GLOBAL RESILIENCE PARTNERSHIP

Uncovering the Opportunities for Improving Road Water Management for Resilience in Mahottari Distict, Nepal

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Roads for Water

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1. Introduction

This report assesses the scope for making use of roads for climate resilience and water management in Nepal. The study is part of the Roads for Water Initiative. The approach has been successfully implemented since 2014 in Ethiopia, Kenya and Bangladesh and first steps have been made to introduce it in Mozambique, Zambia and Uganda. The report presents an overview of problems currently caused by a mismatch between road construction and water management and gives recommendations on how to use roads to increase climate resilience.

With a road inventory of approximately 12,893 km of national and feeder roads and 60,000 km of rural roads, more systematic integration of road building and maintenance and water management presents an important opportunity to increase climate resilience. The report focuses on the southern plains of Nepal, which are facing problems of flooding, sedimentation, siltation and drought. Climate change has further aggravated the situation by causing heavy precipitation during the monsoon and longer drought periods in the dry season. Heavier rain events create more pressure on the road network. Despite the significant increases in road sector funding in the last years, the portion of the budget going to maintenance remains low[1].

Moreover, runoff from road hydraulic structures such as bridges and culverts if not managed properly, can cause flooding, sedimentation/siltation, erosion downstream and damages to structures including the road itself. However, this can be turned around and roads can become instruments for water harvesting and management by for instance diverting runoff to water harvesting ponds or to groundwater recharge structures. The harvested water can be used for livestock drinking or small-scale irrigation. Roads can also be used to manage water catchments – controlling the speed of run-off, mitigating flood run-off and influencing the sedimentation process in the catchments.

Beneficial road water management can bring substantial benefits:

- Climate resilience of road infrastructure and road-adjacent communities will significantly improve
- There will be considerably less damage and less downtime to roads
- Water from the roads can be used for productive uses
- There will be less flooding and erosion damage to the area around the roads
- Enhanced soil moisture and groundwater recharge

2. Methodology

This report is based on field visits conducted in Mahottari District in July 2017. Part of the preparation work was to interview key stakeholders to select the area and roads for the transect survey. Experts and decision makers from the road, water and disaster sectors were also consulted to consider their views on this assessment.

To assess the current status and potential opportunities for beneficial road water management a transect survey was carried out in three different types of roads (one National Highway and two feeder roads) in Mahottari District. The assessment included field observations and discussions with local communities (especially farmers) along the selected roads. Mahottari district lies in the southern plain of Nepal with some of its northern section in hill zone.

[1] Nepal Road Sector Assessment Study: http://rapnepal.com/sites/default/files/report-publication/road_sector_assessment_study_-_main_report_final_30may2013.pdf

Table 1: Transect survey route

Road Classification	Description	Length (km)	Coordinates	
			Start	End
National Highway (H01)	Dhalkebar to Banke River	28.58	N 26055’45.7”, E 085057’27.6” Elevation: 152m	N 27000’48.1”, E 085044’32.9” Elevation: 171m
Feeder Road (F112)	Bastibitti to Mana-hara	12.75	N 26043’42.1”, E 085054’34.9” Elevation: 62m	N 26043’51.5”, E 085044’52.2” Elevation: 58m
Feeder Road (F113)	Mahadaiya-Samsitole-Samsi	21	N 26048’36.1”, E 085044’20.8” Elevation: 74m	N 26055’44.1”, E 085053’29.6” Elevation: 68m

3. General Characteristics of Nepal

Nepal[2] is a landlocked country and is among the least developed countries in the world. It has a population of 26.4 million (CBS, 2011). It is borders China in the north and India in the south, east, and west. Nepal is roughly trapezoidal shaped, being 800 km long and 200 km wide with an area of 147,181 sq. Km. The country is divided into three physiographic areas namely Terai, Hill and Mountain. These ecological belts run from east to west (Figure 1).

