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Resilient Roads in the Fergana Valley

Final Report

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Summary

The report seeks to assess the importance of the road infrastructure for livelihoods and climate change adaption in the Fergana Valley. Based on the conclusions of two CRVA assessment workshops conducted in two jamoat (third-level administrative divisions, similar to communes or municipalities) of Jabbor Rasulov district of Tajikistan and on field observations, it issues recommendations for climate resilient roads and better integration of roads and water management.

Roads tend to be particularly exposed and vulnerable to climate-related hazards, leading to whole range of risks. They are also crucial for post-disaster recovery and reconstruction, and instrumental in any climate adaptation plan. Therefore, in a region strongly affected by climate change and climate risks, a functioning and climate resilient road network is essential.

The main climate hazards identified by participants of the CRVA assessments were mudflows, droughts and strong winds. The conclusions of the workshop confirmed that livelihoods in the district fundamentally depend on roads, making livelihoods vulnerable to road disruptions. Roads are directly used as physical assets, and also contribute to people's wellbeing and social and human capital through socio-economic services. Roads impact both men and women, but since women mostly work as daily agricultural labourers, their livelihoods are highly vulnerable to road disruptions.

If workshops' participants generally assessed the road density as sufficient, they raised issues regarding the quality and vulnerability of the road infrastructure. Observations on the ground also pointed to clear evidence of erosion triggered by roads, drainages and culverts. These negative impacts - which contribute to mudflows and land erosion - could be avoided with proper design and maintenance, and must be addressed to avoid a further worsening of the situation. .

In terms of adaptation measures, participants stressed the need for roadside tree plantations, hereafter referred to as shelterbelts: to stabilize the soil and avoid erosion, to reduce mudflows, but also to protect the fields from the impact of floods and strong winds (which also lead to erosion). Such shelterbelts would also decrease dust, provide shade and shelter during extreme heat, and produce other positive externalities such as moisture control, biodiversity (pest control), fertilizing the soil, and generating alternative livelihoods. Other recommendations include changing drainage and bridge designs, drifts, slope stabilisation, gully plugging, and spot maintenance. Institutional measures would also be required: better coordination between roads and water authorities; more inclusive and participatory processes (integrating local knowledge and needs); and new technical guidelines.

A number of approaches would contribute to a better integration of roads, water and climate risks, and make roads more resilient to climate hazards and climate change in ways that would maximise positive externalities and minimize negative ones. Among these approaches are the closely related concepts of multifunctional roads, green roads, and roads for water, which all build on and integrate Ecosystem-based Adaptation (EbA) tools and methods. By adopting such an approach and working on the watershed level, roads can contribute to restoring ecosystem services such as water provision, water storage (soil, vegetation), slope stabilization, soil fertility, water retention (flood protection), fodder provision and crop production.

The report, which is completed by a field visit report, adds to the above mentioned approaches by providing additional options related to current and future proposals on increasing climate resilience in the Fergana Valley by EbA and Disaster Risk Reduction (DRR) solutions.

Objectives

This report aims to identify solutions for resilient roads located in two *jamoat* in Jabbor Rasulov district of Tajikistan where livelihoods depend on critical infrastructure exposed to flooding, landslides, and mudflows, making use of the outcomes of the Climate Risk and Vulnerability Assessment (CRVA) conducted in the same project. More specifically and as per the terms of reference, it attempts to:

1. Assess the criticality of (feeder) roads (Section 1), in the context of current and future climate risks, based on outputs of the participatory workshop conducted in the district of Jabbor Rasulov and on field observations;
2. Confirm the interlinkages between local livelihood strategies and a functioning road infrastructure (Section 2), and the potential of adapting existing road infrastructure and construction methods for future roads to climate change adaptation and resilience (Sections 4 and 5).
3. Contribute to Impact chains of risk components and potential adaptation options with M&E indicators (Section 3).
4. Draft ecosystem-based or green-grey infrastructure related measures to increase resilience of critical road infrastructure (Section 4 and Annex).
5. Provide Recommendations for further increasing climate resilience in the Fergana Valley by upscaling Ecosystem-based solutions for Adaptation and Disaster Risk Reduction in the framework of a larger project (Section 5).

