. In addition, increasing mining for sand and gravel, clearing of forest on the edge of the Chure and the construction of embankments, all contributed to a transition from a natural system to a human controlled and altered system.

The development of infrastructure contributed to improving agricultural production and reducing risk of flood in the basin. Further water management developments have been proposed: (i) to supply water from the Sunkoshi River to the Kamala River and across larger areas of the Terai; and (ii) to build additional embankments in areas more susceptible to floods and erosion and sediment control measures on the Kamala River and tributaries.

The local population has welcomed these developments and desire more interventions (CSIRO, 2017). However, JICA (2016) identified a series of problems, such as the amount of sediment accumulated in canals in the irrigation development, and that parts of the KIP were incomplete. The reasons include scarcity of financial resources and water user associations that have become inactive. Local assessment shows that water availability will be a persistent problem across the basin, as in most of the medium-sized basins of Nepal (Pandey et al, 2012).

With this in mind, including stakeholders in the process, considering a wide range, and using the best available information are crucial to the development of the 'Kamala Basin Water Resources Development Strategy'.

"Our settlements are prone to flood. Our municipality is surrounded by three rivers. Gagan and Mainavati River in addition to Kamala have surrounded this municipality. And as it is border area, we need to think how we can save this area when it floods."

– Dr Namita Yadav,
Deputy Mayor of Siraha Municipality

"Our municipality has allocated a budget of NPR 1 crore for the preparation of detailed project report (DPR) to build check dams at Gwang Khola and collect water. The Kamalamai Municipality is also working on check dam preparation for the protection of Chure Area. We have also requested that existing Forest Committees take on afforestation activities."

– Khadga Bahadur Khatri,
Major of Kamalamai Municipality

"Kamala has ample water during the planting season but it rains during the same season. But during offseason, the water is scarce and there is a problem in agriculture. Farmers will benefit if we can arrange an underground irrigation system."

– Nuthari Yadav
Agriculture section Kalyanpur Municipality

2.1 Location, geopolitical, physiographic regions and soils

The Kamala Basin is located in the south-east of Nepal, close to the border with India, and has a drainage area of about 208,446 ha, which is equivalent to 1.42% of total area of the country.

Administratively, the basin area intersects three provinces and four districts. The district of Udayapur occupies 20% of the basin in Province number one, Siraha district covers 19% of the area and Dhanusha 14% and both are in Province number two, and Sindhuli district occupies 47% of the total area of the basin and is in Province number 3 (Figure 3).

The basin has elevation ranging from 70 masl in the south part to 2,180 masl in the north-east. The Kamala River originates from the Mahabharat Range or Middle Mountains, and flows through Chure to the Terai plains before entering India.

About 67% of the basin area lies below 600 masl and 27% lies between 600 masl and 1,200 masl, while the remainder, 6% of the area, lies above 1,200 masl (derived from USGS, 2004) (Figure 4).

The topographic characteristics have a strong influence on the economic activities and population distribution in the basin and in neighbouring districts.

The Kamala Basin covers three physiographic zones: Middle Mountains (20%), Chure or Siwalik (64%), and Terai (16%) (Figure 5), embracing areas of 41,181 ha, 133,647 ha and 33,618 ha, respectively.

The Middle Mountains zone is concentrated in the north part of the Basin with elevation varying from 800 to 2,200 masl, bedrocks composed of phyllite, quartzite, limestone.

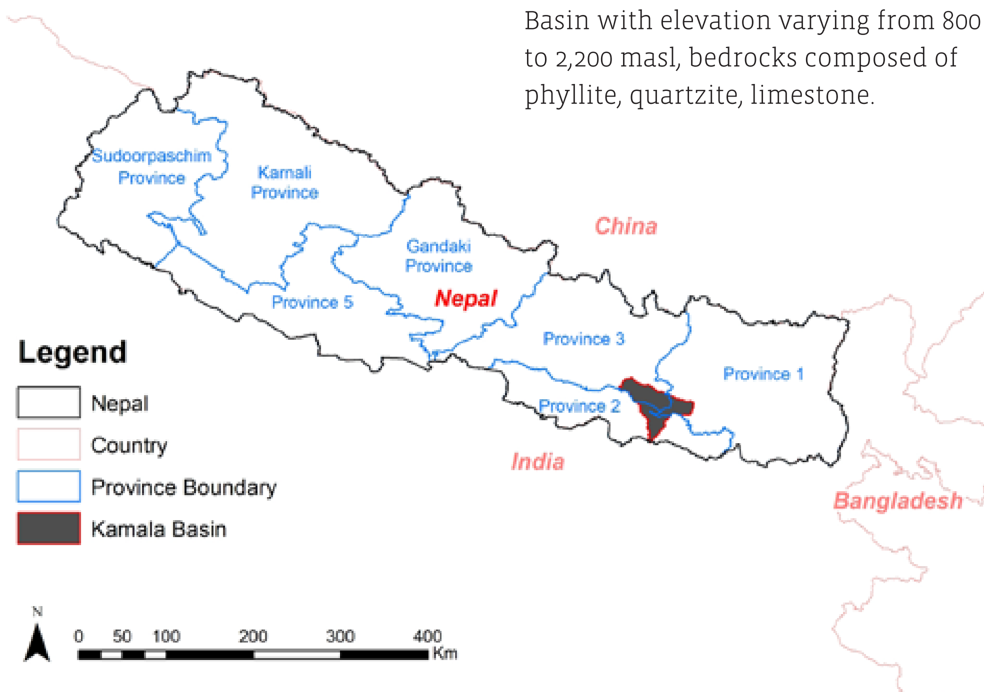


Figure 3 Kamala basin location in Nepal and province boundaries

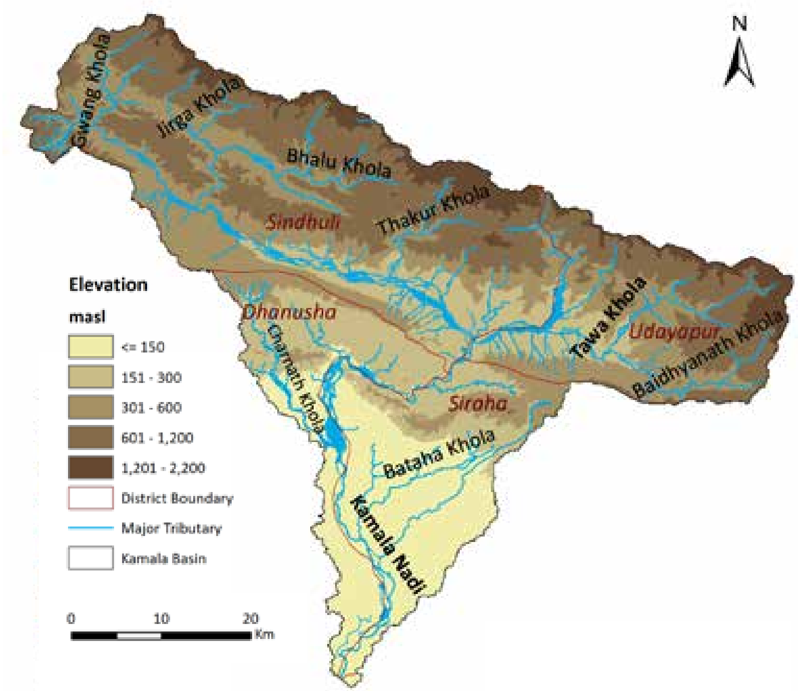


Figure 4 Kamala Basin elevation classes (in metres above sea level, masl), administrative districts in the Basin and river network

Figure 5 Districts and main physiography of the Kamala Basin

Its fertile soil is used for terraced farming to produce mainly rice, wheat and maize crops, and fruit (MOAD, 2017).

The Chure or Siwalik zone is located in the central part of the basin and includes all four districts; the elevation varies from 150 to 1,200 masl. Predominantly composed of tertiary conglomerates, sandstone, siltstone and mudstone, the physiography has been impacted by progressive processes of erosion and degradation of vegetation aggravated by selected deforestation. Its soils are highly susceptible to erosion and forests play an important role in soil and water conservation (MFSC, 2016). The lower part of Chure, also known as Dun valleys, has fertile soils suitable for agriculture.

The Terai is where most of the people live and economic activities happen. Due to the predominantly flat topography and fertile floodplain soils, this part of the basin is where most of the irrigated agriculture occurs.

The Kamala River flows through all three physiographic zones. It originates from Sindhuli Gadi in Sindhuli district in the Middle Mountains zone, and initially goes to the south then changes toward the south-east near Maithan, parallel to the Chure hill.

The river makes a U-bend in the middle of the basin and enters into the Terai at Chisapani.

Within the Chure and Terai zones, the river is successively joined by the Chadaha Khola and Thakur Khola in Sindhuli, the Tawa Khola in Udayapur, the Sualaha Khola in Siraha, and the Charnath Khola in Dhanusha (Figure 4).

The soil texture in the basin is predominantly loam (35%) mainly in the Chure and part of the Terai (DOI, 2017).

Soil texture influences the capacity of the soils to retain water. The ability of soils to hold water is critical for plants and the water holding capacity of a soil can be estimated from its texture. This information is important to estimate water demand for irrigation.

To illustrate, the estimated soil water holding capacity of the soils in the Kamala Basin is shown in Table 1 and reflected in Section 4.2.

Table 1 **Soil type in the Kamala and estimated soil water holding capacity**

Soil type	% area in the basin	Estimated mean soil water holding capacity (mm water/mm soil depth)
Clay	4.3	0.12
Clay loam	12.3	0.14
Fragmental/skeleton	11.2	-
Loam	34.8	0.14
Loamy sand	0.0	0.06
Sand	1.0	0.04
Sandy loam	20.3	0.10
Silty	0.0	0.25
Silty clay	0.7	0.14
Silty clay loam	0.4	0.17
Silty loam	12.3	0.18
Water body	2.4	-

Source: Land Resources Mapping, DOI, 2017 and Saxton and Rawls, 2006

2.2 Climate

The Kamala region is hot and humid during the summer monsoon (June to September) and dry and temperate in the winter (December to February). For much of the basin, rainfall is greater than 1,000 mm during the summer monsoon, and less than 100 mm in winter.

Figure 6 shows that the highest rainfall occurs in the north-west, followed by the north-eastern ranges. This results in an annual pattern of flooding in monsoon months, and drought during winter.

There is global concern that changes to climate might increase temperature and extreme events of rainfall causing adverse impacts, such as increased mortality, increase risk to crop production, flooding and soil erosion (Dunne et al, 2013, Parmesan et al, 2003, Hirabayashi et al, 2013, Yang et al, 2003).

A number of studies have examined historical changes in climate across all or parts of Nepal, and have indicated a general trend of increasing temperature, while changes in precipitation are less clear with high variability between locations and indices (Duncan et al, 2013, Neupane et al, 2017, Ichiyanagi et al, 2007, MoFE, 2019, Scott et al, 2019, Wester et al, 2019).

An analysis of data from meteorological stations closest to the Kamala Basin supports these findings.

Global studies of future climate across Nepal indicate that temperatures and monsoon precipitation are likely to rise (OECD, 2003; IPCC, 2007; GoN, 2008; NCVST, 2009).

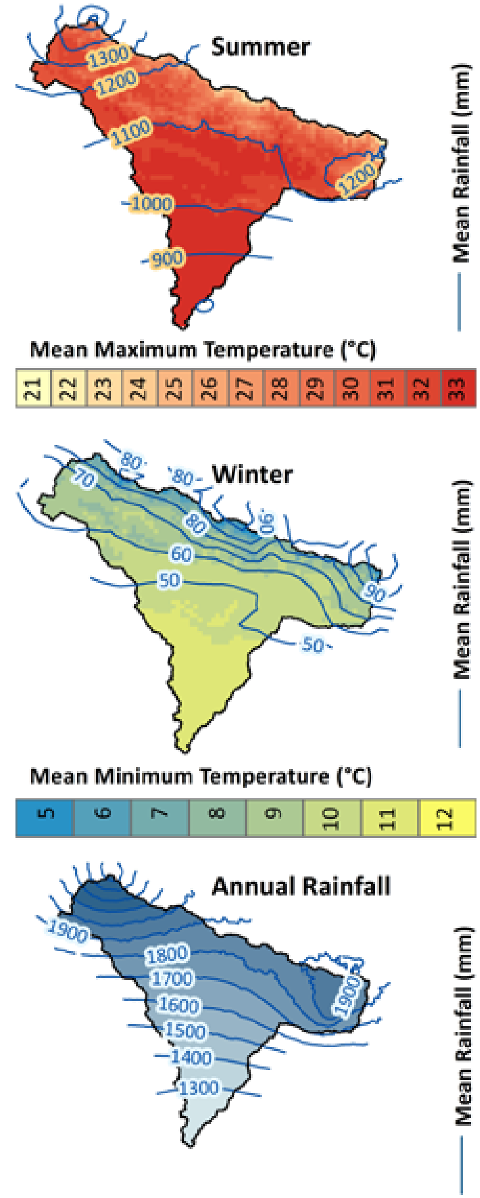


Figure 6 Rainfall and temperature during summer (top), and winter (middle) and annual rainfall (bottom) in Kamala Basin

A recent study of climate change scenarios for Nepal (MoFE, 2019) shows that:

- average annual rainfall is likely to increase 2-6% by 2045
- average annual mean temperature is likely to rise 0.9 to 1.1 °C by 2045
- Rainfall pre-monsoon is projected to decrease by 4-5% for the same period but projections of rainfall have a large degree of uncertainty
- More events of intense rainfall and extreme warm days are likely to occur creating more water-related hazards in the future.

Tipping bucket rainfall gauge at Chisapani Bazaar (above).
The Department of Hydrology and Meteorology is progressively replacing older rainfall gauges with automatic weather stations that send real-time weather information across the mobile networks.

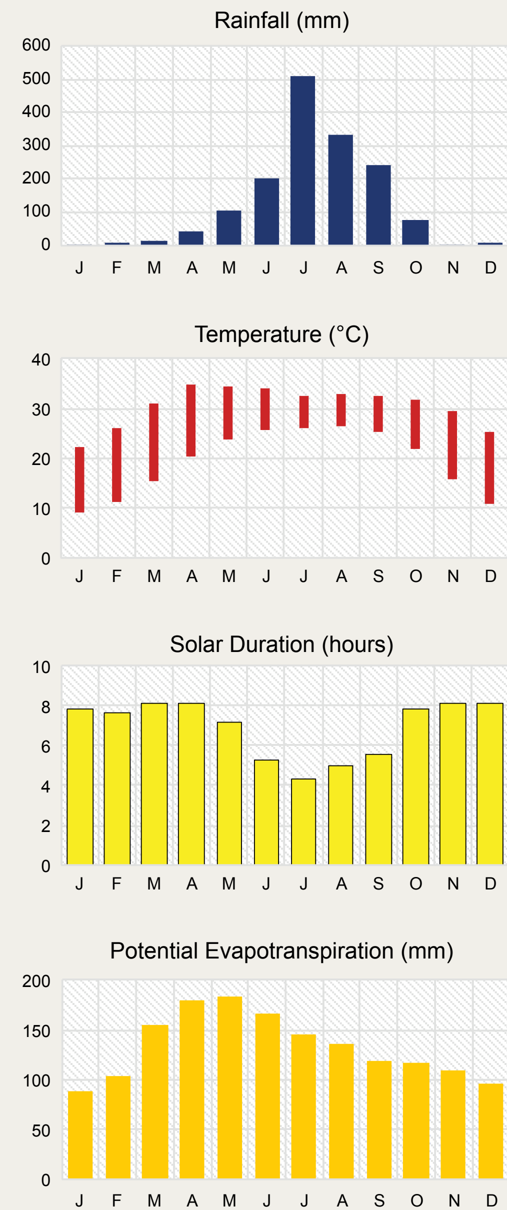


Figure 7 Mean monthly rainfall, temperature, hours of sun and potential evapotranspiration at Chisapani Bazaar meteorological station

2.3 Geomorphology and geology related to sediment erosion and river instability

High sediment loads in the Kamala Basin cause issues for river stability and flood protection. Following a big flood more than 30 years ago, streambank erosion along the Kamala River forced the Chisapani Bazaar settlement to be relocated. The river had been progressively eroding its bank toward the village as the river changed course.

The causes of sediment issues are a combination of natural processes exacerbated by human activities such as deforestation and agriculture. Management responses are particularly expensive.

The GoN in collaboration with the Government of India invested in infrastructure projects to manage sediments and river instability in Dhanusha and Siraha with the construction of gabion embankments to control erosion in the Chure and embankments around the Kamala River and tributaries.