The climate in Nepal varies with the altitude and ranges from tropical to alpine and Nival. There are two season i.e. wet season (June to September) also known as monsoon and dry season (October to May). April and May are the driest and intense water-stress months.

[1] Nepal Road Sector Assessment Study: http://rapnepal.com/sites/default/files/report-publication/road_sector_assessment_study_-_main_report_final_30may2013.pdf

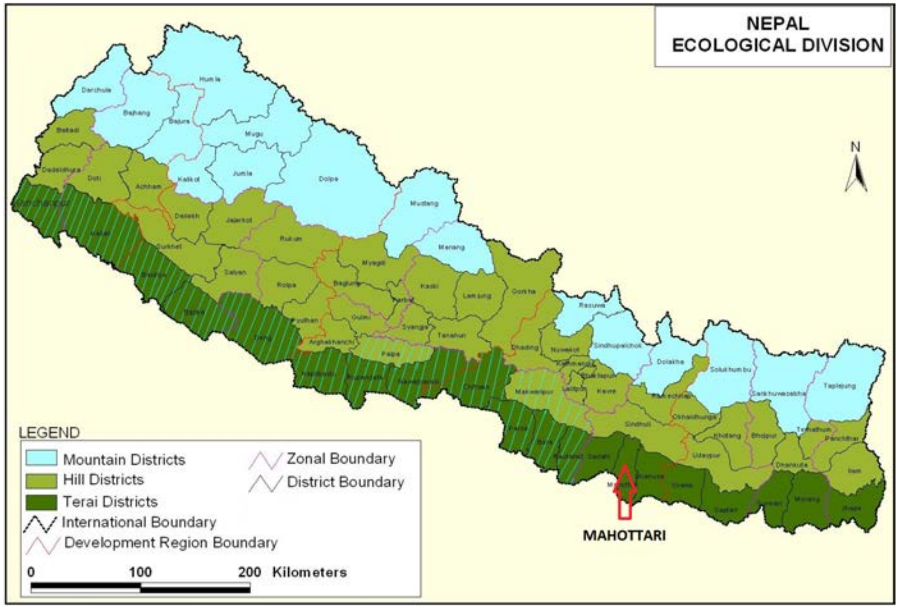

Figure 1: Ecological map of Nepal (showing study district)

4. Road Sector in Nepal

The Department of Roads (DoR) – part of the Ministry of Physical Infrastructure and Transport - is the main body in charge of sector development, planning, design, construction of roads and its maintenance. DoR is supported by 5 Regional Directorates, 34 Divisional Road Offices (DROs), 7 Heavy Equipment Divisions and several project offices. At the central level several branches and units exist, as well as project offices and directorates. According to a Statistics of Strategy Road Network 2015/16

(SSRN 2015/16), the total road network of Nepal is 12,893 km. The road network in five development regions of Nepal is shown in table 2.

Table 2: Length of Road (km) in Nepal

Development Region	Road Classification (Annex 1)			
	National Highway	Feeder Road	Mid-hill Road	Postal Road
Eastern	817.73	1339.23	424	136
Central	876.18	2143.22	148	244
Western	478.16	2038.17	215	60.5
Mid-Western	735.1	1302.22	328	100
Far-Western	568.03	762.45	81	96.2
Total (Km)	**3475.2**	**7585.29**	**1196**	**636.7**

Source: SSRN 2015/16

The maintenance of roads and bridges is operated by division offices in coordination with the Department of Roads (DoR). DoR has categorized the maintenance into five groups:

- Routine maintenance - required continually on every road;
- Recurrent maintenance - required at varying intervals during the year with a frequency that depends mostly on the volume of traffic on the road;
- Periodic maintenance - required only at interval of several years;
- Emergency maintenance - needed to deal with emergencies and problems requiring immediate action when a road is threatened or closed;
- Preventive maintenance - needed to adapt the road to the changing nature of the slopes and streams.