The outcomes should serve as inputs to ongoing projects like a regional project on Ecosystem-based Adaptation (EbA) in high mountainous regions of Central Asia (CA), implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, and commissioned by the International Climate Initiative (IKI) of the Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety (BMU). Additionally, the outcomes should also serve as input to different upcoming projects related to climate change adaptation and disaster risk reduction that are currently in different planning stages.

This report is completed by a field visit report (Annex 1), as well as technical recommendations provided by MetaMeta Research (Annex 2). It also complements the work undertaken by the research team through the CRVA workshop, consigned in a separate report, and builds to a large extent on its conclusions (without duplicating them).

More generally, this report also attempts to produce additional recommendations to the approach and methodology of *Climate Risk and Vulnerability Assessment of peoples' livelihoods and road infrastructure in the Fergana Valley* (UNIQUE/GIZ 2018), and to complement and detail the conclusions and recommendations developed in *Climate Risk Assessment for Ecosystem-based Adaptation – A guidebook for planners and practitioners* (GIZ et al. 2018) regarding road related aspects.

Overall, this report focuses on specific questions, provides detailed complements of information to these three publications, and attempts to make useful recommendations for GIZproposals related to roads and climate resilience.

1. State and vulnerability of the road infrastructure

This part assesses the criticality of (feeder) roads, in the context of current and future climate risks, based on outputs of a participatory CRVA workshop conducted in the district of Jabbor Rasulov and on field observations.

Roads in Tajikistan and in the Fergana Valley: situation and why an intervention is justified

Due to its size, mountainous terrain, and existing infrastructure, **roads provide the backbone of the transportation system in Tajikistan**. Internal transportation needs are currently mainly served by a

26,766 km long road network (Government of Tajikistan 2011), consisting of:

1. Public (State) roads under responsibility of the Ministry of Transport and Communications. The Public road network is made up of 13,975 km of roads, which are further divided into:
- 5,291 km of Republican roads. Republican roads are the main arteries of the network, and include 17 international roads.
- 8,684 km of Local roads, or feeder roads. They consist of 1,261 roads of variable length that link settlements in rural areas to main roads.

2. Departmental, or non-public roads. They consist of 12,791 km of "industrial, technological and access roads to various sites and farmland. They do not depend on the Ministry of Transport, but on "several ministries and departments, committees and executive bodies of state power, of cities and regions" that are responsible for their construction and maintenance (Government of Tajikistan 2011).

If the Government of Tajikistan's priority in terms of transport lays in the improvement of the rail network[1], important investments in the improvement and rehabilitation of the road infrastructure have been carried out and will be expected in the coming years. This is due to the acknowledged strategic importance of roads as well as on the current situation and transportation needs. In 2011, it was assessed that 75 percent of republican roads had lost all or part of their pavement, and 60 to 80 percent of the road network was not suitable without significant rehabilitation (Government of Tajikistan 2011). The National Development Strategy (NDS) 2030 of Tajikistan also cites low roads' density and quality as a major impediment to economic development, and mentions the need to improve the road connectivity and quality to conform with "international" standards (Government of Tajikistan 2016). Citing the study by UNIQUE/GIZ: "Most of the Central Asian infrastructure, including roads, were established during the Soviet times and are currently in poor conditions due to lack of proper maintenance (and finances). For example in Tajikistan, about USD 1 billion in road assets were lost between 1990 and 2010, and 80% of the 14,000 km road network under the Ministry of Transportation and Communication's (MOTC) control is beyond repair" (ADB, 2011) (UNIQUE/GIZ 2018: 4).