Natural sediment processes

Natural sediment processes include erosion, transport and deposition. Sediment and soil erosion are influenced by rainfall patterns, geology, hill slope and density of vegetation cover (Figure 8).

The hills of the Chure are susceptible to soil erosion and landslides because of loose rock formations and fragile strata (GoN, 2017). The rock formations are mainly composed of sandstone, mudstone, conglomerate, shale and claystone, with Karst systems in the Middle Mountains.

During rainfall events, sediment in the form of loose inorganic rock material and topsoil from the upland areas are transported downstream. During heavier events, landslides can contribute particularly large quantities of sediment.

The Chure region has been identified as being one of the main contributors of sediment load to the rivers originating from the southern region of the Basin (Adhikari, 2013).

Influenced by slope and river transport capacity, coarse and mixed texture sediment creates braided river channels (anastomosing) in the valleys with multiple in-channel features, such as sand and gravel bars.

The river channels in the basin are composed of boulders and gravels, sands and finer sediments, with a mix of sediment across the river corridor. Progressing downstream, the mix of particles changes in proportion, transitioning from sand and gravel to a higher proportion of sand and silts downstream. Part of the sediment is temporarily deposited along the river corridors, including stream banks.

When the Kamala River enters the Terai, the river slope reduces and the river tends to change shape and course frequently during the wet season.

Sedimentary deposition and river meandering occur naturally across the Gangetic plains which includes the Terai region (Chakraborty et al, 2010).

Human disturbance of sediment processes

Human activities in the Kamala region disturb the natural sediment and soil erosion processes, affecting the river shape and movement and causing pathways for deposition.

Three main disturbances contribute to sediment erosion and loss of topsoil: 1) intense sediment mining for the construction industry in Nepal and India, 2) degradation of vegetation in the Chure Hills and along the riparian areas, and 3) expansion of the unsealed road network.

These disturbances contribute to lateral river migration and marked river widening with streambank erosion, and are often associated with bed rising (aggradation). Due to the combined causes to higher sediment load, river bed levels have risen significantly, and around 2 metres of accumulation have been reported over the past 50 years in some stretches of the Chure rivers (Adhikari, 2013).

These problems have been observed particularly in the Kamala and Tawa rivers. Downstream, channel-floodplain connectivity has progressively been reduced through the construction of raised levees and modification of the river channel dimensions and shape.

Sediment management responses

Given the susceptibility of the Middle Hills and Chure to erosion, the Rastrapati Chure Conservation Program was created in 2014. The program focuses on conservation and protection projects of recharge areas, vegetation improvement, habitat conservation, erosion reduction and irrigation support, with the involvement of the local community.

Some recent erosion-reduction works involve streambank stabilisation, roadside erosion mitigation and different types of bioengineering works, which may often involve the construction of gabions.

Figure 8 (Top) Unstable hills causing erosion and sedimentation
Figure 9 (Bottom) Gabions built to protect the river banks

Awareness exists of the streambank protection needed in order to reduce the vulnerability of villagers and lands to the risk of rapid river migration (avulsion).

In the Terai, the Kamala River has been modified after construction of engineered infrastructure such as channel embankments and raised levees. Since 2002, infrastructure works have narrowed the river and increased its banks through levees in order to reduce bank instability and overbank flooding.

The project, implemented in Dhanusha and Siraha districts, created around 65 km of river embankment, and constructed levees and revetments in the form of gabions, piled geo-bags or sandbags, and porcupines (Figure 9).

Despite these flood control measures contributing to reduce the impact of monsoon precipitation, the risk of recurrent floods continues to threaten some of the weaker sections of the embankments.

Additionally, streambank erosion has been reported in combination with overbank flooding and riverbed aggradation. Considering the context of disturbances, it is likely that changes in river course might not be solely triggered by intense rainfall and high energy flooding.

The associated flooding may have resulted from combined and cumulative effects of local disturbances affecting sediment influxes from tributaries, or increases in the sediment load, or from local changes in channel slope (Jones and Schumm, 1999).

Factors affecting stream stability, other than rainfall

- Slope of gullies in part of the catchment, potentially formed after landslides, road construction or land degradation.
- Poorly and discontinuously vegetated stream banks.
- Intense mining of river material, including boulders, gravels and sands from stream banks, beds and other geomorphic features.
- Uncontrolled access to streams by people, livestock and motorised vehicles, disturbing riverbeds and banks, and even weakening constructed levees.
- Expansion of unsealed road construction, altering the nature of sediment delivery paths and overland flow in forested environments and potentially triggering gullying and land sliding processes.
- Deforestation in the Chure and material and sediment extraction in the hills and the plains.

2.4 Current land use and recent land use change

Land cover in Nepal over different periods (1990, 2000 and 2010), was estimated by ICIMOD (2013) using Landsat satellite images with a spatial resolution of 30 m.

Land use in the Kamala Basin was estimated using these land cover shapefiles. Changes in land use were determined by comparing land covers between 2000 and 2010.

In addition to land cover from the ICIMOD (2013) study, the global forest change dataset from Landsat 2000–2017 (Hansen et al, 2013), global human built-up and settlement extent dataset from Landsat 2010 (Wang et al, 2017) and Google Earth historical imagery were also applied to verify changes of land use in the basin.

In 2010, the coverages of forest and agricultural areas were about 59% and 35%, respectively (Uddin et al, 2015), with forest predominantly happening in the Chure and Middle Mountains zones and agriculture in the Terai and valleys of the Chure. In the upper basin, areas are terraced for agriculture.

The agricultural area in the Chure is generally developed along the Kamala River and Tawa River.

The land use classification shows the following attributes.

Forest Land

Forests are mainly composed of hardwood species, with a predominance of broad-leaved trees with a range of crown densities, and include protected and non-protected forests.

Agricultural Land

Agricultural land is located in the Middle Mountains, Chure and Terai. The cultivation of sloping lands in the hills is common practice in Nepal and occurs in the Kamala Basin using terracing. The type of terrace is a function of water availability for irrigation, physical constraints and cropping possibility.

The main area of agriculture is concentrated in the lower part of the Chure and the Terai plains with access to water for irrigation.

Shrubland and Grassland

The shrubland and grassland vegetation exists in all four districts and occupies about 2.3% of the basin land area.

Other Lands

The settlement or residential areas (including rural and urban), barren land, land covered by water bodies, sandbars and other wasteland are classified under 'other land'. The total area covered by the other land category is about 7,500 ha, which is about 3.6% of the total basin area. Within this category, barren land comprises about 2.4%, residential area about 0.4% and water bodies around 0.8% of the total basin area (JVS and PEI, 2018, Uddin et al, 2015).

Land Use Change

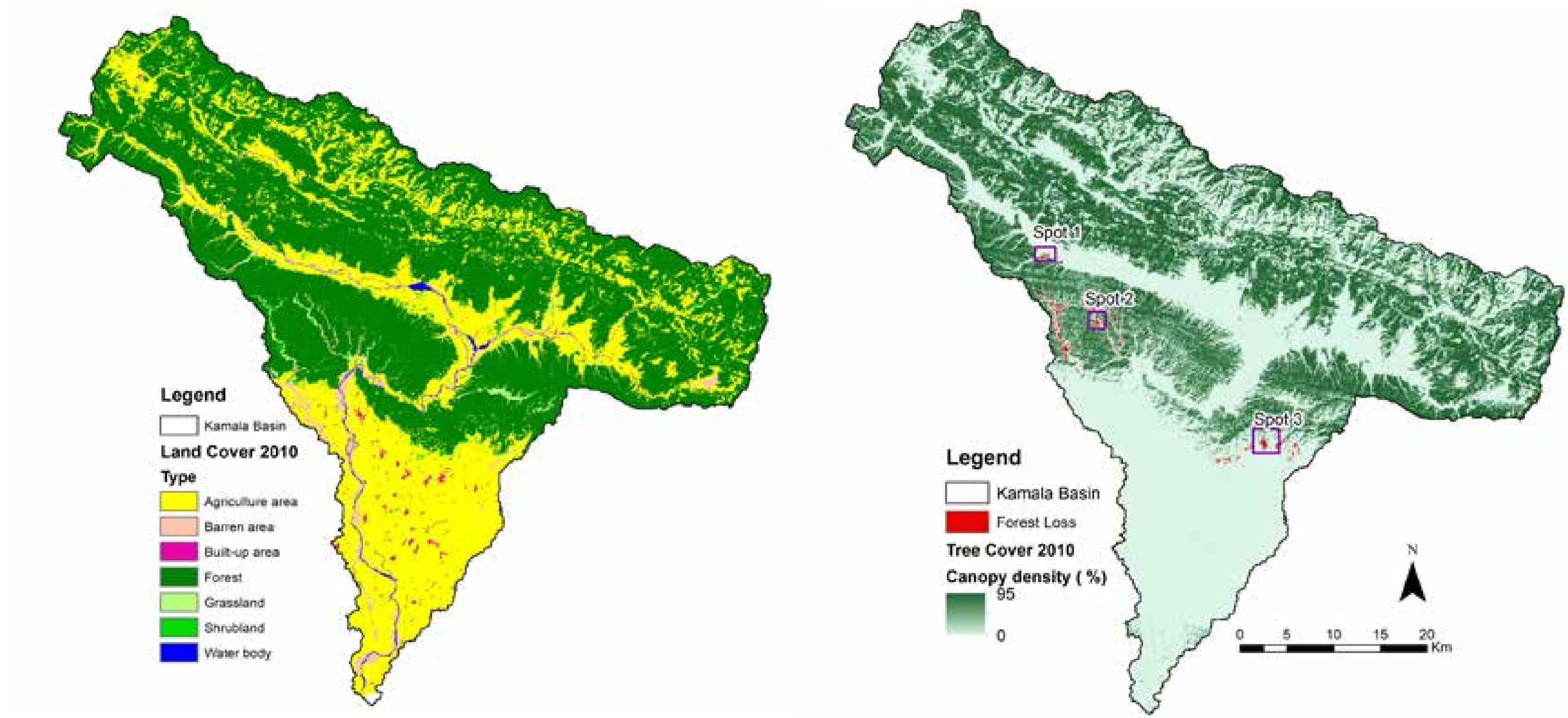
Nationwide changes in land use and land cover have been reported in several studies (GoN, 2017, NAST, 2012). However, there is no study showing detailed land use change patterns in the Kamala Basin. One of the major areas where land use change has occurred is in the Chure range. Some of the common threats identified through local community consultation and workshops are overgrazing, forest fire, over exploitation of resources, in-migration, flooding and encroachment (Karna, 2007).

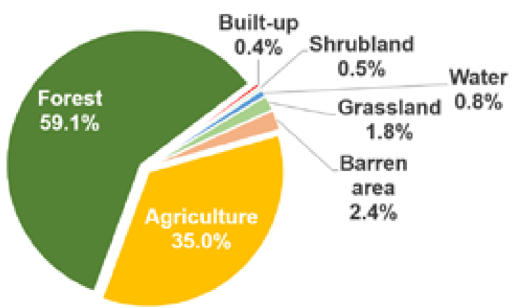
In most cases, forest and river terraces have been impacted for agricultural and settlement purposes (Neupane and Dhakal, 2017), which have historically posed additional flooding threats from the Kamala River.

Figure 10 shows the current land use classification and the canopy cover density in 2000 and 2010 from ICIMOD's regional database (Uddin et al, 2015). Comparing the forest cover in 2000 and 2010, it is estimated that 2,800 ha of forest was changed to other types of land use in the basin over this period, which represents 1.3% of the total area of the basin.

There are some places where significant loss of forest has been occurring in the Kamala Basin, as shown by comparing land use between 2000 and 2018 in the images of three selected spots in the basin. The main observed changes are expansion from forest to agriculture and human settlement in the basin.

At Spots 1 and 2, for example, land conversion has taken place along the river stream. Evidence of forest loss has also been found between boundaries of forest and agriculture regions, as shown in Spot 3.





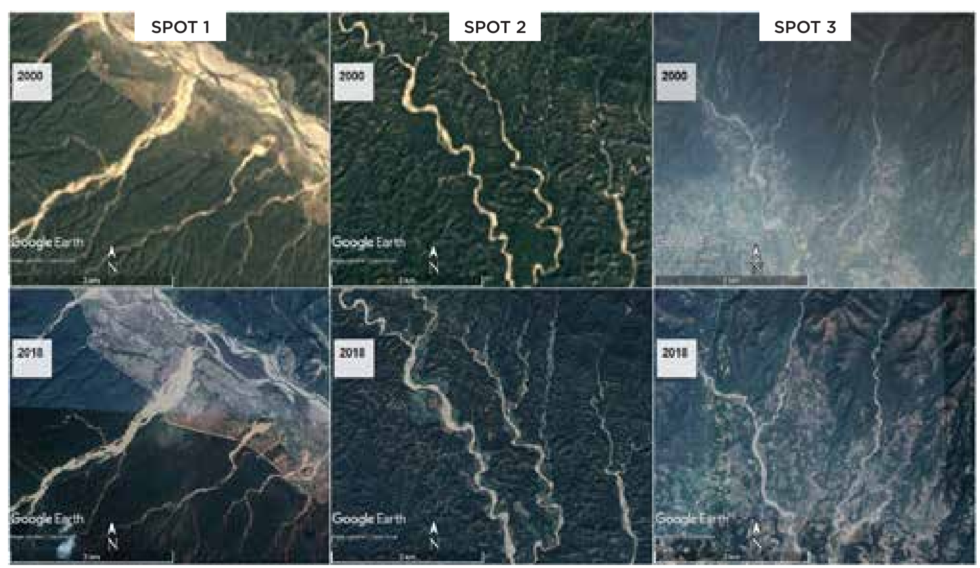


Figure 10 Land use cover (Uddin et al, 2015) in 2010 (top left map and pie chart), tree cover in 2010 (top right map) and examples of forest loss in three spots in the Kamala Basin between 2000 and 2018 *(Landsat imagery is courtesy of United States Geological Survey)*

2.5 Socio-economic conditions and trends

Demography and settlements

The Kamala Basin had a population of approximately 610,000, with approximately 120,000 households, in 2011 (CBS, 2019).

Settlements happen across the four districts of the Kamala Basin: Siraha, Sindhuli, Dhanusha and Udayapur districts. Table 2 presents the population, municipalities and other statistics of the basin across each of these districts.

The Kamala Basin is a densely populated basin. In 2017 the density was approximately 290 people per km^2 (CBS, 2019); in contrast the population density of Nepal as a whole was 204 people per km^2 in 2017 (World Bank, 2019).

Data from two of the Poverty and Vulnerability Assessment (PVA) surveys conducted with 544 randomly selected households located across 11 different municipalities in the Siraha, Sindhuli and Udayapur districts of the Kamala Basin in the period 2011–2012 (ICIMOD, 2019) show that approximately 82% of households reported a male head, with an average age of 49 years, and 5.8 household members. Female household heads were on average 43 years old and led households of 4.7 members. Approximately one third of male household heads, and half of the total female household heads, were illiterate.

Ethnicity, caste and religion

The Kamala Basin comprises a heterogeneous mix of caste and ethnic groups. With regards to caste, the Brahmin, Chhetri, Janajati of hill, Newar and Dalits dominate the population of the hilly regions while Terai/Madhesi dominate the population in the Terai regions, followed by Janajati of Terai (CBS, 2019).

In terms of ethnic and caste groups, in the hill districts the main groups are Chhetri, Magar, Rai, Tamang, Brahmin and Newar. In the Terai districts the major ethnic and caste groups are the Yadav, Muslim, Koiri/Kushbaha, Mushar and Teli (CBS, 2019).

Land tenure

Across the four districts of the Kamala Basin, there are more than 270,000 land holdings. Of these, approximately half of the holdings have 0.5 ha or less, which clearly reflects the importance of small agriculture and strong economic limitations.

For large agriculture, communities in the district of Siraha have the largest share of larger farms (over 3 ha), with 4% of district landholdings. In contrast, communities in the district of Sindhuli only have 0.1% of farms with area of 3 ha or more. In terms of tenure, most holdings are owned by the farmers, with approximately 10% of the land being rented (CBS, 2019).

Migration

Often young family members out-migrate in the search for better jobs, either in cities in Nepal or in foreign countries, in particular Malaysia, Japan, South Korea and the Gulf countries.

As an example of the level of migration in the Kamala Basin, the PVA data show that in the sample of two Sindhuli municipalities, in 2011–2012, 33% of the households had at least one member who had migrated to look for work opportunities elsewhere. Of those, half migrated to a foreign country.

This rate, however, seems to have increased in recent years as it has been estimated that out-migration is much more widespread, In 2014 alone, more than half a million people left Nepal to work in foreign countries (Shrestha, 2017).