The DoR has envisaged that the future road construction, maintenance and upgrading of the existing road must be implemented in a sustainable way.

5. Study Area

The southern plains of Nepal – known as 'Terai' – cover 17% of the total area of the country and borders India. Though it covers a relatively small portion of the country it is the food basket since it produces 56% of total national cereal production. To the north of Terai plain is the Churia Range[3] which run from east to the west of the country. Dozens of rivers and streams originate from Churia and carry tremendous amount of sediments during monsoon. The sediments deposit on the Terai plain. Flash floods are a common phenomenon resulting on flood and inundation in the Terai plain. This threatens the position of Terai as the food basket of the country. Climate change has worsened the situation by causing recurrent floods and droughts. Mahottari district (and the Terai plain) has been selected for this assessment due to its importance for the country's food security and its vulnerability to climate change.

Mahottari District[4] lies in the central development region of Nepal with 1002 sq. km of area and 627,580 population (CBS, 2011). Its elevation ranges from 61 to 808 masl. The adjoining districts are Jankapur in the east, Sarlahi in the west, Sindhuli in the North and Bihar in the south. The northern part of Mahottari is Siwalik bhawar commonly named as Churia range (slope range from 10 to 25 degrees), which covers 14% of its total area, and the rest in the south is a plain area whose slope range from 3-10 degrees. The maximum temperature is recorded to be 42 ^{0}C and the temperature minimum can go down to 5 ^{0}C. The average yearly rainfall in Mahottari district is 1840 to 2200 mm (District Profile, 2012). More than 80% of the rain is concentrated in four months i.e. June to September. The total road network in Mahottari District is 185.03 Km: 109.2 km of feeder roads, 47.79 of National Highway and 28 km of Postal Road. The road network is shown on figure 2.

[3] Churia Range has very fragile geology. It covers 12% of the total country area. It is also known as siwalik.

[4] Northing range between 260 36' to N 280 10' and Easting 850 41' to 850 57'