Moreover, **the road network is also fundamental in terms of facilitating international trade**. Consequently, road infrastructure projects financed by multilateral financing bodies are under construction and will be constructed in the coming years. This infrastructure investment will mostly happen under the umbrella of CAREC 2030[2]. In addition, the development of the Chinese led Belt and Road Initiative (BRI) may also lead to further road corridors being built and updated with Chinese funding (currently providing 88% of bilateral loans in Tajiikistan), such as the Dushanbe–Chanak highway, which connects Tajikistan's capital to Uzbekistan.[3] Although Tajikistan may not be at the centre of the BRI as far as international road corridors linking China's heartland to Europe are concerned, the country remains one one important node, and the Fergana Valley in particular, being shared by Tajikistan, Uzbekistan and Kyrgyzstan is one region that will most likely attract transport infrastructure funding in the future.

Central Asia is strongly affected by climate related hazards, and is and will be strongly affected by

[1] Based on the estimation that it carries 95% of international freight and on the estimation that "investments in railway infrastructure will be more profitable than other sectors" Government of Tajikistan, 'State Target Program for the Development of the Transport Complex of the Republic of Tajikistan until 2025. Approved Government Decree of April 1, 2011 No. 165', in Ministry Of Transport (ed.), (Dushanbe, 2011).

[2] "It will continue to assist in completing road corridor investments, paying more attention to sustainability of road infrastructure. There will be an increased focus on road safety and road asset management. Institutional and financial reforms in the road transport sector will help improve road maintenance practices and enhance road asset life cycles. Adb/Carec, 'Carec 2030. Connecting the Region for Shared and Sustainable Development', (Manila, 2017) at 13.

[3] The 345-kilometer highway was upgraded by the Chinese companies thanks to a US$296 million loan from Beijing.

the impacts of climate change: higher average and extreme temperatures (1.5-2 °C for 2050; +6 °C by 2100), changes in precipitation patterns, extreme meteorological events, are expected to lead to water scarcity, droughts, decreased agricultural yields, increased slope instability, and more deleterious impacts (For the latest and accurate overview on the literature on the subject, see (Muccione and Fiddes 2018). The Fergana Valley is said to be one of the most vulnerable, climate-sensitive and natural resource depleted regions of Central Asia.

Roads are particularly exposed to climate hazards such as landslides and debris flows, **but also in general vulnerable to climate risks** (adapted from ADB 2014):

- Changes in temperature impact road pavements (for example, heat-induced heaving and buckling of joints, thermal expansion and contraction, water/ice infiltrations, etc.).
- Changes in temperature impact the permafrost and thus the infrastructure lying on permafrost.
- Changes in precipitation and water levels impact road foundations.
- Extreme weather events such as storms affect the capacity of drainage and overflow systems to deal with stronger or faster water flows, leading to floods and siltation, impacting bridges, etc. (ADB 2014: 6-7).

In these circumstances, a climate resilient road network is fundamental. Moreover, **roads are also very important for post-disaster recovery and reconstruction**. Therefore, in a region strongly exposed to climate risks and affected by climate change, having a performing and resilient road network is essential.

Another impact, which is less or only partially accounted for in the literature, is **the impact of roads on the environment**. For instance, roads can facilitate erosion due to road cutting, increase and concentrate the runoff, and lead to dust formation from road pavement abrasion. The opening of roads in hilly terrain also opens up fresh mountain slopes and increase the air-surface exposure, drying out the soil and vegetation (Van Steenbergen and Yakami 2018: 13). The road surface can be a source of sediments too. In places, it was found that road can increase erosion by 12 to 40% compared to the original situation (Van Steenbergen and Yakami 2018: 15) Part of these impacts are addressed in standard Environmental Impact Assessments (EIA), but part of the impact of roads on the hydrology (surface and groundwater flows) are often more difficult to predict and therefore seldom properly planned and accounted for. In fact, due to poor hydrology related considerations in road construction, roads can increase climate risks, trigger erosion and siltation, or block ground water flows leading to local droughts and floods, possibly risking damage to the foundations of the road itself. Road construction can equally offer potential for positive impacts on certain environmental factors, particularly the hydrology, by increasing water recharge and availability, when accompanied by the right measures. Roads that integrate these aspects into their design can be called “multifunctional roads” (Demenge et al. 2015; Demenge and Mehta 2017).