Employment and Income

The main source of employment and income in the Kamala Basin is agriculture, which occupies more than 70 percent of the workforce. Out-migration for foreign employment has enhanced remittances and consequent economic activities in the basin, but has contributed to a shortage of labour for agriculture activities.

Table 2 Key indicators across the four Kamala Basin districts

District	Dhanusha	Sindhuli	Siraha	Udayapur	Total
Number of urban municipalities	5	2	6	2	15
Number of rural municipalities	1	3	2	2	8
Number of wards	30	42	62	23	157
Number of households	22,214	57,544	42,913	17,511	119,535
Number of land holdings	96,006	51,233	88,527	54,919	290,685
Land holdings below 0.5 ha	41,250	28,979	31,554	31,868	41,250
Total population	118,933	179,911	224,264	85,137	608,245
Female population	59,771	94,459	116,042	45,030	315,302
Multi-dimensional poverty rank [1]	n.a.	8	12	9	

Sources: CBS (2019) and Gerlitz (2015). 1 The higher the ranking, the higher the multi-dimensional poverty incidence in the district. Ranking constructed out of a total of 23 analysed districts (the PVA data does not record observations from households in the district of Dhanusha, so it is not possible to measure its multi-dimensional poverty).

The other employment opportunities in the Kamala Basin are jobs in schools, governmental offices, non-governmental offices and in the private sector, such as labour for construction, materials transportation and construction of roads, water supply, building and irrigation works.

Remittances are another important source of revenue for households. It is difficult to estimate the real level of remittances received by households in the basin as these range from very little to the majority of the income of a household. A PVA sample of 232 households in two municipalities of Sindhuli shows that a quarter of the households received remittances, and within this the average household received approximately half of its total income from remittances.

In terms of poverty, using the PVA data, Gerlitz et al (2015) provide a detailed analysis of multi-dimensional poverty across the country and rank the districts of Udapayur, Siraha and Sindhuli within the top half in terms of multi-dimensional poverty in Nepal (Table 2) – Dhanusha was not covered in the study.

This information, although not specific to the Kamala Basin since the existing data covers the whole districts and not just communities in the basin, indicates that the incidence of poverty is still relatively high in the basin, in comparison to other regions of the country.

Workforce, education and gender

Based on national statistics, the United Nations Development Programme (UNDP) ranked Nepal 118 out of 189 countries on its gender inequality index. In practice, gender can influence participation in programs, access to health care, education and credit, control of household and community resources, and influence political processes (Kadel et al, 2017).

Nepal has embraced many policies to empower women in each of these areas (e.g. including political representation as part of the constitution). Challenges remain in educational attainment, division of domestic chores, access to resources and representation.

In the Terai districts of Dhanusha and Siraha, attainment of secondary education or further studies is twice as likely for men than for women. In comparison, in the districts of Udayapur and Sindhuli, secondary education is less unbalanced.

Due to poor economic conditions and a scarcity of colleges and universities in the basin, most students do not have the opportunity to acquire higher education in their preferred areas. Female students are mostly affected in such circumstances, because their parents hesitate to send them away from home, or because early marriage is still prevalent in many communities, which increases school or college dropouts.

Women can spend an hour or two each day fetching water for drinking and other household purposes in Chure and Middle Mountains areas such as Katari Municipality, Udayapur. Likewise, they also spend hours at public taps, tube wells, wells, and rivers washing clothes and utensils.

Young women complained that despite being educated they are involved only in household tasks, while they would prefer to undertake work in small and medium-sized enterprises (CSIRO, 2017).

As discussed earlier, large numbers of people migrate out of their home districts. The majority of the migrant workforce are men (typically 20–44 years old) and with low levels of education, skills and qualifications.

Access and control of resources

Irrigating farm land is a major challenge faced by women in the Kamala Basin, especially during the dry seasons when the groundwater level and the flow of water in the Kamala River and its tributaries are low.

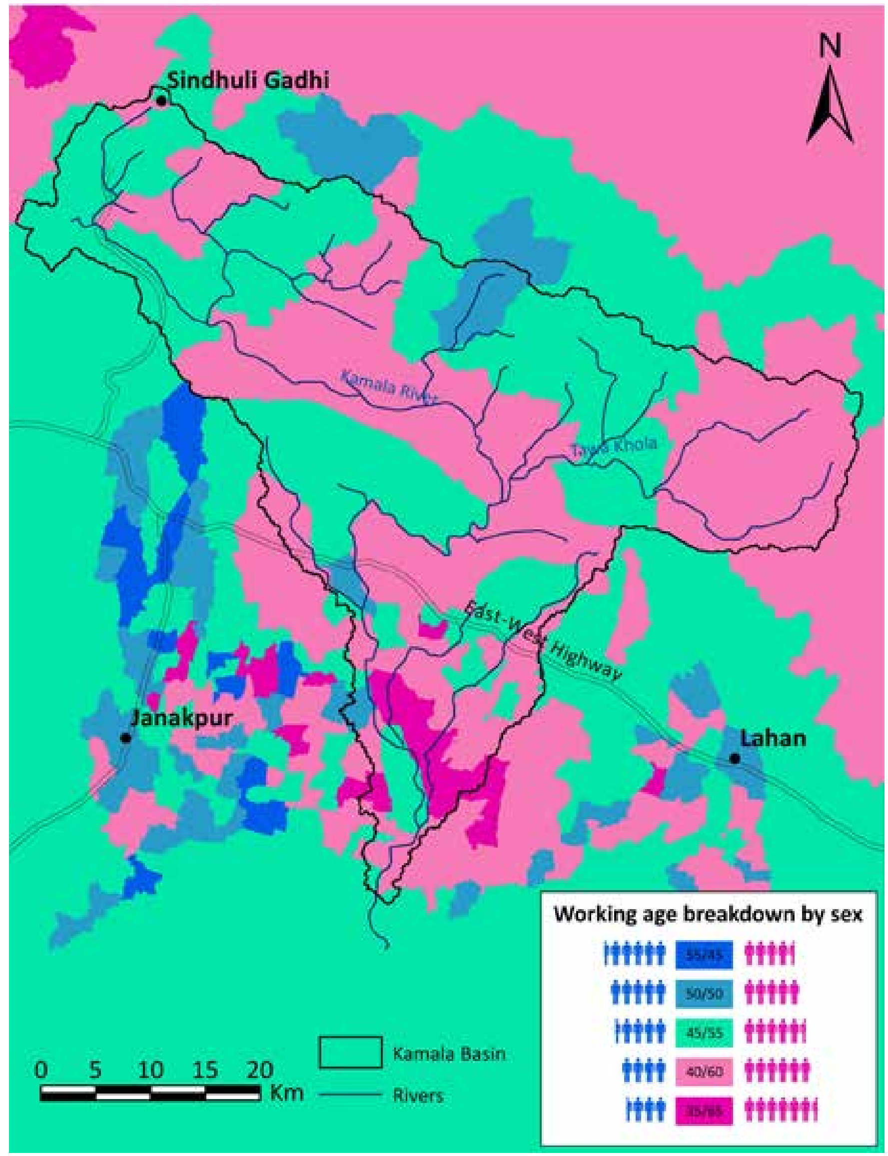


Figure 11 Working age and gender in the basin and surrounds

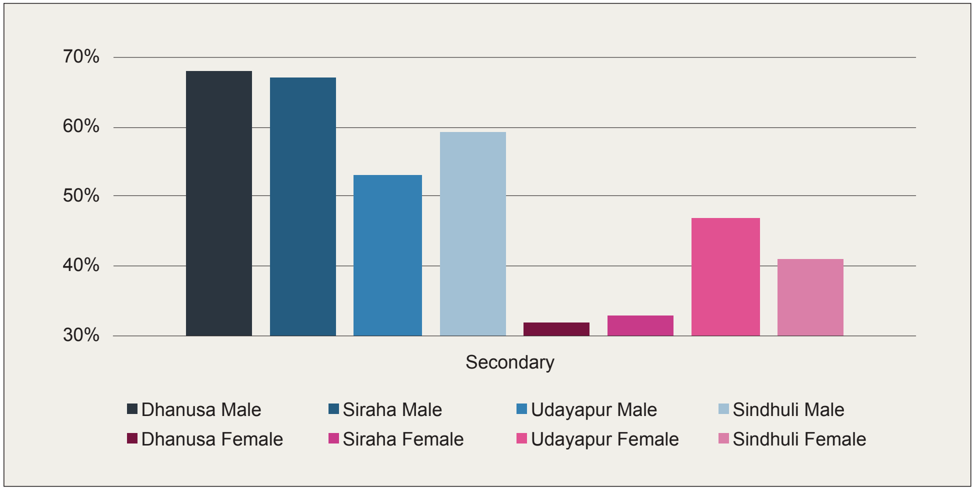


Figure 12 Secondary education in the districts by gender

In such situations, women farmers were found to be more vulnerable. For example, in some places, farmers who had access to electricity near their farms are able to use electric motors to extract water from the tube wells nearby. However, this was not feasible for most, and especially for women farmers, who lack technical skills and hesitate to speak to others and ask for help.

Some farmers also buy water from deep boring suppliers. This option is feasible to only those women farmers who can afford to pay 300–400 NPR per hour to irrigate 1 Kattha (0.34 ha) of land.

In such circumstances, women farmers in the Kamala Basin have no other option than to wait for rainfall.

In addition to this, during wet seasons, in places where water is distributed through the irrigation channels, women find it difficult to access water for their farm lands as they have to compete with men to channel water to their farm lands.

The prevalence of a patriarchal system sets boundaries on women's behaviour, making them less competitive and too shy to request equal rights in water distribution from irrigation channels. Further, as per the conversation with Dalit women from Karjhana Municipality, it was found that Dalit women face more challenges in competing with male as well as upper caste groups to irrigate their farm lands. They stated that they would get to irrigate the farm lands only after the upper caste groups irrigated theirs.

Representation

Increasingly, representation of women is being mandated at a number of levels. Supported by quotas in Nepal's constitution, at the 2017 local elections 40 per cent of elected officials were female. Likewise, quotas exist for Water User Group associations (33%) and a range of similar groups.

Key positions are still held mainly by men. For example, most mayors in the districts of the Kamala Basin are men, all the members on the KIP's main committee are men (JICA, 2016), and domain experts are far more likely to be men. JVS and PEI (2018) report that women in the community feel the need for better avenues to voice their problems if they are to take equal benefit from the managed irrigation systems.

Cultural

The Kamala River is used as a site for religious events such as cremations and festivals. In particular, the river is considered holy just downstream of Kamalamai Temple, Sindhuli. The Triveni Ghat in Dudhauli is a significant location in the local community for festivals and rituals.

Figure 13 Cultural water

Environmental flow

Environmental flows 'describe the quantity, timing and quality of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that are dependent upon these ecosystems' (Brisbane Declaration, 2007, Arthington et al, 2018).

The concept of environmental flow has been applied elsewhere to understand the link between river flow characteristics and ecological components. It is however, less developed in Nepal. Currently, provision shall be made to release water which is higher of either at least 10% of the minimum monthly average discharge of the river/stream or the minimum required as identified in the environmental impact assessment study report (MoWR, 2001). Determination of this value is derived using a hydrological method which calculates a fixed percentage of the mean monthly flow or minimum mean monthly flow in a section of the river. This method however, does not account for the natural variability of flow in the river (Alfredsen, 2015).

It is recognised that variable water regimes are required to maintain a dynamic river system where natural biodiversity and ecological processes are preserved (Postel and Richter, 2003, Lytle and Poff, 2004). Environmental flow assessments provide an understanding of the required flows in river systems considering seasonal flows, natural high flows, extreme low flows, floods and inter annual variability that determine the flow regimes of river systems. Substantial effort is needed to better understand environmental flow requirements across the Kamala Basin and in Nepal.

2.6 Biodiversity

Many livelihoods in Nepal and the Kamala Basin, such as farming and fishing, depend on biodiversity, while culturally, the environment and biodiversity support large festivals, requiring clean water and abundant food.

Species diversity is very high across Nepal, with the country supporting 3.2 and 1.1% of Earth's known flora and fauna, respectively, with a high level of endemic species (Ministry of Forests and Soil Conservation, 2014). This is significant when Nepal as a country only occupies 0.1% of global land area.

Kamala Basin biodiversity

There are very few studies that identify the species of flora and fauna that are present in the Kamala Basin. Some data on presence or absence of fauna exist, but information on native vegetation species can only be drawn from broader ecoregion studies.

These studies describe the Kamala Basin as being predominantly of the Tarai-Duar Savanna and Grasslands ecoregion with the northern section occupied by the Himalayan Subtropical Broadleaf Forests ecoregion including churia forests (Paudel et al, 2012).

A study reported across Nepal's churia forest zone indicates substantial biodiversity in this zone with 281 tree species, 186 shrub species and 322 herbaceous plant species (DFRS, 2014). It is difficult to pinpoint whether these species are all present in the Kamala Basin.

Sal forest, tropical deciduous riverine forest and tropical evergreen forest occur within the Savanna and Grasslands ecoregion. Tall grasses grow in riverine grasslands and forests (Paudel et al, 2012).

Again, it is unclear which species within these vegetation types grow within the basin and thus if any species are threatened.

Local faunal studies undertaken with the basin indicate key mammal species such as Asiatic Elephant are present as well as grassland species such as hog deer and barking deer. Studies suggest there are up to 29 fish species, one of which is near threatened (Shrestha 2008); 26 reptiles and amphibians (Shah and Tiwari, 2004, Aryal et al, 2010), three of which are vulnerable; 65 bird species (Parajuli, 2016) including the globally threatened Lesser-adjutant stork (Leptoptilo javanicus); and 46 mammals, with two endangered, two vulnerable and six near threatened.

Across Nepal, many species of flora and fauna are vulnerable. The Kamala Basin is both flood and drought affected, impacting freshwater fish and other aquatic species such as frogs and invertebrate species, as well as terrestrial animals and their habitats.

Figure 14 Frog species (left) and Kingfisher (right) at Kamala Basin

Other threats include habitat loss from deforestation, invasive species, wildlife poaching, fishing methods harmful to other animals/plants such as electrofishing and poisoning, landslides and damage caused by floods and landslides.

In-stream aquatic ecology is impacted by river mining for construction and associated erosion. A significant threat is posed to both flora and fauna with river flow regime alteration or diversion related to irrigated agriculture, and climate change.

A study undertaken by Doody et al (2016) uses conceptual models to highlight some of the key indicators of ecological change that might occur in relation to river or wetland regime changes. The relationship between ecological assets such as birds, fish and macroinvertebrates and flow regime changes is likely transferable to ecological assets in the Kamala Basin.

The Lesser-adjutant stork, for example, occurs in the basin and requires trees higher than 30 metres tall in order to successfully nest. Deriving baseline 'flow-ecology' relationships and improving conceptual models provides a means by which to monitor ecological flow-related changes in the future (Doody et al, 2016).

However, more detailed surveys are required to understand species presence and function across the Kamala Basin.

3 Water availability and sources

3.1 Surface water

There is limited available data on surface water in the Kamala Basin. Discharge was measured at the Chisapani (26.421 N, 86.175 E) hydrological station in the Dhanusha district during operations from 1956 to 1970 and 2000 to 2004.

The mean monthly flow data of the Kamala River obtained from the Koshi Basin Master Plan Study (JICA, 1985) from 1956 to 1970 at Chisapani station (station 598) was 44.70 m^3/s.

The minimum, mean and maximum monthly flows over this period are shown in Figure 15. The data shows extreme monthly streamflow caused by rainfall quantity and intensity.

During the dry season the rivers that originate in the Chure have either a very low volume of water or no perennial surface water flowing.

In contrast, during the wet season, rivers carry high volumes of water and sediments, varying with rainfall intensity during the monsoon season (Hannah et al, 2005).

However, even in the monsoon season, these rivers change water flows a few hours after rainfall events.

Due to the high level of infiltration and permeability in the rivers corridor the level of the rivers rise and decline quickly.