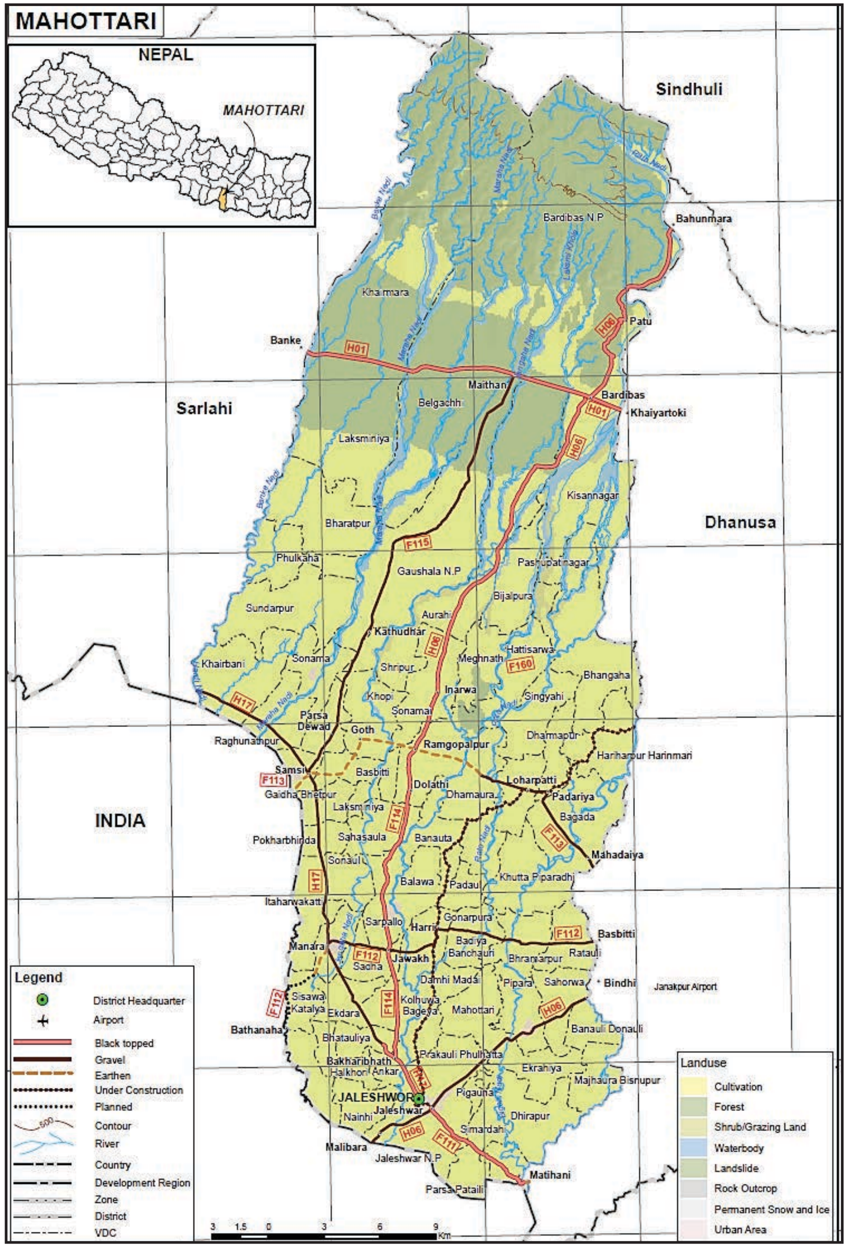

Figure 2: Road Network of Mahottari District

6. Roads and Water related challenges in Mahottari District

i. Siltation and sedimentation caused by road hydraulic structure

Siltation and sedimentation are common in most of the rivers that originate from or pass through the Churia range. There were 18 bridges along the span of 29 km of national highway. Almost 90% of them showed sedimentation and siltation problems as shown in Plate 1a. The braided nature of rivers is due to heavy load of sediment flow during monsoon causing river bed rise. The silting up in the river bed and blockage of culverts is leading to flooding and inundation of land and deterioration of road infrastructures. In areas where the deposited sediments fulfill the required quality for construction purposes, small-scale sand mining could be an important source of income. Controlled sand mining could be an option to ensure the safety of the roads, reduce maintenance costs and at the same time create economic opportunities. Controlled sand mining in this assessment is defined as the excavation and use of sand from culverts, road sides, bridges and other parts of the road for economic purposes without damaging the road and without changing the flow dynamic of with within these hydraulic systems.

The following aspects need to be considered when promoting controlled sand mining from roads:

- **Quality of sand:** this need to be checked and compared with the quality requirement for different construction purposes.
- **No damage on the road:** when removing sand from road hydraulic structures care should be taken not to damage the road but enhance its safety through removing the excess sediment deposits only; it should be considered as a maintenance practice.
- **No effect on the flow dynamics:** the road hydraulic structures are designed to regulate and allow easy flow of water with no erosion. Uncontrolled sand excavation could change the flow dynamics leading to erosion or other types of road damages by water. Care should be

taken not to change the flow dynamics of water in such structures.

- **Avoid conflicts over sand use:** with increase in sand price, the economic benefit from such resources could be quite significant and lead to conflicts over it use. It is necessary to consider emerging conflicts over the use.

(a) (b)

Plate 1: Silting up and blockage of hydraulic structure in Mahottari, Nepal: a) reduced gap between river bed and bridge due to siltation and b) pipe culvert blocked by debris and plants

ii. Erosion

Erosion and scouring downstream of culverts is a recurrent issue. In few cases, erosion in causeways results on the structures collapsing (Plate 2). This is due to high amounts of concentrated run-off during the rainy season.