In general, and as it will be highlighted later in this report (Section 3), **a functional and resilient road network is essential for any climate adaptation plan for the populations of the region** (for instance based on regional integration of agricultural value chains, etc.). And there is also a potential to increase people’s resilience, through the concept of “road for water”.[4]

Therefore, these elements all concur to justify interventions that would aim at better integrating climate risks into road planning, construction and management, in order to:
- increase the resilience of the road infrastructure in line with increasing the resilience of the population.
- decrease the negative impacts of roads and their construction on the environment, on people’s assets and their livelihoods.

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[4] See http://roadsforwater.org/.

Situation of roads in Jabbor Rasulov district based on the conclusions of the workshops

Two workshops on Climate Risk Vulnerability Assessements (CRVA) were conducted in Khujand and in Golekandoz, with representatives of two different jamoats from the Jabbor Rasulov district in the Tajik part of the Fergana Valley in attendance respectively (See the main report for specific conclusions). The opportunity was used to analyse, in more detail, peoples' livelihood options in relation to road infrastructure in the Fergana Valley, and to understand how livelihoods were affected due to flooding, landslides, droughts, and mudflows triggered by climate risk.

Road conditions

Participants of the workshop stated that although they consider **the density of the road networks sufficient for their needs, the bad condition of the roads is posing a challenge** as it is leading to high vehicle maintenance costs and therefore high transportation costs for people of the region. Generally, roads are affected by erosion/collapse along the river, rock falls, mudslides, and bridges that are destroyed by trucks (60t and plus). Capacities to maintain roads and deal with disruptions are also limited. Local roads, whose construction dates back to Soviet times, were built and maintained by kolkhozes; today they are mostly maintained and repaired by community work (people provide labour and funding), although financial capacities are insufficient. The district's road department is in charge of a 13km long "non-republican" road, although people frequently take part in the maintenance.

Roads and climate risks

In terms of climate risks, participants mentioned that the greatest threat is by far posed by mudflows as these have the potential to destroy almost all infrastructure types along their paths: roads, irrigation canals and drinking water networks, bridges[5], electric poles, sometimes houses and granaries. Participants ranked "Infrastructure (including roads)" and "Erosion of river banks" as being most at risk from mudflows.

Most important risks linked to mudflows	
Destruction of agricultural land	2
Irrigation infrastructure	1
Infrastructure and roads, bridges, buildings	4
Infectious Diseases	2
Erosion of river banks	4

Table 1: Risks ranking linked to mudflows

Participants also ranked the quality of roads and road disruption as the number one vulnerability factor when dealing with droughts (for instance, when water has to be transported).

Road disruptions due to mudflows happen once or twice a year, and particularly affect internal/local roads which are built in more exposed places. As it will be seen further in this report, all livelihood activities depend to some degree on the road network and are therefore highly affected by road disruptions.

When the road is impassable or bridges are damaged or destroyed, people cross the river when it is dry or use old off-road capable trucks. These trucks at times "go through the fields" which is likely to cause more destruction to farmers' assets. To clear the debris and repair the road, communities

[5] Need resistant design (fords and Irish bridges)

receive the support of the Committee for Emergency Situations (CoES). The capacity of the population to deal with emergency situations remains though insufficient. Private owners of machinery are also hired to clear mud from the road and other damages. Clearing the damage can take from 1 week to 1 month (as it happened when the bridge in Qurgoncha was destroyed in 2005), causing difficulties for residents to access the market. They managed by using an existing bypass road.

Other issues linked to extreme heat (we were told that temperatures of 50 °C were recorded locally in 2018, although not formally acknowledged by the authorities) were equally mentioned by participants of the workshops. When **heat waves** occur, the tar melts and can be deformed by traffic. Since trucks (vehicles of more than 6t per axle) are not allowed to drive from 10am to 8pm in summer (May 1st – Aug 31st) when the temperature is above 26 °C, this also creates traffic disruptions, with direct impacts for the economic activity. People also mentioned the **need for shade and shelters** for motorists when ambient temperatures reach certain levels and the road surfaces heat accordingly.