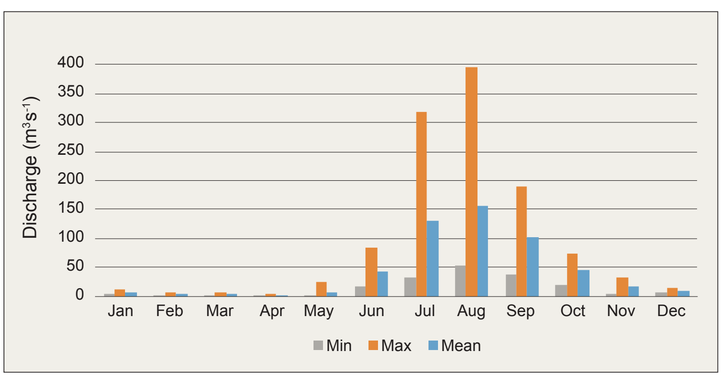


Figure 15 Minimum, maximum and mean monthly discharge of Kamala River at Chisapani station (1956–70)

Figure 16 Kamala River during monsoon season

Surface Water

Streamflow has been measured in the past at Chisapani, Ranibas and Inarwa (border with India). Technical issues from the high sediment loads make it difficult to measure streamflow and to maintain measurement stations. The longest records of flow are from Chisapani, though the records are mainly from German-supported studies in the 1960s (Muehlbauer, 1977). Since 2018 the DHM has installed two new automatic hydrological and precipitation stations in the Basin: Ranibas (86.03E, 27.70N) and Titriya (86.22E, 26.89N).

From past existing measurements and applying hydrological models, a historical sequence of streamflow across the Kamala Basin shows:

- **Spatial variability:** As with most catchments, although rain is predominantly in the hills, the water is accumulated in the rivers as the water travels downstream.
- **Flood variability:** The volume of water in a flood in a wet year is more than twice the streamflow of an average year.
- **Dry winters:** The water flowing during the winter cropping season (December to March) is a small fraction of the monsoon flow. An average of 61 MCM is insufficient to meet water demands in the Kamala Irrigation Project.

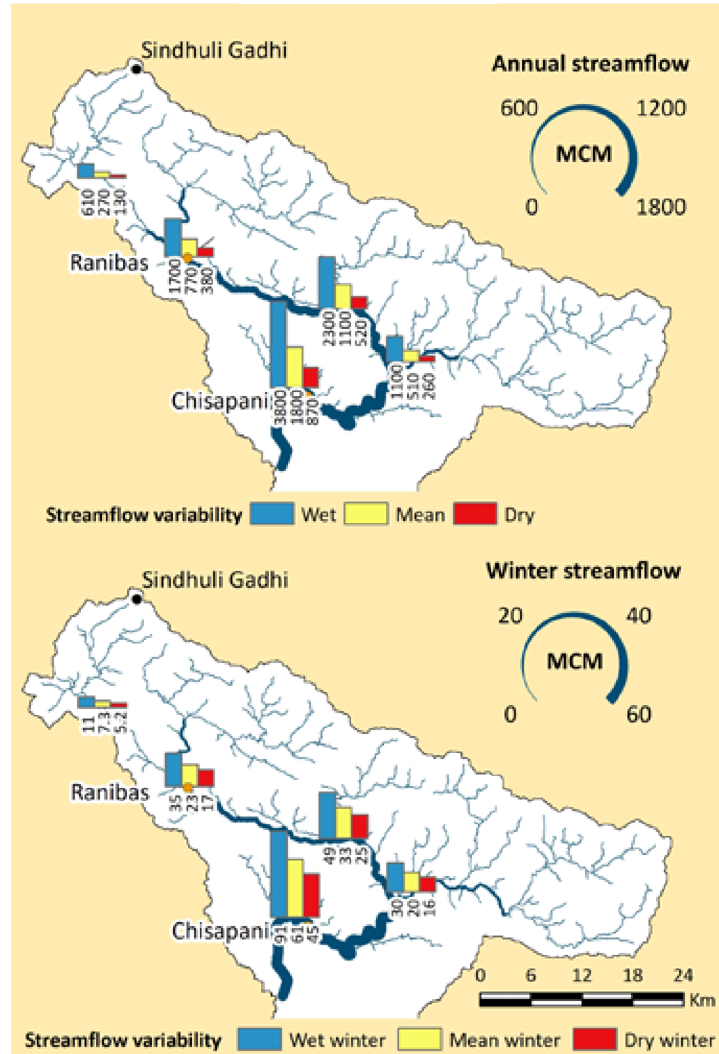


Figure 17 Annual and winter streamflow estimations, across the Kamala River, in millions of cubic metres (MCM) in average wet, mean and dry years (top figure) and winters (bottom figure)

3.2 Floods

Flooding in the Kamala Basin and surrounds threatens people's lives and causes major damage. Three people died in Dhanusha in the 2017 flooding, and the Ministry of Home Affairs estimates around 127,000 people were displaced from Dhanusha and Siraha (NPC, 2017).

The total recovery needs are anticipated to be in the order of USD 40 million, with housing (53%) and irrigation infrastructure (24%) the largest expenses.

Flooding is unavoidable due to the intense monsoon rainfall (e.g. >0.3 metres of rainfall in 24 hours) (NPC, 2017).

The heavy rainfall leads to several types of floods:

- Flash flooding from local rainfall in the Chure or Middle Mountains.
- Temporary waterlogging on the Terai plains..
- Build-up of waters flowing down the Kamala River, changing the river's course and spilling over banks, especially at the confluence of the Kamala and Tawa Khola and the Terai plains (e.g. floods in 2007).
- Failure of infrastructure such as embankments, drains and culverts.

Flood impacts

The villages along the Kamala River's edge in the Terai were badly affected by a flood in 2007.

On July 24, the Himalayan Times reported that the floodwaters, 'swamped houses, plantations, roads, markets, government offices and schools in the district headquarters of Siraha'.

About 1.5 km of embankment was destroyed and there was severe riverbank erosion.

In the 2007 floods, the waters inundated the flood plains for about a week due to overbank flow and the river flowed along alternative courses in Dhanusha and Siraha districts. In 2008 the Kamala River flowed changing the channel direction as shown in the satellite imagery.

The damage on the Indian side in the same flood event was reported to be severe, particularly due to the wider area under influence and flatter slope resulting in the water taking a longer time to drain (MOAC and FAO, 2011).

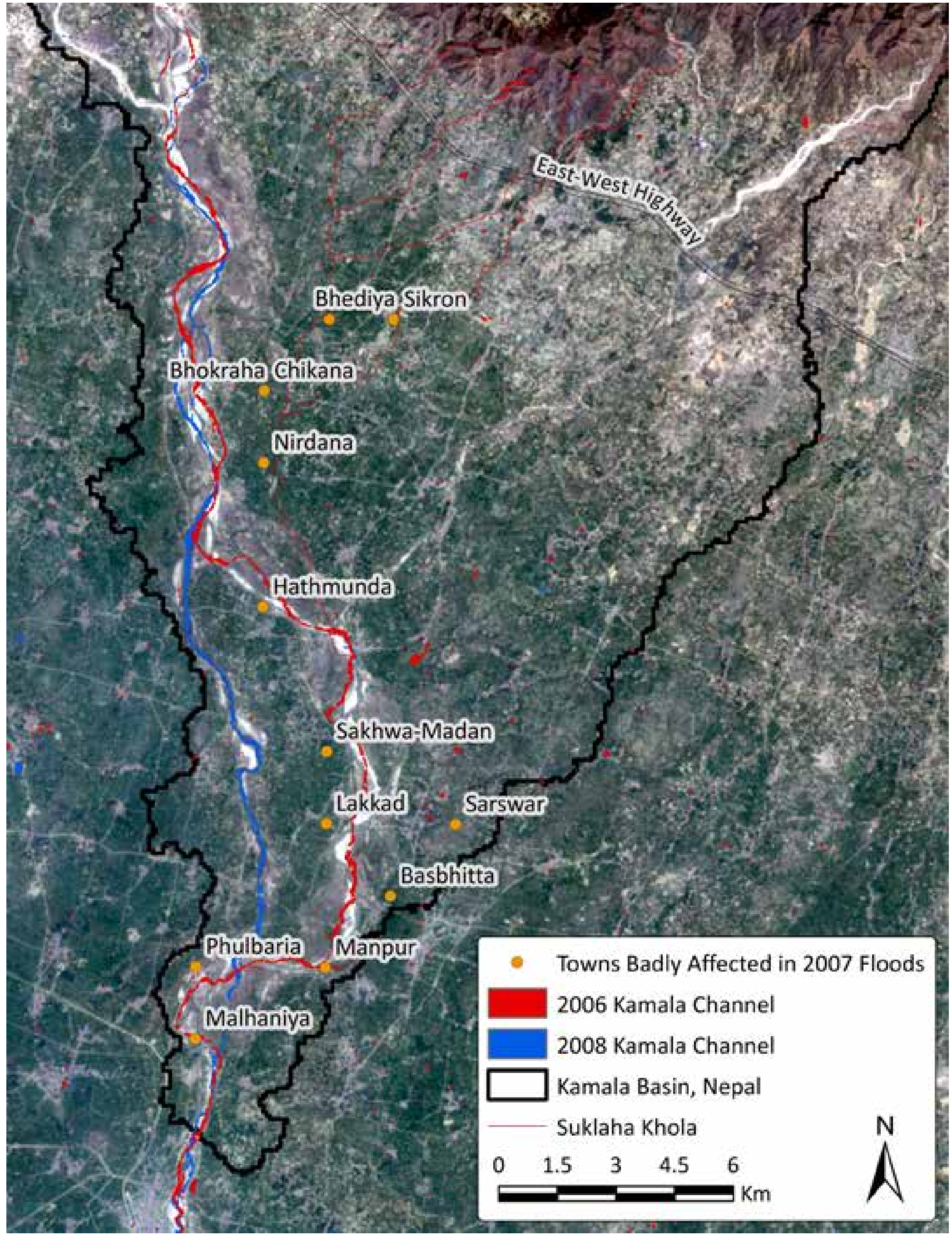


Figure 18 Communities affected by floods in the Kamala Basin in 2007 and change in the river channel from 2006 to 2008

3.3 Groundwater

Groundwater forms a significant component of the total water resource in the Terai plains. In Dhanusha and Siraha, groundwater supplies 85% of household domestic water needs and around 70% of households use groundwater for irrigation (Okwany et al, 2013).

GoN (2017) reports that there are 6,293 shallow tube wells in Dhanusha, and 5,932 shallow tube wells and 48 deep tube wells in Siraha. The current rate of extraction is considered sustainable and expansion is being promoted widely.

The major factors that determine sustainable levels of groundwater use are the volumes of recharge and extraction.

The Groundwater Resources Development Board (GWRDB) estimates recharge of the Terai plain at 8,800 MCM per year (GWRDB, 2019). Other studies have estimated the recharge for the Terai plains in the range 5,800 MCM/a to 10,745 MCM/a (Mukherjee, 2018).

Annual groundwater recharge in the Siraha and Dhanusha districts was estimated to be in the range of 122 to 279 MCM/a for Siraha (Kansakar, 1992) and 145 to 352 MCM/a for Dhanusha (Shrestha, 1992).

The GWRDB (2019) estimates annual consumption of groundwater across the whole Terai in Nepal at 756 MCM for irrigation and industrial purposes and 297 MCM for drinking water use.

Estimates of groundwater consumption for the Kamala Basin were not available. Analysis of data from observation bores of Dhanusha and Siraha districts suggests that shallow groundwater occurs across the Terai areas of the Kamala Basin and water levels come close to the ground surface after the rainy season.

Over the period 2004 to 2013 the observation bores indicated that groundwater levels varied in the range 0.1 to 7.5 m below ground, with seasonal patterns of filling during the monsoon and drying during the winter.

This indicates that water is available to be used. Based on the observed minimum and maximum water levels, it is estimated that annual

Table 3 Estimated number of shallow (STW) and deep (DTW) tube wells constructed for the purpose of irrigation within districts of the Kamala Basin (GoN, 2017).

District	Number of STW	Area in STW (ha)	No. of DTW	Area in DTW (ha)	Total irrigated area (ha)
Dhanusha	6,293	17,576	88	3,049	20,625
Sindhuli	164	412	0	0	412
Siraha	5,932	20,495	48	1,228	21,723
Udayapur	632	1,909	0	0	1,909
Total	**12,921**	**40,390**	**136**	**4,277**	**44,667**

replenishable groundwater could support irrigation of at least 9,250 ha of land in the Kamala Irrigation Project area. Increased usage may also favour availability of more storage for groundwater recharge.

Recorded discharges of the shallow tube wells in Dhanusha district range from 9 l/s to 16 l/s while it was 11 l/s in the Siraha district. This indicates a high groundwater yield, favouring extraction using irrigation tube wells and pumps.

Pumping

IFPRI (2016) reports that most shallow tube wells in Dhanusha use a 4.8 HP diesel pump. One pump costs approximately 20,000 NPR and could service around 4.8 ha.

Farmers rent out their pumps to other farmers and on an average one pump serves about 9 farmers within a radius of 1.8 km. Operating hours vary across seasons and districts. For example in Dhanusha a pump runs for an average of 81 hours during Kharif season, 104 hours during Rabi and about 17 hours in summer.

Figure 19 Open well and hand pump used for extracting water for domestic needs

Sugden (2014) reports that inequalities in landlord-tenant relations also affect the capacity of farmers to access groundwater from shallow tube wells. Typically, a landlord owning a larger landholding bores a well to access water and buys a pump set to extract the water (though some bores are collectively managed).

In Dhanusha around 30% of farmers owning 3 ha of land also own a pump set. For tenants, they typically rent the well and/or pump set from the landlord to irrigate their crops. The inequality reveals itself as increased usage costs for renters compared to owners and an increased capacity for owners to pump groundwater compared to renters.

Prospects

Despite opportunities to profitably irrigate land using shallow tube wells, IFPRI (2016) shows that the purchasing of pumps in Dhanusha appears to have plateaued since 2010. The water to diesel price ratio is much higher than in neighbouring countries (3.2 for Nepal vs 2.2 for Bihar or 2.0 for Bangladesh). Use of deep tube wells is also limited because of the equipment required for drilling as well as the high costs involved in maintenance.

Construction of deep tube wells is subsidised by the Government with 0 to 5% of the total costs paid by the farmers. The Government's allocation of funds to the deep tube well scheme is insufficient to meet all requests for new projects. The small number of operational schemes means that maintenance costs remain high, and most schemes fall into disrepair.

Kamala hydrogeology

The hydrogeology of the Terai plains in the Kamala Basin is composed of two major depositional units – the Bhabhar zone (towards the north) and the Terai (Shreshta et al, 2018).

The Bhabhar zone is situated in the foothills of the Chure, consisting of alluvial and colluvial coarse sediments.

The Bhabhar zone has an unconfined aquifer with a generally deep watertable. Intersection of the Bhabhar zone and the Terai plain marks the northern boundary of the Ganga basin.

The Southern Zone is underlain by recent alluvium with an average thickness of 1,500 m formed by the deposition of sediments in the rivers running from the North.

The rivers and streams frequently shift along the plain, sometimes over kilometres. Consequentially, the sediments are cross-bedded, eroded, reworked and redeposited, resulting in aquifers that provide valuable groundwater resources.

The depth profiles in the region, comprising alternating sand and gravel of various sizes mixed with clay, favour high groundwater potential (Figure 20).