Erosion at the edges of the road and gully formation was also observed due to uncontrolled run-off (Plate 3). Soil erosion control measures such as roadside vegetation can be used to protect the land adjacent to the road. The vegetation will lessen the impact of direct rain, slow down the run-off

(a) (b)

Plate 2: Erosion and scouring at the downstream of Culvert (a) and Causeways (b)

and increase infiltration. Other options are check dams, soil bunds, rock mattress and sediments traps.

(a) (b)

Plate 3: Erosion and gully formation from the edge of a road in (a) yellow and red circle, (b) close up click at a red circle section in plate 3a

Due to heavy precipitation in 2015, a gully was formed along a national highway (H 01). The gully is more than 3 m wide, 1.5 m tall and 100 m (Figure 3).

Figure 3: A gully formed during heavy rains in 2015

There are many opportunities to make better use of culverts and run-off from the road surface while reducing erosion. This can be done by (Plate 4):

- Flood water spreaders from paved road surface – these spread road surface run off to adjacent land
- Flood water spreaders from culverts – these take water from road culverts and spread it widely over the land, avoiding the development of gullies in the process
- Road side infiltration trenches – these collect run-off obstructed by roads into recharge structures

This will increase soil moisture, groundwater recharge and reduce erosion on the roadsides.

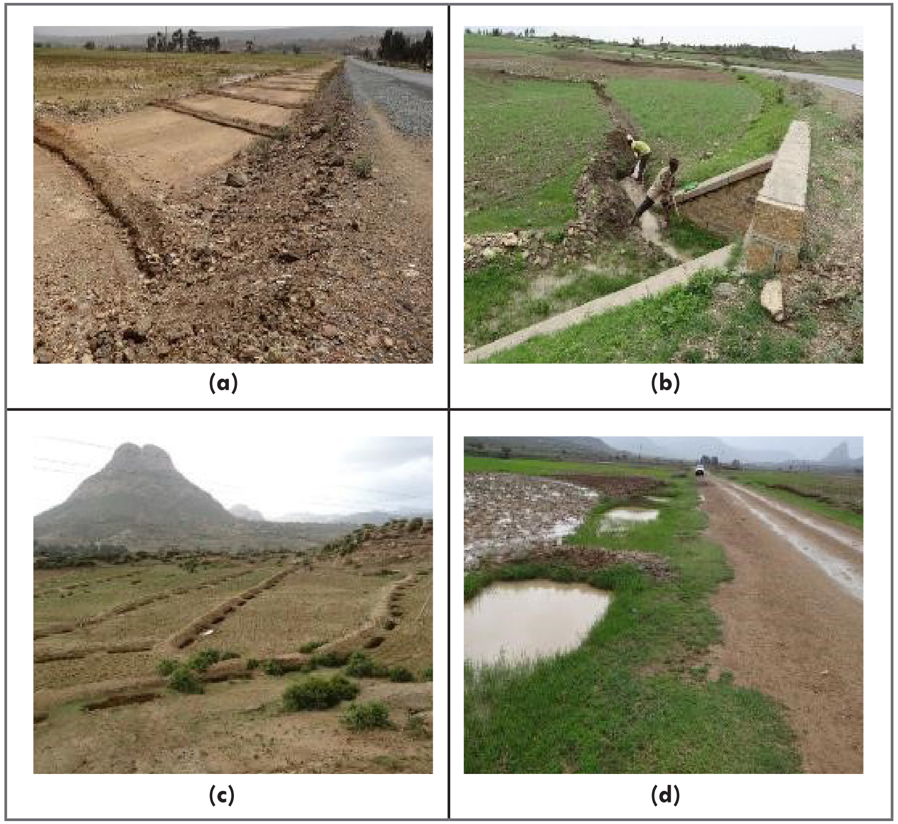

Plate 4: (a) Flood water spreader from paved road surface (b) Flood water spreader from culverts (c) Infiltration trenches fed by road water (d) Road side infiltration trenches – all pictures from Ethiopia.

iii. River bank cutting at both sides of hydraulic structures like bridges

Most of the bridges are constructed in the meandering section of a river. The river section at the bridges is narrower. During heavy rains, river flow along with sediments result on bank cutting in the upstream and downstream of the bridge (Plate 5). Soil and water conservation measures such as contour bunds, terraces, trenches and tree planting should be implemented in the upstream area to retain water and decrease the amount of sediments and the speed of runoff. Low-cost structural measures that help to prevent the erosion of riverbanks and the loss of agricultural and residential land can be constructed with local materials. Check dams can be placed at intervals to divert water and additional support is provided by spurs. Bamboo rhizomes can be planted between them and Napier grass (Pennisetum purpureum) is planted at the back of the structures so that as the plants grow their roots help to anchor the structure.

Plate 5: (a) River bank cutting in Mahottari; (b) river bank protection using local materials (Credit: WOCAT 2013)

iv. Settlement of Hydraulic Structures

Settlement of bridge pier foundation and spurs due to scouring was observed (Plate 6) due to high water flow with heavy sediment loads.

v. Water logging

When roads are constructed in a raised embankment water logging upstream of the road and downstream of culverts is very common (Plate 7).

Plate 6: Effect of water in the hydraulic structures (see red circle): (a) collapse of part of spur, and (b) settlement of a bridge pier (construction of new bridge is ongoing on the left side)

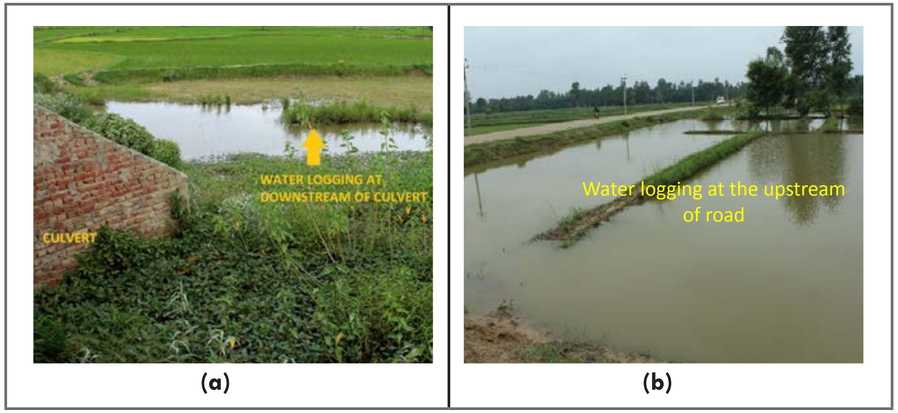

Plate 7: Water logging (a) at the downstream of the culvert and (b) upstream of the road due to raised embankment for road

Though not designed with this purpose, some of the raised embankments are acting as water retention structures and are used for livestock watering. Roads compartmentalize run-off and this could be considered when designing roads and drainage structures to allocate areas for rice cultivation. The retained run-off also recharges groundwater, which is a very valuable resource since during dry season most of farmers depend on groundwater for irrigation. More reliable water sources would lead to high yields by, for instance, encouraging farmers to introduce high-yielding rice varieties and apply fertilizers.

vi. Other water related problems on the road

In case of feeder roads, especially low volume or unpaved roads, the road surface is often damaged due to lack of proper structures to drain water, creating a muddy road surface during rainy season and interrupting or blocking traffic flow. The water from road could be diverted to the adjacent land to increase soil moisture on farmland, stored for future use or used to recharge groundwater through construction of recharge pits.

(a) (b)

Plate 8: Muddy road surface interrupts/blocks traffic flows during rainy season

Water bars (Figure 4) are a great solution to safely dispose water from the road surface to adjacent land. Water bars are narrow earthen structures built across roads to reduce the speed of water and consequently reduce erosion and uncontrolled runoff. They dispose excess runoff to adjacent land. Runoff should be disposed into vegetated areas or water harvesting structures to avoid erosion. They generally have a height of 75 to 150 mm, with a travel length of 0.3 to 1 m. These structures can be constructed with hand tools, but bulldozers are most commonly used.