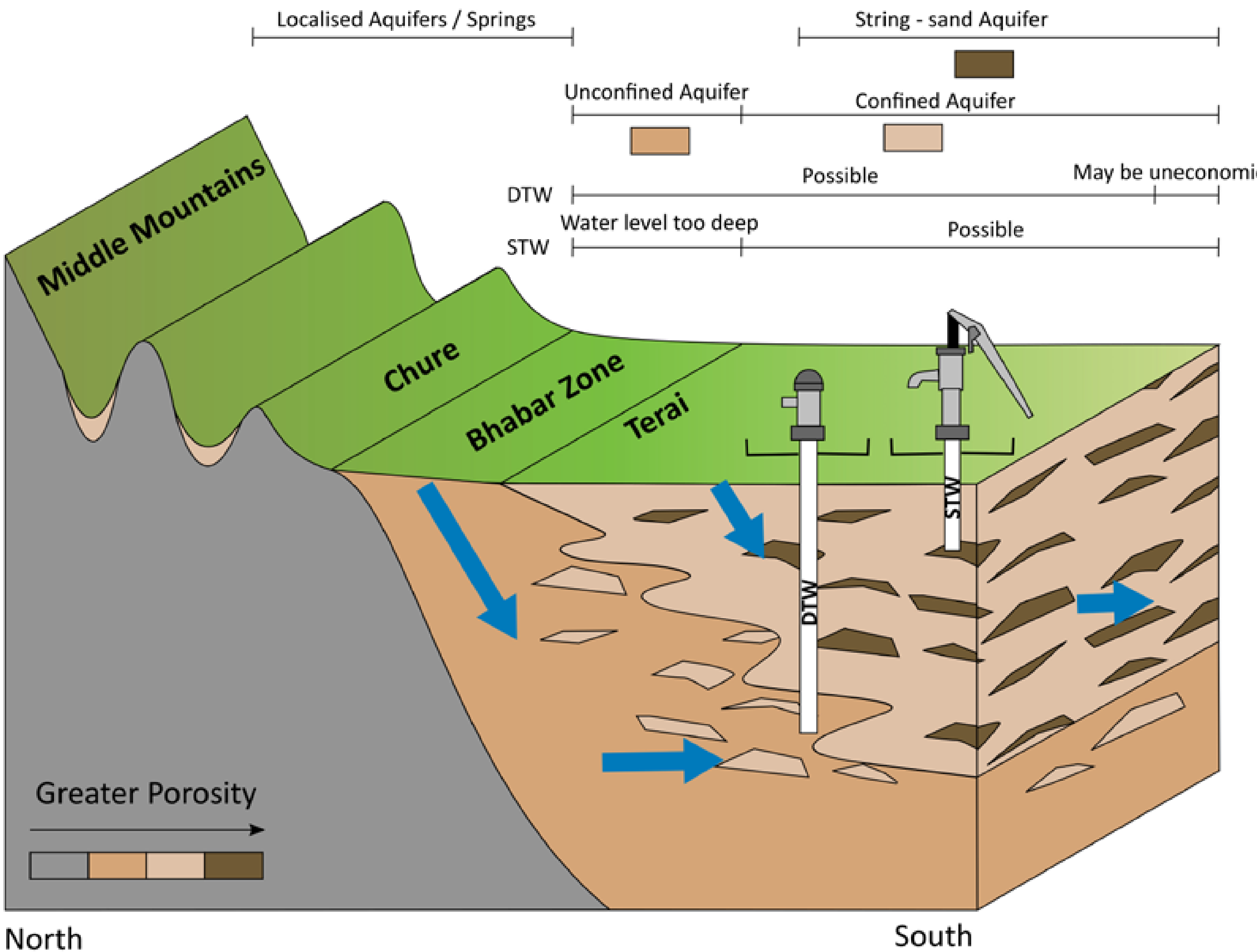


Figure 20 Hydrogeology representation in the Kamala Basin (adapted from GDC, 1994)

3.4 Water quality

Surface water quality

Surface water contamination can cause sickness, ecological decline and damage to infrastructure.

In terms of sickness, although there have been few studies in the Kamala Basin on water quality, there is evidence of human and animal faecal contamination.

In one study of the Ghwang Khola (Kamalamai) river, in the north-west of the Basin, total coliform counts were >300 CFU/100 ml – well above World Health Organization (WHO) guidelines of nil contamination (ITECO et al, 2015).

The contamination increases downstream, with records above 1,100 CFU/100 ml in India (CPBC, 2013). As a consequence, all water needs to be treated before it can be used for drinking or cleaning purposes, to avoid gastrointestinal diseases.

These diseases can lead to diarrhoea and vomiting, and in children can contribute to malnutrition and cognitive delay (Rodríguez et al, 2011, Guerrant et al, 2008).

The Kamalamai municipality has responded to try to reduce the risk through becoming a *'no open defecation area'* and undertaking measures such as building latrines.

In terms of ecological decline, measurements by Shah (2019) in the Kamala River show raised nitrate levels (1.1–3.2 mg/L) and phosphate levels as high as 6.8 mg/L. The raised levels indicate that some fertiliser from farming is entering the river network as organic pollution, which stimulates the growth of plants and algae.

Based on counts of macroinvertebrates, Shah (2019) report the river health is 'good' in Chiyabari (in the upper reaches of the Basin), deteriorating downstream to 'fair' by Dudhuali, according to the GRSbios/ASPT scale (Nesemann et al, 2007).

Given the observation of algae, uncontrolled waste dumping and risk factors such as low flows and rising temperatures, water quality monitoring should be established.

In terms of damage to infrastructure, the greatest issue is the high levels of sediment. When mobilised, sediment can fill storages and complicate the design of irrigation infrastructure. The largest sediment loads are transported during the monsoon season.

Groundwater quality

For groundwater, the main challenge that has been identified is arsenic contamination. Arsenic contamination is linked to many long-term health problems, e.g. cancers, infant mortality and developmental delays (WHO, 2001).

Between 1999 and 2004, three major systematic studies were undertaken to measure arsenic concentration in groundwater samples in the Terai region (Department of Water Supply and Sewerage, Nepal Red Cross and National Arsenic Steering Committee).

Further scientific studies have been conducted to assess the causes of arsenic contamination (Bhattacharya et al, 2003, Shresta et al, 2003, Shrestha, 2004, Pokhrel et al, 2009, Thakur et al, 2011).

These studies show different values of arsenic contamination in ground water indicating that arsenic is non-uniformly distributed across the Terai with one study suggesting about 27.3% of total tube wells in the Terai contaminated with arsenic above the WHO guideline value of 10 ppb.

However, based on the National Arsenic Steering Committee study (NASC, 2007) of all 56,531 shallow tube wells in Dhanusha, a lesser (but significant) 4% of tested shallow tube wells were contaminated with arsenic above 10 ppb, and 0.7% of tube wells measured arsenic above the Nepal Interim Standard of 50 ppb.

The district profile for Dhanusha suggests that the highest concentrations of arsenic are close to the Kamala River (ODDC, 2008).

Figure 21 (top) Algae and litter in the Kamala River downstream of Sindhuli
Figure 22 (bottom) Surface water in the irrigation canal affected by waste

4 Water use and water demand

4.1 Socio-economic dependence on water

Economic drivers and limitations

Given that agriculture is the main economic activity, livelihoods in the Kamala Basin are heavily dependent on the availability of water. As mentioned above, around 70% of all employment in the basin relates to agriculture, which creates high economic dependence on water.

However, precise data does not exist regarding how many rural households have access to irrigation water. Available data indicates that approximately half of the total suitable cultivable agricultural land, approximately 54,000 ha, have been irrigated (JVS and PEI, 2018).

In terms of modern irrigation systems, in the sample of the PVA data fewer than 1% of households claimed to have invested or bought assets related to irrigation systems.

Water social conflicts

Based on the PVA surveys, 70% of households reported no social conflict as consequence of water disputes within the same village, while 24% reported that conflicts occurred only occasionally.

Around 6% of households in the sample reported frequent social conflict emerging within the village, as a consequence of water disputes with households in other comunities.

Energy

From the PVA data it can be observed that 70% of households report using wood, baked cow dung, sawdust, grass or other natural materials as their main fuel for cooking. The remainder of households used mainly cylinder gas and other systems.

In terms of energy sources for lighting, 72% of households reported access to electricity from connection to the national grid, while 10% of households reported renewable solar/ wind/turbine energy as their main electricity source.

The data also show that households in the district of Sindhuli spent on average 8,000 NPR per year, while households in Udapayur and Siraha spent approximately 4,200 NPR per year on energy needs.

Observed and understood social conflict

- Where people are forced to relocate to new land due to flooding, cutting trees creates conflict regarding the share of natural resources.
- Low efficiency of irrigation due to high water loss and low water availability has resulted in conflict around water sharing among farmers.
- Upstream deforestation, especially in the Chure, leading to erosion and sedimentation in the river, has caused difficulty in the livelihoods of indigenous people depending on fishery for their survival.
- There has been conflict regarding unfair sharing of compensation and benefits among the basin people during cases of flooding due to embankment and other interventions.
- There is also a problem of water scarcity during the dry season for women and girls who, due to the lack of access to drinking water, have to travel a longer distance for water collection.

Figure 23 Water use by the community at the Kamala Irrigation Project canal

4.2 Agriculture, irrigation and livestock

Agriculture is the main economic activity and occupation for the people living within the Kamala Basin and its four districts. Crop production through irrigation is the major water use in the basin. Crop production is predominantly done by smallholders, with subsistence farming mainly producing traditional crops of rice, wheat and maize.

Agricultural practices are based on farmers' experience and tradition, limited by the workforce, land size and water availability during the dry season.

Rice is planted at the beginning of the monsoon season, followed by wheat. This last crop depends on the availability of water for irrigation.

Farmers show a desire to have access to water all year round in order to be able to produce a third crop during the dry season if water for irrigation becomes available.

In some parts of the basin, where irrigation systems or access to water are available as in the Kamala Irrigation Project areas, it is possible to observe the production of vegetables, mustard, peas, millet and potatoes as diversification.

However, the production of these commodities still happens on a small scale and is generally localised in the vicinity of urban settlements. More recently, farmers have increased access

Figure 24 Paddy field cultivated with rice during the monsoon in the Terai

to chemical fertilisers, insecticides and improved seeds. Mechanised practices are growing but still limited.

Different practices are applied on each different land type and are dependent on water availability. The cropping practices of the Chure and Middle Mountains regions are based on terraced farming since access to irrigation is much more limited than in the Terai.

Alternative crops such as barley and buckwheat are more common in these regions.

In the Terai, rice-based cropping occurs on irrigated low lands while maize-based cropping patterns are practised in uplands. Early paddy rice is also grown in low-lying areas and its coverage area is fairly small.

After rice, wheat is grown to a large extent in irrigated fields during winter (November to March). Farmers reported that it is becoming more frequent to lose production of wheat due to the lack of water for irrigation at the end of the winter season (CSIRO, 2017).

Other crops such as potato and mustard are also grown during winter. Maize is grown in both irrigated and rain-fed areas but its coverage is comparatively low (MOAD, 2017).

Cropped area distribution

The area cultivated in the four districts of the basin is shown in Table 4.

Table 4 Estimated crop areas in the four districts of the Kamala Basin

District	Cultivated area (ha)							
	Rice	Maize	Wheat	Millet	Oilseed	Sugarcane	Potato	Vegetables
Dhanusha	65,540	2,019	40,000	300	3,373	3,605	2,320	8,054
Sindhuli	14,900	24,815	5,650	11,700	5,174	17	2,140	2,474
Siraha	51,575	1,750	15,210	640	7,046	2,200	1,900	4,961
Udayapur	13,380	17,388	5,100	2,760	5,511	15	760	1,290
Total	**145,395**	**45,972**	**65,960**	**15,400**	**21,104**	**5,837**	**7,120**	**16,779**

Source: MOAD, 2017

Irrigation systems and main projects

There are several irrigation schemes in the Kamala Basin and its districts that allow farmers to produce, in general, two crops per year. The largest system is the KIP.

The KIP was constructed between 1975 and 1980 to provide irrigation water to the southern part of the basin. The infrastructure is designed to irrigate 25,000 ha in the Dhanusha and Siraha districts, (JICA, 2016).

The water is diverted to two main canals (West and East) and is distributed in eight branches in the Eastern canal and four branches in the Western canal.

The GoN is responsible for the distribution, operation and maintenance to the main canal and branch canals, and the water user associations are in charge beyond that.

The budget for the operation and maintenance of the KIP in 2016/2017 was 18,545,000 NPR (red book from JICA, 2016). The irrigation service fee varies from 150 to 300 NPR per hectare per year, which is collected from 60% of users with a distribution of 80% to local committees and 20% to the GoN (JICA, 2016). The share of the fee is 50% to the main committee, 25% to the second level committee and 25% to tertiary committees (JICA, 2016).

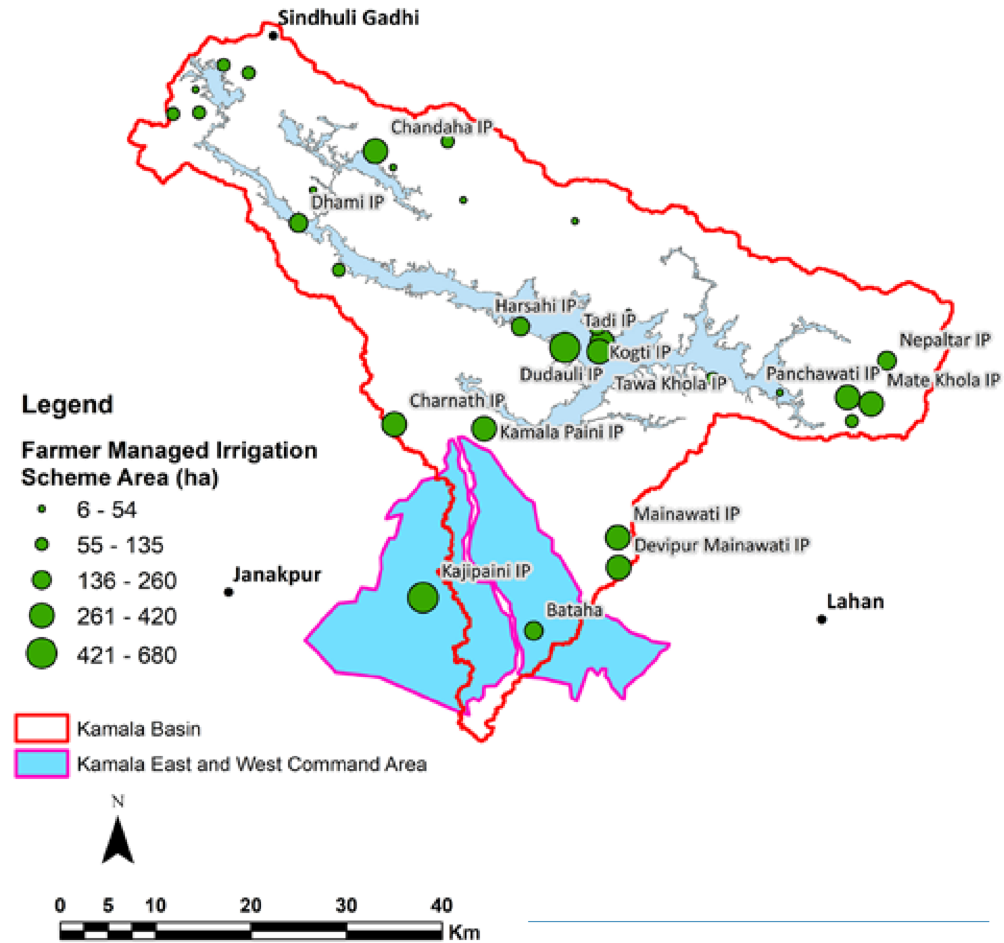


Figure 25 Management Irrigation schemes in Kamala Basin and surrounding districts

The most recent study on the KIP was undertaken as part of the JICA (2016) examination of irrigation scheme maintenance. The report shows that around 36,000 households benefited from the irrigation system.

However, the report identifies factors that limit the effectiveness of the irrigation scheme, including:

- When the project was completed, there were no canal sluice gates at the farm scale (on tertiary canals) so farmers used improvised ditches (JICA, 2013). Without infrastructure to deliver water to specific farms, farmers often flood irrigate. This leads to delivery of water that is not based on crop requirements.
- Shoals are forming on both the upstream and downstream sides of the weir, which are related to the width (span) of the headworks and the siting of the scheme. Trees have grown over the shoals, indicating that maintaining the river regime is not part of the maintenance schedule.