Figure 4. Water bar in place (Source: United States Forest Service, 2017)

7. Current Practices of Road Water Management in Mahottari District

The discussions with the officials and experts from the roads department, local communities in Mahottari and field observations revealed that:

i. Water from roads (either water from the road surface, water trapped in the upstream due to construction of road or water from cross-drainage structures) is rarely used or is not considered a resource. From road design phase to road construction and maintenance, the main focus is always on proper drainage of water to safeguard road asset. From the experts to the local lay person, water from road is always considered an enemy.

ii. Agriculture and aquaculture are two main economic activities in Mahottari that need huge amount of water. Neither sector has made any effort to make use of water from the road. Pumping of groundwater is costly (and the source is depleting) and there is a lack of other source of water for agriculture except in few cases where they have surface irrigation services. Most of the land during dry season (except those with canal irrigation service) is left fallow.

This year (2017) farmers faced a prolonged drought due to a late start of the monsoon. Normally the monsoon starts by mid of June, but Mahottari and its adjoining districts only saw monsoon the last week of July. Knowingly or unknowingly, some efforts on road water harvesting initiated by farmers have been observed.

a. Roadside trenches

Trenches were observed along a feeder road on both sides of the road. Cut and fill approach is commonly used by the road department to improve road or as a part of road maintenance (majorly in low volume or unpaved roads). The trenches were excavated during that process and were not filled afterwards. As the rains were delayed some farmers tapped water stored in the trenches from one rain in June to the adjoining farmland (Figure 5). Further, we can also see some field bunds that retain rain water in farm plots to improve soil moisture, reduce rill erosion and mitigate sheet flow peaks and help rebuilt soil fertility. These trenches can also be used to drain paddy fields when there is excess water and to recharge groundwater and therefore secure water levels.

b. Pond culture

Rearing fish in ponds is a common and ancient practice in the area. The ponds harvest water from the surrounding area. There are dozens of ponds along the feeder roads in Mahottari district and in some cases road water is also drained to the pond, such as the pond shown on Figure 6. The ponds

Figure 5: Farmers constructing temporary dam structure in trench created by road department to irrigate adjoining paddy field with flooding method. After construction of temporary dam structure, they will send canal water and irrigation paddy field by surface irrigation method

Figure 6: A community pond used for rearing fish on the upstream side of a feeder road (F113)

are also used for livestock watering. If planned properly, these ponds could be designed and placed in such a way that they maximize water harvesting from roads by for instance harvesting water from culverts.

8. Potential for Beneficial Road Water Management

There is great potential to implement road water management for climate resilience and livelihood improvement in the Terai plains of Nepal:

a. Groundwater recharge: Shallow groundwater is a major source of water for domestic use in the southern plane areas of Nepal such as the Mahottari district. Water demand is increasing both for domestic and agriculture use, which is putting more pressure on groundwater resources. Farmers are growing more sugarcane which is high water demanding. Moreover, groundwater is increasingly used in the agricultural sector due to the Government's policy to provide subsidies for tube wells for irrigation. Groundwater can be recharged by diverting water from road surface and cross-drainage structures to recharge areas.

b. The trenches along feeder roads present a great opportunity for beneficial road water management. The already existing trench, if not filled by farmers, can have multiple benefits. i) act as a water storage from road and surroundings, ii) act as recharge pit, iii) slow down a runoff during monsoon, iv) water from trench can be diverted or pumped for agriculture and livestock watering during the dry period, v) can allow proper drainage and create conditions to introduce high yielding varieties and for proper management/use of fertilizers. Farmers and local experts need to be made aware of these opportunities.

c. Large investments are made each year for road maintenance and improvement of unpaved roads. And every year, damages are done by water due to its management issue. Maintenance or improvement of road is generally done by filling

(a) (b)

Plate 9: Road side trench with high potential for groundwater recharge, water for agriculture during dry period and water for livestock

soil from the roadsides. Sandy soils are very prone to erosion and are commonly washed away during heavy rain. There is need to introduce road water management technologies such as water bars, roadside trenches and flood water spreaders to protect road infrastructure and increase water availability for productive use.

d. Huge investments are made in the soil and water conservation as part of climate change adaptation. Road water management measures should be part of these as they increase resilience of both road infrastructure and roadside communities.

e. There is a potential of harvesting subsurface water from the river bed loaded with sediments (sand and gravels). In few cases, it is already in practice i.e. using subsurface water for irrigation in the downstream.

f. Controlled or gated culverts could be put in place to actively regulate water levels in rice fields. In this way, roads will play an active role in water management in the Terai plains. Fish ponds should be created in areas currently experiencing waterlogging by installing gated culverts to create the ponds.

g. Locating, sitting and designing ponds and borrow pits should be done is away that they also serve for road water harvesting. They can also be located in low areas where they are filled by seepage.

9. Conclusion and way forward

There is a strong case to systematically introduce beneficial road water management in the Terai plains of Nepal. This will reduce road maintenance costs and increase water availability for productive use. Currently, there are plenty of missed opportunities due to a lack of awareness among experts and communities. Sensitization of main stakeholders and local communities, the development of technical specifications and subsequent integration of beneficial road water management on ongoing programs will seize these opportunities and lead to increased climate resilience in Nepal.

Annex 1 ROAD CLASSIFICATION

Roads in Nepal are classified as follows:

A. Administrative Classification

Administrative classification of roads is intended for assigning national importance and level of government responsible for overall management and methods of financing. According to this classification roads are classified into:

1. National Highways (NH): National Highways are main roads connecting East to West and North to South of the Nation.
2. Feeder Roads (FR): Feeder roads are important roads of localized nature. These serve the community's wide interest and connect District Headquarters, Major economic centres, Tourism centres to National Highways or other feeder roads.
3. District Roads (DR): District Roads are important roads within a district serving areas of production and markets, and connecting with each other or with the main highways.
4. Urban Roads (UR): Urban Roads are the roads serving within the urban municipalities.

The overall management of NHs and FRs comes within the responsibility of the Department of Roads (DOR). These roads are collectively called Strategic Roads Network (SRN) roads. District Roads and Urban Roads are managed by Department of Local Infrastructure Development and Agricultural Roads (DoLIDAR). These roads are collectively called Local Roads Network (LRN) roads.

B. Technical/ Functional Classification[5]

For assigning various geometric and technical parameters for design, roads are categorized into classes as follows:

1. Class I: It is the highest standard roads with divided carriageway and access control (Expressways) with ADT of 20,000 PCU or more in 20 years perspective period. Design speed adopted for design of this class of roads in plain terrain is120 km/h.
2. Class II: Roads with ADT of 5000-20000 PCU in 20 years perspective period. Design speed adopted for design of this class of roads in plain terrain is 100 km/h.
3. Class III: Roads with ADT of 2000-5000 PCU in 20 years perspective period. Design speed adopted for design of this class of roads in plain terrain is 80 km/h
4. Class IV: Roads with ADT of less than 2000 PCU in 20 years perspective period. Design speed adopted for design of this class of roads in plain terrain is 60 km/h

For the design of roads the class of the road is taken as the basic deciding factor, which is ascertained based on the traffic volume on the road. But an approximate correlation can be established between the administrative and functional classifications of the roads as follows in the table below.

Table 1: Approximate Correlation between administrative and functional classification

Road/Location	Plain and Rolling terrain	Mountainous and steep terrain
National Highway	I, II	II, III
Feeder Roads	II, III	III, IV

[5] Approximate equivalence with road classification in other countries is as follows: class I roads correspond to expressways, class II –to arterial roads, class III-to collector roads and class IV-to local roads

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