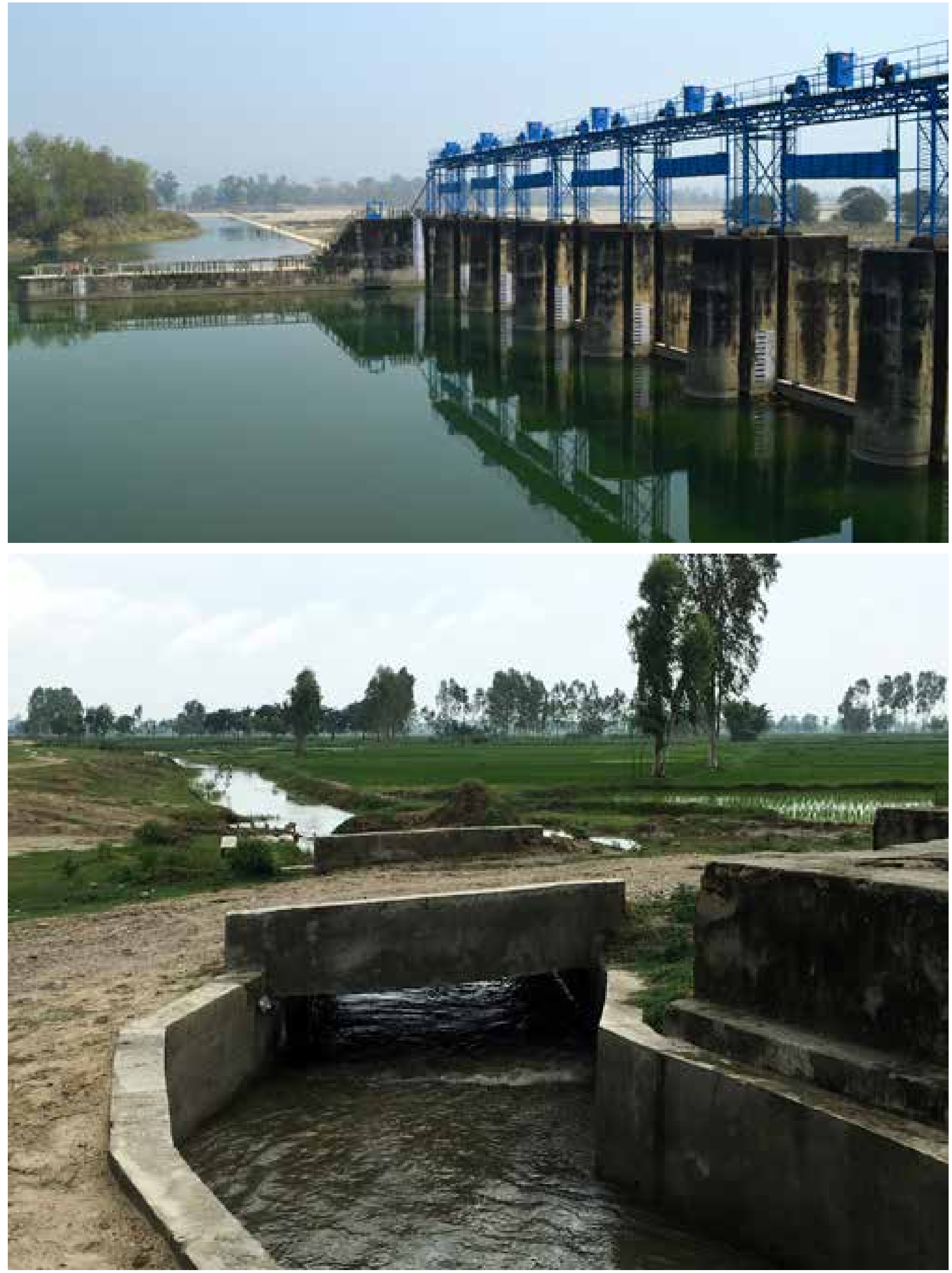


Figure 26 Kamala Irrigation Project command area (top) and irrigation canal branch (bottom)

- The maintenance budget or operating arrangements are insufficient to adequately maintain the infrastructure, resulting in deterioration of the headworks and canals. In the main canals, the lack of maintenance is evident from the establishment of trees and bushes. Secondary canals also suffer from siltation problems and collection of debris and are partly malfunctioning (JICA, 2016). The amount of sediment accumulated in canals is too large to be removed manually (JICA, 2016).
- In order to avoid sedimentation build-up, the barrage is not used to store water. Hence, water scarcity during the dry season remains a problem, with an irrigation duration around 6 weeks ending between January and mid-February.
- Some areas within the command area do not have access to irrigation water. One Farm Management Irrigation Scheme (FMIS) in the command area receives water from spring sources.
- Allocation is rostered between users. However, it seems that farms closer to the main canals and headworks have greater and more reliable access to water.
- The water user associations are not well organised, and are becoming inactive due to a lack of tertiary canal infrastructure to manage (JICA, 2016), as well as pressures of labour out-migration.

There are several small and medium farm management irrigation schemes providing surface water irrigation across the basin.

In the Kamala region, a series of projects have constructed 32 farmer managed irrigation schemes covering an area of 6,297 ha.

Projects from the Department of Irrigation's database (JICA, 2013) included the Irrigation Sector Project 1989 (ISP), Second Irrigation Sector Project 1997 (SISP), Community Managed Irrigated Agriculture Sector Project 2006 (CMIASP) and Medium Irrigation Project (MIP).

Further irrigation through groundwater is estimated to support additional irrigation of 13,240 ha of land in the Kamala region in 2013/14: 12,710 ha in the Terai and 529 ha in the Dun valley bottoms (assuming the wells reported in GoN, 2017 are evenly distributed across irrigable land in Dhanusha and Siraha districts).

This gives a total estimated irrigable area of 44,537 ha, with 37,710 ha in the bounds of the KIP. The area planted within this command area varies with year and season. Based on satellite imagery (LandSat), the winter season cropping within the KIP is estimated to be 23,385 ha in 2014 with a growth rate since 1988 of around 2% per year.

Crop production, diversity and yields

The production and yield in the Kamala Basin varies between the four districts and is influenced mainly by irrigation availability. It is also influenced by other factors such as precipitation, temperature, and the quality of inputs (such as improved seeds), use of fertilisers and effective control of pest and diseases.

The average agricultural yields of the main crops in the basin districts are presented in Table 5.

New non-traditional activities are emerging, showing that some diversification is occurring in the region. This is more frequent in the steeper part of the basin in Sindhuli and Udayapur, where mushroom farming and beekeeping is growing.

Agroforestry is also significant, with 25% of households in Dhanusha and 18% in the other districts having planted trees, mainly for wood production. Table 6 shows the number of holdings per activities and Districts.

Crop water and irrigation demand

Crops have different requirements for water and these are strongly influenced by the weather conditions, the soil's capacity to retain water, and the phase of the crop production.

Figure 27 Irrigated crop production in the Dhanusha district

Table 5 Yields of major crops in the Kamala Basin

District	Crop Yield (t/ha)							
	Rice	Maize	Wheat	Millet	Oilseed	Sugarcane	Potato	Vegetables
Dhanusha	3.4	2.7	2.6	1.0	0.6	42.0	13.1	12.4
Sindhuli	3.6	2.8	2.5	1.0	0.9	37.0	9.7	10.0
Siraha	3.0	2.0	2.0	1.0	0.4	45.5	13.0	14.9
Udayapur	3.9	2.0	2.4	1.3	0.8	43.1	12.1	12.4
Mean	**3.5**	**2.4**	**2.4**	**1.1**	**0.7**	**41.9**	**12.0**	**12.4**

Source: MOAD, 2017

Table 6 Ancillary agriculture and agroforestry in the total area of the four districts in the basin

District	Total holdings	Approximate number of holdings						
		Mushroom farming	Sericulture	Beekeeping	Fishery	Forest for wood	Forest for herbal	Forest for soil/water conservation
Dhanusha	96,006	43		172	215	23,958	86	-
Sindhuli	51,233	673	122	1,467	31	9,079	61	61
Siraha	88,527	83	83	124	498	16,130	-	-
Udayapur	54,919	515	-	377	137	9,433	172	686
Total	**290,685**	**1,314**	**205**	**2,140**	**881**	**58,600**	**319**	**747**

Source: CBS, 2019

Estimates of crop water demand are crucial to design irrigation systems able to supply the necessary volume of water, and calculate the time when irrigation is required in order to optimise production and increase water use efficiency (amount of dry matter produced by volume of water used). There are models that estimate the volume of water necessary for irrigation that consider local characteristics, crop variety, and management adopted.

Estimations of complementary irrigation for the main crops growing in the Dhanusha district, using the Agricultural Production Systems Simulator (APSIM) (Holzworth et al, 2014), considering the climate occurring from 1991 to 2016, are shown in Table 7.

The estimations vary between years, depending on rainfall distribution, but also depend on the irrigation systems and efficiency.

Livestock

Livestock is an important source of income and protein to households in the districts of the basin. The main livestock are cattle, buffalo, goat, sheep and pig.

The livestock not only produce meat and dairy products but also provide organic manure for farming that in many cases is the only source of fertiliser used on plantations.

In Sindhuli and Udayapur more than 94% of households have some livestock, compared with 86% in Siraha and 82% in Dhanusha. The average numbers of livestock owned by households in Sindhuli and Udaypur districts are 10 and 9 compared with 4 in Dhanusha and Siraha (Table 8).

Table 7 Estimation of the minimum, maximum and mean complementary irrigation requirement for the main crops planted in Dhanusha (values in mm per rotation considering the climate which occurred from 1991 to 2016 and 30% inefficiency in delivering the water)

Crop	Irrigation (mm)		
	Minimum	Maximum	Mean
Rice	0	208	150
Wheat	132	307	231
Maize	53	274	170
Total	**185**	**789**	**551**

Table 8 Livestock populations in households of the four districts of the Basin

District	Total holdings	Holdings with livestock	Approximate number of livestock heads					
			Cattle	Buffalo	Goat	Sheep	Pig	Others
Dhanusha	96,006	78,834	99,934	51,445	126,605	1,751	1,965	-
Sindhuli	51,233	48,669	133,144	57,030	264,019	2,542	18,357	2,507
Siraha	88,527	76,533	115,513	56,920	132,482	2,100	2,245	249
Udaypur	54,919	51,629	130,021	37,597	267,810	2,701	30,017	172
Total	**290,685**	**255,665**	**478,612**	**202,992**	**790,916**	**9,094**	**52,584**	**2,928**

Source: CBS, 2019

Figure 28 Woman in the paddy field

Women's participation in agriculture

Agricultural and livestock production is strongly dependent on women. They are mainly responsible for several activities related to crop livestock production.

The women's tasks include seed selection, transplanting, weeding, harvesting and feeding livestock. Due to extensive out-migration of young men to foreign countries the workload for women has increased and they are spending more time in farming activities, including responsibilities related to irrigation.

Women have started to perform some jobs traditionally done by men such as water transporting and management. Agricultural women workers are involved on a permanent basis, occasional basis and exchange of labour basis.

The involvement of women as permanent workers is less common than for men, while on an occasional and exchange of labour basis women's involvement is higher in all districts. The role of women is still limited in decision-making processes around agricultural activities.

4.3 Human water consumption

Domestic water use

Estimates of Nepal's domestic water consumption vary from 36 to 104 litres of water per person per day depending on access to water and household wealth (Raina, 2017). In urban areas most households have access to a piped water supply and the per capita consumption is about 60 to 75 litres per day. In areas that do not have a piped water facility, the per capita consumption decreases to 40 to 50 litres per day (Frérot, 2011).

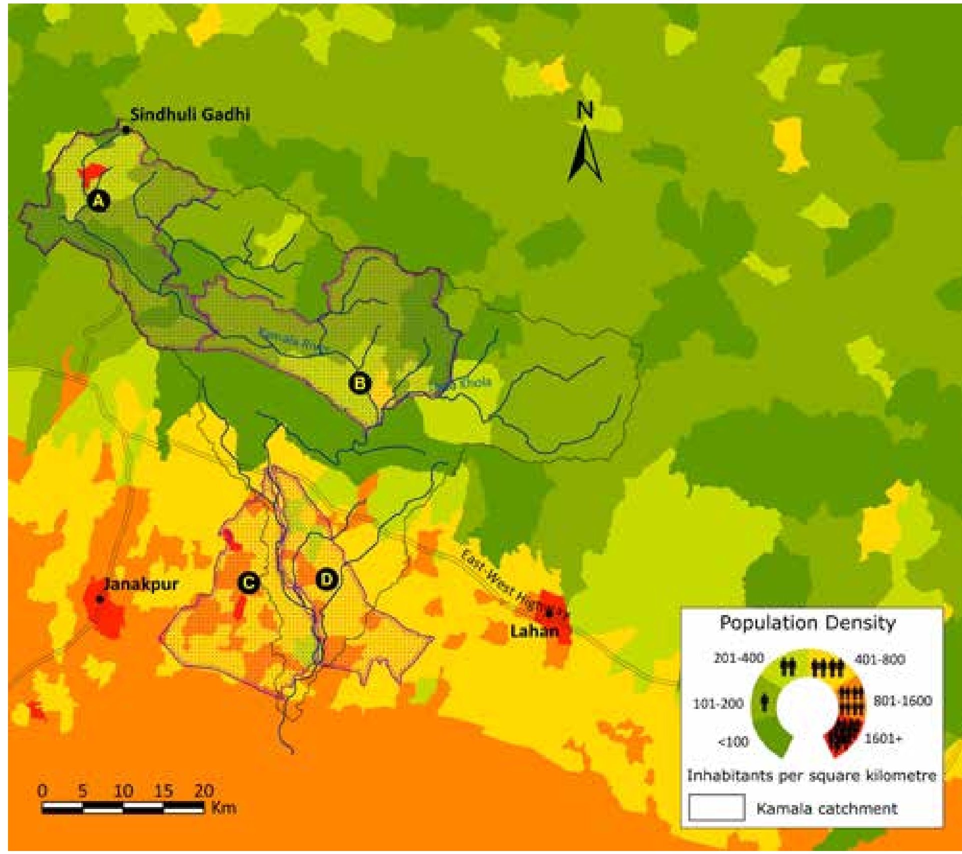


Figure 29 Population density in the Kamala Basin and four main areas of domestic water consumption

In the Kamala Basin, domestic water consumption is mainly concentrated in four areas:

- Kamalamai municipality (A) supplies water to 36,000 people through a piped system. The system uses around 1.0 MCM of water annually.
- Dudhouli municipality (B) supplies water to 65,000 people through open and shallow wells. They need around 1.4 MCM of water annually.
- East (D) and West (C) irrigation command areas have populations of 114,000 and 209,000 people, respectively. They use shallow tube wells to access around 2.5 and 4.6 MCM of water annually.

Population growth is greatest in centres such as Lahan and Janakpur, which are supplied from deep tube wells. Therefore, domestic water use is likely to remain a small, but important, consumer of water.

4.4 Synthesis of water use in the Basin

Water availability in the Kamala Basin is highly variable and dependent on the monsoonal pattern of precipitation. The Basin is consequently vulnerable to both flooding and water scarcity.

Historical measurement at Chisapani streamflow station (1956-80) shows an annual average streamflow of 1,410 MCM/year, with 1,288 MCM occurring during the monsoon (May – October) and only 122 MCM during the dry season.

The current water use in the Basin has been estimated using hydrological modelling, recent local measurements of streamflow and secondary data of groundwater extractions. However, a lack of more recent long-term accurate measurements has required a number of assumptions to be made, and the values provided should be considered as preliminary estimates only.

Irrigated agriculture uses approximately 183 MCM which is equivalent to 93% of the water used in the Basin, estimated to be 197 MCM. Water supplied to households is estimated to be 9.5 MCM, livestock uses around 3.2 MCM and industry around 1.0 to 2.0 MCM per year based on estimation of number of livestock and water consumption of cement industries in the region respectively (Figure 30).

Within the KIP command area, water for irrigation is primarily supplied through canal systems with some farmers supplementing surface water with groundwater (Bastakoti et al, 2019 reporting up to 25% of farmers for winter crop), and some using groundwater entirely (survey data from Sugden et al, 2014 showing between 10% and 80%).

During the entire year, it is estimated that the mean volume of water used in the KIP is around 168 MCM, with 136 MCM from surface water and 32 MCM from groundwater.

The estimated volume used during the dry season in the KIP is 40 MCM, with 61% of the volume being extracted from surface water and 39% from groundwater.

With respect to the FMIS, most is irrigated through surface water (5,877 ha). Remote sensing in this region identified about 1,230 ha of this land cultivated in the winter (with a high level of uncertainty). Most of the area is assumed to be cultivated during pre-monsoon and monsoon seasons. Given these assumptions, the FMIS would require a volume of 16 MCM during the year, with 1 MCM during the dry season.

Although irrigated agriculture is the largest consumer of water, water availability is still a major limitation on crop growth and productivity, especially during the dry season.

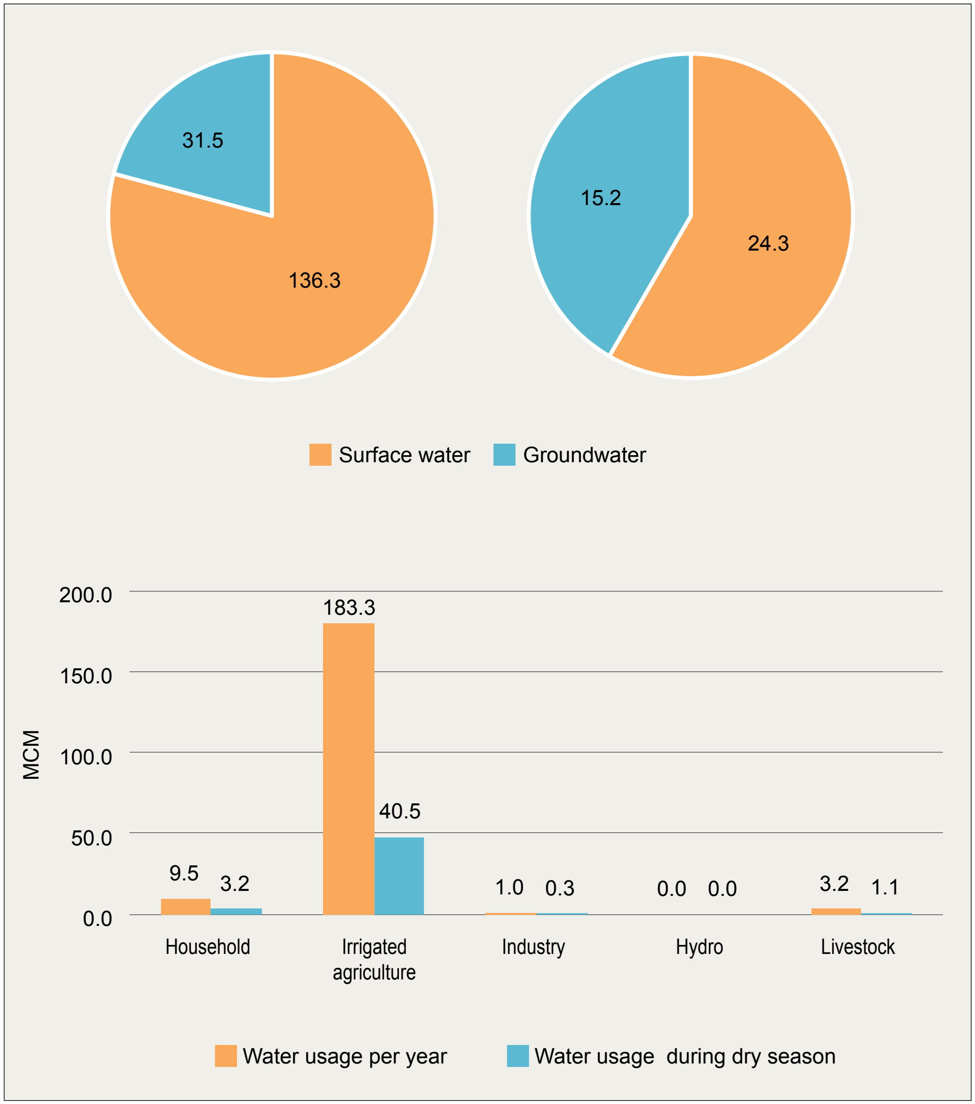


Figure 30 Surface and groundwater volume (MCM) estimated usage in the KIP in all year (top left) and during dry season (top right) and estimated water use by sectors in the Basin (bottom).

4.5 Sediment mining

The Chure region is one of the major sources of construction materials, including sand, gravel, stone and forest products. Dolomite and limestone are also mined from the basin. It is estimated that about 6.5 million cubic metres of sand, gravel and boulders are supplied annually from the Chure region to fulfil construction demands in the country, and to export to India.

The current river sediment extraction that occurs in the basin affects river stability and this alteration poses risks related to flooding and inundation (Adhikari, 2013).

There is no precise information about the location and number of mining sites in the basin. The GoN, at the local level, has focused on regulating the sediment produced by mining activity in the basin, but some trends suggest that this activity is increasing as the GoN also permits export of this material to India (Adhikari, 2013).

In relation to river material extraction, more attention has been given to restrictions for boulder-size extraction, and it is recognised that this activity is only partially controlled and not consistent across the basin. Due to these challenges in fully controlling river material extraction, a complete inventory of quantities and the corresponding location of all sites, are not well known.

The data available on mining activity show a total of 33 riverbed material extraction sites reported in the Sindhuli and Dhanusha districts (JVS and PEI, 2018). However, it is recognised that this figure is incomplete and the number of sites and the actual extracted amounts may exceed the recommendations provided in previous environmental impact assessment studies.

Part of these extraction restrictions prohibits sediment mining from downstream of the Kamala embankment to near the border with India during the wettest months. However, there are at least 50 known extraction sites upstream of the embankment of the Kamala River, and several more that may have not been approved.

River sediment mining modifies the shape and structure of in-channel geomorphic features, which are natural river-channel controls. If it is done in an uncontrolled manner and without considering its effects on both flow and sediment movement, it can greatly affect the river's natural capacity to adjust to those rapid disturbances.

This type of mining may increase sediment mobilisation as these natural control features are weakened, ultimately affecting the relative stability of a river (Erskine et al, 1985).

Uncontrolled mining of river sediments modifies the natural sediment transport, erosion and deposition processes and respective frequency of occurrence and spatial distribution.

In combination with intense rainfall and flooding, sediment mining can accelerate local erosion and river bed scouring. Mining activity also increase river bed sedimentation in nearby locations or downstream of mining sites. As consequence, it may increase susceptibility to overbank flooding, river lateral migration and occurrence of avulsion (Erskine et al, 1985).

The braided segments of the rivers are likely to have large sediment loads relative to transport capacity, as this is a known common characteristic of braided systems, but additional accumulation may be occurring as a result of sediment disturbance, or changes in the flow regime.

Even more so, river bed deposition has been identified as being naturally more accentuated along the Terai, given its topographic setting and its marked decrease in slope, with a gradient between 0.2 and 1% (Jain and Sinha, 2003, Sinha et al, 2005, Adhikari, 2013).

Sediment mining represents a significant source of disturbance in the Kamala River and large amounts of sediments are reaching the Indian border.

However, as several controls are altering the river systems in the basin at once, and can change simultaneously, it is difficult to isolate the effects of one single control (Hicks et al, 2007), as all these occur simultaneously and are contributing to increasing sediment sources in the basin.

Figure 31 A small-scale sediment-mining site (top) and a large-scale extraction site (bottom) that uses heavy machinery

Sediment mining facts

- The construction industry is the main user of the extracted material. This includes road construction and river engineering works, erosion control or irrigation-related works. Part of the material is also exported to India.
- Sediment extraction could be exceeding quantities licensed by the District Development/Coordination Committees, based on yearly Environmental Impact Assessments.
- No boulder extraction is allowed during the monsoon season from the Kamala River within the river segment, starting from the embankments constructed for flood control.
- Outside of the monsoon season, the four districts in the Basin have different control measures – some allow heavy machinery.
- Data collection on sediment extraction quantities would help in establishing best practices for this activity in order to minimise negative impacts that affect the capacity of the rivers for self-adjustment.

Governance related to water management activities

Broadly speaking, governance refers to how society decides to address an issue of concern. Governance involves specific rules (formal and informal) and instruments which attempt to balance the interests and ideas of different groups.

Nepal's 2015 Constitution establishes a three-tier system of government – federal, provincial, and local – which devolves power to lower levels of government, from the previous unitary state. The transition to a federal system is necessarily complex. For example, it includes the reassignment of some previously central government agencies and personnel to fall under the jurisdiction and authority of provincial and local governments. These changes are intended to make governance more accountable and representative. It is also the aspiration that this devolution and decentralisation will deliver more equitable development outcomes.

The Kamala Basin now encompasses three provincial governments and 23 local governments (15 Municipalities and eight Rural Municipalities).

River basin governance cuts across many domains and issues. These include: sustaining watershed resources; reducing water- and watershed-induced hazards; as well as meeting sectoral demands in a context of constrained natural and human resources.

Not all of these reside within any single agency, and so the shift to a multi-level government structure increases the need for efficient coordination across sectors as well as between different tiers of government.

State actors differ with respect to their capability to govern water. Planning resources and capability were previously concentrated at the federal level. (This is reflected in the 2005 National Water Plan, 2015 Agricultural Development Strategy, 2017 Disaster Risk Reduction Strategic Action Plan, and 2018 draft Irrigation Master Plan, all prepared at the national level). As provinces prepare baseline reports and development plans, planning capacity is emerging at the sub-national level.

A major challenge for all levels arises from inadequate financial and human resources to implement plans (interview with manager of a groundwater development office in the Kamala Basin, November 2018).

The democratic governance of river basin planning, and water allocation, poses additional challenges. River basin planning faces the challenge of uneven distribution of water and land resources, needs, and human capability – of planners as well as of water users – at different geographic scales. One example of uneven distribution of capability to express interests and to plan is the priority given to some water resource development options over others.

Complex inter-basin diversion has dominated planning discussion around the Kamala Basin, compared to discussion over options such as hill irrigation systems, water use efficiency, and groundwater (Kamala Basin Initiative consultation workshops, Janakpur and Lahan, 2018).

Looking forward, it is likely to see pressure from Nepali society for river basin planning processes to become more technically accessible, and to further aspirations at the sub-basin level. Allocating water among multiple uses in multiple locations in a fair and accountable manner poses particular challenges in basins such as the Kamala, which are seasonally water-scarce.

One set of challenges arises because recently elected local and provincial governments are now responsible for spatial planning and infrastructure programming within their jurisdictions, leading to a possibility that their water-related interventions will be uncoordinated. In order to meet diverse needs with constrained water resources and public finances, several local governments in the basin have expressed an interest in collaborative planning (Kamala Basin Initiative consultation workshop, Lahan, 2018). It appears that no organisational platform exists to support such collaboration.

Existing institutions (policies and legislation) provide only general guidance on water resources development planning. The 2018 draft Water Resources Policy intends to govern water and land resources so as to accrue 'optimal' economic, social and environmental benefit.

The draft Policy states that sectoral strategic plans (master plans) shall be consistent with river basin plans. The draft Policy does not yet provide guidance for how optimal portfolios of benefits should be defined. In response to this gap, the Kamala Basin Initiative aims to offer specific technical and process guidance to address the challenge of 'optimal' social choice.

The Kamala Initiative is using scenario analysis and multi-criteria analysis to guide the strategic prioritisation of water resource development options.

The Initiative is promoting diverse interests to evaluate and formulate cooperative water resource development options. This may contributes to reduction of potential future water conflicts between different levels of government.

Issues and challenges for achieving sustainable use of water resources

Synthesizing the main issues related to water resources management in the Kamala river Basin. In doing so, the authors recognise that the community, and all levels of government, are already working to address many of the issues of concern. An ongoing process to establish a strategy is underway to identify development goals and actions to improve the welfare of the community in the Kamala Basin.

ISSUE 1 Monsoonal floods are impacting communities and infrastructure

- Floods are primarily a consequence of heavy rainfall events, which may increase in intensity in the future.
- Flooding in the basin can endanger life and causes significant economic and infrastructure damage.
- There are a range of flood controls in place including gabions, check dams and embankments.
- The effectiveness of these controls is not fully quantified or understood, and is likely to be mixed and to depend on local situations and the severity of the rainfall events.

ISSUE 2 High sediment loads in the river system are increasing flood risk and damaging infrastructure

- The Kamala Basin naturally generates high sediment loads. This drives the river to change shape and migrate as it dynamically responds to the floods and sediment.
- The dynamic nature of the river system can be difficult to live with – causing villages and towns to be relocated, with water (and sediment) swamping agricultural land.
- Sediment is deposited in barrages and canals, contributing to high maintenance costs.
- Clearing vegetation along slopes, riparian zones and floodplains increases sediment transport and causes extreme changes in the river channel form.
- Sediment mining and road construction increase transport of sediment and riverbed instability.

ISSUE 3 Water availability is constraining agricultural production

- The agricultural sector is the largest consumer of the water available, which is supplied by a mix of surface water and groundwater schemes.
- With the current infrastructure, there is insufficient surface water available for farmers to meet their winter and summer irrigation requirements. This reduces productivity and yields, as well as limiting crops to a maximum of two crops per year.
- While there has been an increase of groundwater consumption, it appears to have plateaued. Groundwater diesel pumping appears significantly more expensive than in neighbouring Terai regions in India.

- Balancing the temporal and spatial distribution of water in the Kamala Basin could increase the value of agriculture through the ability to support year-round cropping, or diversifying to higher value crops.

ISSUE 4 Infrastructure design, construction and maintenance are not meeting current needs

- Water resources infrastructure in the basin includes water supply systems, sediment control structures, flood control levees, farmer-managed irrigation systems and the jointly managed Kamala Irrigation Project (KIP).
- The KIP is deteriorating due to its age and the need for machinery to conduct maintenance, as well as the overall cost of general maintenance and declining level of collective action among the beneficiary farmers.
- There is insignificant industry support to economically fix deep groundwater bores when the pumps fail or require maintenance.
- Water treatment plants are not all operational.
- Low quality roads impact on transport costs.
- There is a lack of adequate storage for crops.

ISSUE 5 Labour is scarce, land per household is limited and agricultural profitability is low

- The Kamala Basin is densely populated (290 people per km^2), with a rich mix of castes and ethnic groups, which varies between the hilly regions and the Terai.
- Working age men are out-migrating to earn remittances as unskilled labour. They are mostly unavailable to work when there is peak agricultural demand for labour.
- There are proportionately more women of working age involved in agriculture, however their representation at committee level appears to be low.
- Understanding and adoption of the technical aspects of modern agricultural practices are generally low.
- Land holdings are very small (half of holdings have 0.5 ha or less) and hence production is fragmented and limited.
- Agricultural products such as rice and wheat are, in general, more expensive to grow in Nepal than India due to different input costs, subsidies and policies.

ISSUE 6 Institutions need stronger integration

- Coordination between agencies is being built at each tier of government.
- Organisational platforms to support collaboration between local governments, or between local and provincial governments are needed.
- The financing commitments from GoN are variable.

- There are limitations of information, monitoring and evaluation systems and human resources at all levels.
- The coordination of interests, and dispute resolution processes, between different sectors and Provinces requires development and testing in the contemporary context of Nepal.

ISSUE 7 Potable water for domestic purposes is not uniformly accessible

- Several schemes are underway to improve access to water, water treatment and hygiene practices.
- In the hill regions, women can spend an hour or two each day fetching water for drinking and household purposes, reducing the time for other activities.
- Open wells are widely used and have high potential for water contamination.
- There is evidence of contamination of waters with faecal matter and arsenic.

Issue 8 Knowledge about key issues and primary data is limited

- This report, and others quoted here, often rely on a single source of primary information, which is often 20+ years old (e.g. groundwater studies).
- There was no information about sediment quantities or sediment control effectiveness.
- There was a lack of continuity in the monitoring of streamflow, command area irrigation operation and water quality.
- There is limited information about water use in irrigation systems and best practices to increase water use efficiency.

References

Adhikari BR, 2013. Flooding and Inundation in Nepal Terai: Issues and Concerns. Hydro Nepal, 12, 59–65.

Alfredsen NR, 2015. Environmental Flows in Nepal - An Evaluation of Current Practices and an Analysis of the Upper Trishuli-IHydroelectric Project. Hydro Nepal, pp 8-17.

Arthington AH, Bhaduri A, Bunn SE, Jackson SE, Tharme RE, Tickner D, Young B, Acreman M, Baker N, Capon S, Horne AC, Kendy E, McClain ME, Le Roy Poff N, Richter BD, Ward S, 2018. The Brisbane Declaration and Global Action Agenda on Environmental Flows (2018). Policy and Practice Reviews , Volume 6, Article 45.

Aryal PC, Dhamala MK, Bhurtel BP, Suwal MK, Rijal B, 2010. Turtles of Nepal: A field guide for species account and distribution. Environmental Graduates in Himalaya (EGH), Resources Himalayan Foundation and Companions for Amphibians and Reptiles of Nepal (CARON). Kathmandu, Nepal.

Bastakoti R, 2019. Kamala irrigation study, crop production, water availability and factors affecting water access. Technical Report submitted to CSIRO Land and Water. 96p.

Bhattacharya P, Tandukar N, Nekul A, Valero AA, Mukherjee AB, Jacks G, 2003. Geogenic arsenic in groundwaters from Terai Alluvial Plain of Nepal. In Journal de Physique IV, 107, 173–176.

Brisbane Declaration, 2007. The Brisbane Declaration: environmental flows are essential for freshwater ecosystem health and human wellbeing.10th International River Symposium, 3–6 September 2007, Brisbane.

CBS (Central Bureau of Statistics), 2019. Household and Population/VDC_Municipality. Available at: https://cbs.gov.np/vdc-municipality-in-detail/

Chakraborty T, Kar R, Ghosh P, Basu S, 2010. Kosi megafan: Historical records, geomorphology and the recent avulsion of the Kosi River. Quaternary International, 227(2), 143–160.

CPBC, 2013. Water Quality Data 2013. Central Pollution Control Board. https://www.cpcb.nic.in/wqm/2013/RIVERWATER%20DATA%202013_7.htm. Accessed 16/4/2019.

CSIRO, 2017. Kamala basin field trip report to support the basin planning process in Nepal. Technical Report EP175317, 53 pp.

Shah DRT, Shah T, 2019. Kamala River basin, CSIRO internal report, 21 pp.

DFRS, 2014. Churia Forests of Nepal. Forest Resource Assessment Nepal Project/ Department of Forest Research and Survey. Babarmahal, Kathmandu, Nepal.

DOI, Department of Irrigation, 2017. Irrigation Annual Book – 2016/17, Jawalakhel, Lalitpur.

Doody TM, Cuddy SM, Bhatta LD (Eds), 2016. Connecting flow and ecology in Nepal: current state of knowledge for the Koshi Basin. Sustainable Development Investment Portfolio (SDIP) project. CSIRO, Australia. 194 pp.

Duncan JM, Biggs EM, Dash J, Atkinson PM, 2013. Spatio-temporal trends in precipitation and their implications for water resources management in climate-sensitive Nepal. Applied Geography, 43, 138–146.

Dunne JP, Stouffer RJ, John JG, 2013. Reductions in labour capacity from heat stress under climate warming. Nature Climate Change,3(6), 563.

Erskine W, Geary PM, Outhet DN, 1985. Potential impacts of sand and gravel extraction on the Hunter River, New South Wales. Australian Geographical Studies, Vol 23. April 1985.

Foran T, Almeida AC, Penton DJ, Shrestha M, 2018. Participatory river basin planning for water resource management in Kamala Basin, Nepal, International Commission on Irrigation and Drainage (ICID), 8th Asian Regional Conference, Kathmandu, May 2018. http://www.icid.org/8arc_postproceedings.pdf, 495–507.

Frérot A, 2011. Water: Towards a Culture of Responsibility. UPNE.

GDC, 1994. Reassessment of groundwater development strategy for irrigation in the Terai, 6 volumes, Cambridge, UK: Groundwater Development Consultants, Ltd.

Gerlitz JY, Apablaza M, Hoermann B, Hunzai K, Bennett L, 2015. A Multidimensional Poverty Measure for the Hindu Kush–Himalayas, Applied to Selected Districts in Nepal. Mountain Research and Development, 35(3), 278–288.

Guerrant RL, Oriá RB, Moore SR, Oriá MO, Lima AA, 2008. Malnutrition as an enteric infectious disease with long-term effects on child development. Nutrition reviews, 66(9), 487–505.

GoN (Government of Nepal), Ministry of Environment, Science and Technology, 2008. Nepal Thematic Assessment Report: Climate Change. Government of Nepal, Ministry of Environment, Science and Technology, Singhadurbar, Kathmandu.

GoN (Government of Nepal), Ministry of Agricultural Development, 2015. Agriculture Development Strategy (ADS) 2015 to 2035: Part 1.

GoN (Government of Nepal), President Chure-Tarai Madhesh Conservation Development Board, 2017. President Chure-Tarai Madhesh Conservation and Management Master Plan. 267 pp.

GWRDB, 2019, Groundwater Resources Development Board Hydrogeological Studies, Ministry of Energy, Water Resources and Irrigation. http://www.gwrdb.gov.np/hydrogeological_studies.php

Hannah DM, Kansakara SR, Gerrard AJ, Rees G, 2005. Flow regimes of Himalayan rivers of Nepal: nature and spatial patterns. Journal of Hydrology, 308, 18–32.

Hansen, MC, Potapov PV, Moore R, Hancher M, Turubanova SA, Tyukavina A, Thau D, Stehman SV, Goetz SJ, Loveland TR, Kommareddy A, Egorov A, Chini L, Justice CO, Townshend JRG, 2013. High-Resolution Global Maps of 21st-century Forest Cover Change. Science 342, 850–853.

Hicks DM, Duncan MJ, Lane SN, Tal M, Westaway R, 2007. Contemporary morphological change in braided gravel-bed rivers: new developments from field and laboratory studies. In Gravel-bed rivers VI: from process understanding to river restoration. Amsterdam, Netherlands: Elsevier, pp. 557–586.

Hirabayashi Y, Mahendran R, Koirala S, Konoshima L, Yamazaki D, Watanabe S, Kanae S, 2013. Global flood risk under climate change. Nature Climate Change, 3(9), 816.

Holzworth DP, Huth NI, deVoil PG, Zurcher EJ, Herrmann NI, McLean G, Chenu K, et al, 2014. APSIM – Evolution towards a New Generation of Agricultural Systems Simulation. Environmental Modelling & Software, 62, 327–50.

Ichiyanagi K, Yamanaka MD, Muraji, Y, Vaidya BK, 2007. Precipitation in Nepal between 1987 and 1996. International Journal of Climatology, 27(13), 1753–1762.

ICIMOD (International Centre for Integrated Mountain Development), 2019. Poverty and Vulnerability Assessment (PVA). http://www.icimod.org/pva

ICIMOD, 2013. Land cover of Nepal 2010. Kathmandu, Nepal: ICIMOD.

IFPRI, 2016. Groundwater Irrigation in the Eastern Gangetic Plains (EGP): A comparative study of Bangladesh, India and Nepal, International Food Policy Research Institute, NASC Complex, CG Block, DPS Marg, New Delhi – 110012.

IPCC, 2007. Climate Change 2007: The Physical Sciences Basis. Summary for Policymakers (Summary for policymakers), Intergovernmental Panel on Climate Change (IPCC): 21.

ITECO Nepal Pty Ltd, SILT Consultants Pty Ltd, and Unique Engineering Consultancy Pty Ltd, 2015. Updated Initial Environmental Examination Report (IEE) for Kamalamai Small Towns Water Supply and Sanitation Sector Project, Sindhuli District. http://cpcb.nic.in/wqm/2013/RIVERWATER%20DATA%202013_7.htm

Jain V, Sinha R, 2003. River systems in the Gangetic Plains and their comparison with the Siwaliks: a review. Current Science, 84, 8, 1025–1033. Special Section: Late Cenozoic Fluvial Deposits.

JICA, 1985. Koshi River Basin Master Plan, Ministry of Water Resources/Japan International Cooperation Agency.

JICA, 2013. Preparatory survey on JICA's cooperation program for agriculture and rural development in Nepal – Food production and agriculture in Terai – Final Report. Japan International Cooperation Agency (JICA), 263 pp.

JICA, Japan International Cooperation Agency, 2016. Data collection survey on promoting operation and maintenance of irrigation scheme in Terai. Federal Democratic Republic of Nepal, Department of Irrigation, Ministry of Irrigation, 140 pp.

Jones LS, Schumm SA, 1999. Causes of avulsion: an overview. Fluvial Sedimentology VI Edited by Smith ND. The International Association of Sedimentologists. 28, 171–178.

JVS and PEI, 2018. Jalsrot Vikas Sanstha and Policy Entrepreneurs Inc. in Collaboration with Commonwealth Scientific and Industrial Research Organisation. Kamala Basin Study Data Collection. Report prepared for CSIRO, July 2018, 101 pp.

Kadel LM, Lacey J, Ahmad F, Hayes K, Gurung Goodrich CG, Cruz Lopez D, Milne G, Darbas T, Olsen K, 2017. Making Gender Count: Leveraging M&E to mainstream gender. A project undertaken within the South Asia Sustainable Development Investment Portfolio (SDIP). CSIRO, Australia.

Kansakar DR, 1992. Shallow groundwater resources of the Siraha district, Eastern development region, Nepal, Technical report No 18, United Nations Development Program and His Majesty's Government of Nepal.

Lytle DA, Poff NL, 2004. Adaptation to natural flow regimes. Trends in ecology and evolution, 19(2), 94-100.

Karna P, 2007. A Study Report on Economic Evaluation of the Churia Region, IUCN Nepal.

MFSC (Ministry of Forests and Soil Conservation), 2016. Forest Sector Strategy, 2016–2025. 94 pp. http://mofe.gov.np/downloadfile/Forestry%20Sector%20Strategy%20%20(2016-2025)_1526466721.pdf

MOAC and FAO, 2011. Disaster Risk Management Plan Siraha District, Government of Nepal, Ministry of Agriculture and Cooperatives.

MoWR, 2001. Hydropower Development Policy, 2001. Approved by His Majesty's Government on 15 October 2001 (2058.6.29), Ministry of Water Resources, Singh Durbar, Kathmandu, Nepal.

Mukherjee A (Ed.), 2018. Groundwater of South Asia. Springer.

Ministry of Forests and Soil Conservation, 2014. Nepal fifth national report to convention on biological diversity. Environment Division, Ministry of Forests and Soil Conservation.

MOAD, 2017. Statistical Information on Nepalese Agriculture, Ministry of Agriculture Development, 2017.

MoFE, 2019. Climate change scenarios for Nepal for National Adaptation Plan (NAP). Ministry of Forests and Environment, Kathmandu.

Muehlbauer J, 1977. German Mission for water resources development in Nepal: final report. Kathmandu: German Agency for Technical Cooperation Ltd. 201 pp.

NASC - National Arsenic Steering Committee, 2007. Report on blanket tube well testing in Sunsari, Bara, Dhanusha, Kailali and Kachanpur district-2007. A report prepared by NASC/UNICEF by Genesis consultancy (P) Ltd, Kathamadu.

NAST, 2012. Intervention Status Mapping of Churia Region: Concept and scope, final report submitted to Rastrapati Chure Conservation Program Coordination Unit, Nepal Academy of Science and Technology, Khumaltar, Kathmandu.

NCVST (Nepal Climate Vulnerability Study Team), 2009. Vulnerability Through the eye of Vulnerable: Climate Change Included Uncertainties and Nepal's Development Predicaments. Institute for Social and Environmental Transition (ISET). Kathmandu.

Nesemann H, 2007. Aquatic invertebrates of the Ganga River system. Chandi Press: 263 pp.

Neupane M, Dhakal S, 2017. Climatic Variability and Land use Change in Kamal Watershed, Sindhuli district, Nepal. Climate, 5, 11.

NPC, Government of Nepal, National Planning Commission, 2017. Nepal Flood 2017: Post Flood Recovery Needs Assessment, https://www.npc.gov.np/images/category/PFRNA_Report_Final.pdf.

ODDC, 2008., District Profile, Dhanusha, Office of the District Development Committee.

OECD, 2003. Development and climate change: Focus on Water Resources and Hydropower. Paris, Organization for Cooperation and Development: 64.

Okwany R, Siddiqui S, Rajmohan N, Prathapar Sanmungam A, Bastakoti RC, 2015. Assessment of Water Resources and Demand for Irrigation in Nine Districts within Eastern Gangetic Plains, Final Report – ACIAR Reference Number C2013/099, Australian Centre for International Agricultural Research.

Pandey VP, Manandhar S, Kazama F, 2012. Water poverty situation of medium-sized river basins in Nepal. Water resources management,26 (9), 2475–2489.

Parajuli K, 2016. Survey of bird species richness in Kamala River Basin, lowland Nepal. Tribhuvan University, Kathmandu, Nepal. https://www.academia.edu/11620946/Survey_of_Bird_Species_Richness_in_Kamala_River_Basin_Lowland_Nepal.

Parmesan C, Yohe G, 2003. A globally coherent fingerprint of climate change impacts across natural systems. Nature, 421, 6918, 37.

Paudel PK, Bhattarai BP, Kindlmann P, 2012. An overview of the Biodiversity in Nepal *in* Kindlmann (ed) Himalayan Biodiversity in the Changing World.

Pokhrel D, Bhandari BS, Viraraghavan T, 2009. Arsenic contamination of groundwater in the Terai region of Nepal: an overview of health concerns and treatment options. Environment International, 35, 157–161.

Postel S, Richter BD, 2003. Rivers for Life: Managing Water for People and Nature. Island Press, Washington DC.

Raina A., 2017. Inequities in household water consumption in Kathmandu, Nepal. Global Water Forum.

Rodríguez L, Cervantes E, Ortiz R, 2011. Malnutrition and gastrointestinal and respiratory infections in children: a public health problem. International Journal of Environmental Research and Public Health, 8, 1174–1205.

Saxton KE, and Rawls WJ, 2006. Soil Water Characteristic Estimates by Texture and Organic Matter for Hydrologic Solutions. Soil Science Society of America Journal, 70, 1569–1578.

Scott CA, Zhang F, Mukherji A, Immerzeel W, Mustafa D, Bharati L, 2019. Water in the Hindu Kush Himalaya. In The Hindu Kush Himalaya Assessment, pp. 257–299. Springer, Cham.

Shah KB, Tiwari S. 2004. Herpetofauna of Nepal: A Conversation Companion. IUCN Nepal, Kathmandu, Nepal.

Shrestha BR, Whitney JW, Shrestha KB (eds), 2004. The State of Arsenic in Nepal, 2003. National Arsenic Steering Committee, Environment and Public Health Organization, Kathmandu, Nepal, 126 pp and CD-ROM.

Shrestha RR, Shrestha MP, Upadhyay NP, Pradhan R, Kadka R, Maskey A, Maharjan M, Tuladhar S, Dahal BM, Shrestha K, 2003. Groundwater Arsenic Contamination, Its Health Impact and Mitigation Program in Nepal, Journal of Environmental Science and Health, Part A, 38:1, 185-200.

Shrestha EK, 1992. Shallow Groundwater Resources of the Terai, Dhanusha District Nepal, Technical Report No 28, United Nations Development Program and His Majesty's Government of Nepal.

Shrestha M, 2017. Push and pull: A study of international migration from Nepal. Policy Research Working Paper 7965. The World Bank.

Shreshta SR, Tripathi GN, Laudari D, 2018. Groundwater Resources of Nepal: An Overview, Chapter 11 in Mukherjee A (ed). Groundwater of South Asia.

Shrestha TK, 2008. Ichthyology of Nepal: A study of fishes of the Himalayan waters. Himalayan Ecosphere, Kathmandu, Nepal.

Sinha R, Jain V, Babu GP Ghosh S, 2005. Late Quaternary geology and alluvial stratigraphy of the Ganga basin. Himalayan Geology, 26, 223–240.

Sugden F, 2014. Landlordism, tenants and the groundwater sector: lessons from Tarai-Madhesh, Nepal. Colombo, Sri Lanka: International Water Management Institute (IWMI). 33 p. (IWMI Research Report 162).

Thakur JK, Thakur RK, Ramanathan AL, Kumar M, Singh SK, 2011. Arsenic contamination of groundwater in Nepal—an overview, Water, 3, 1–20.

Uddin K, Shrestha, HL, Murthy MSR, Bajracharya B, Shrestha B, Gilani H, Dangol B, 2015. Development of 2010 national land cover database for the Nepal. Journal of Environmental Management, 148, 82–90.

USGS, 2004. Shuttle Radar Topography Mission, 1 Arc Second scene SRTM_u03_n008e004, Unfilled Unfinished 2.0, Global Land Cover Facility, University of Maryland, College Park, Maryland, February 2000.

WHO, 2001. Arsenic Contamination in Groundwater Affecting Some Countries in the South-East Asia Region; Washington, DC, USA.

Yang D, Kanae S, Oki T, Koike T, Musiake K, 2003. Global potential soil erosion with reference to land use and climate changes. Hydrological Processes,17, 2913–2928.

Wang P, Huang C, Brown de Colstoun EC, Tilton JC, Tan B, 2017. Global Human Built-up and Settlement Extent (HBASE) Dataset from Landsat. Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC).

Wester PA, Mishra A, Mukherji A, Shrestha AB, (eds), 2019. The Hindu Kush Himalaya Assessment—Mountains, Climate Change, Sustainability and People Springer Nature Switzerland AG, Cham.

World Bank (2019). Data Bank. Available at: https://data.worldbank.org/indicator/EN.POP.DNST.

Abbreviations

CFU	colony-forming unit
CMIASP	Community Managed Irrigated Agriculture Sector Project 2006
CSIRO	Commonwealth Scientific and Industrial Research Organisation
cumec	cubic metres per second
DHM	Department of Hydrology and Meteorology, Government of Nepal
DPR	Detailed Project Report
DOFE	Department of Foreign Employment
DOI	Department of Irrigation, Government of Nepal
DTW	Deep tube well
FMIS	Farm management irrigation schemes
GCMs	Global Circulation Models
GoN	Government of Nepal
GWRDB	Groundwater Resources Development Board
ha	hectare
HP	horsepower
IPCC	Intergovernmental Panel on Climate Change
ISP	Irrigation Sector Project 1989
JVS	Jalsrot Vikas Sanstha
KIP	Kamala Irrigation Project
KRB	Kamala River Basin
masl	metres above sea level
MCM	million cubic metres
MCM/a	million cubic metres per annum
MIP	Medium Irrigation Project of DOI
OECD	Organisation for Economic Co-operation and Development
NPR	Nepalese rupee
PEI	Policy Entrepreneurs Incorporated
ppb	parts per billion
ppm	parts per million
PVA	Poverty and Vulnerability Assessment
SISP	Second Irrigation Sector Project 1997
STW	Shallow tube well
UNDP	United Nations Development Programme
USD	United States dollar
WECS	Water and Energy Commission Secretariat, Government of Nepal
WHO	World Health Organization