Damages triggered by roads

According to participants, culverts and road drains concentrating water had not led to erosion so far (which was shown to be not necessarily factual in all cases by field observations done during this study), but stagnating water does sometimes affect roads. When deformation happens, these are compacted by the use of heavy machinery. The compaction does lead to changes in the circulation of underground water flows, although this result does not seem to have led to observable negative consequences yet.

Other issues linked to roads identified by participants during the workshop sessions were the formation of **dust clouds from the roads**, as all local roads are non-gravelled. This dust reduces the visibility, is seen as at the origin of allergies within people and pest attacks affecting the cotton plantations **as it gets carried by wind onto plants into fields**. In order to remedy these problems, people cover dust roads with gravel.

Interestingly people **stressed the need for shelterbelts**, “Not just one or two layers [of trees] but as many as possible”, as a way to:
- protect the soil from wind and water erosion;
- stop mud flows
- protect the fields from the impact of **strong winds** (which lead to erosion in the fields; mud flows and winds were cited as the two strongest climatic hazards during the workshop in Golekandoz).

It is noteworthy that people insisted on this type of measure, which is a form of EbA and part of Green Road approaches, and has many positive externalities in terms of moisture control, biodiversity (pest control), fertilization of the soil, and generating alternative livelihood options. Such measures are also part of Tajikistan’s strategy in terms of air quality control. It cites as a measure for protection against air pollution the development of the road network and improvement of the quality of their maintenance, notably through the “creation of protective lanes along the roads on the roadside” and “a protective forest” (Government of Tajikistan 2011). Although it is a rather narrow perspective compared to all benefits linked to road plantations, this suggests a possible alignment between EbA and official government policies.

Roads in Jabbor Rasulov district: conclusions from the field visit.

See annex 2 for the detailed field visit.

The field visit greatly complemented the information garnered during the workshops by providing direct evidence of the state of degradation and challenges affecting roads in Jabbor Rasulov district.

Most of all, **observations on the ground pointed to clear evidence of erosion being triggered by roads, drainages and culverts.** These negative impacts, which contribute to mudflows, appear to be avoidable if adequate measures were applied. Moreover, negative impacts triggered by roads often end up threatening and damaging the road infrastructure itself, often beyond repair. Hence **these challenges need to be addressed before irreparable damage is caused.**

Damages to the road infrastructure	**Damages caused by the road**
Road damaged or eroded by the river and mudflows, sometimes beyond repair; Eroded ditches; Mud and debris flows obstructing the road; Bridge washed away	Land erosion triggered by the road, drainages and culverts; Erosion and siltation of agricultural land leading to loss of topsoil

Table 2: climate-related impacts caused to the road and by the road.

Overall, it seems the impact of roads on the environment, and the necessity to integrate water and climate considerations into road design, building and maintenance are not clearly understood yet by local people and by the authorities. There seems to be some **potential for capacity building in this sphere:**

- better coordination between roads and water authorities;
- more inclusive and participatory processes (integrating local knowledge and needs);
- Dissemination of appropriate technical guidelines.
This is particularly the case for roads that are locally built, without the help of central authorities, and where fostering changes and cross-sector cooperation is easier to achieve.

2. Linkages between local livelihood strategies and a functioning road infrastructure

Roads and livelihoods

One of the purposes of the research was to understand how **local livelihoods depend on a functioning road infrastructure**. The response is that livelihoods in the district fundamentally depend on roads, making livelihoods extremely vulnerable to road disruptions.[6] As mentioned in the UNIQUE/GIZ's study: "For agriculture-dependent livelihoods, connectivity to markets plays an important role which is affected by damaged roads and loss of productive lands as a result of natural and climate-related hazards"; in the Fergana Valley's countries, agriculture accounts for between 20% and 30% of GDP (UNIQUE/GIZ 2018: 17), and a large proportion of the population – often the most vulnerable – directly depends on agriculture for incomes. But as the table below shows, in the two *Jamoat* where the workshop took place, except for distant and long-term migrations, **roads enter as physical assets (or capital) as a direct component to peoples' livelihoods**. Most livelihoods are either roads and transport based (eg. Mechanical shops, busses, etc.), or depend on roads and the transportation system for the movement of goods and people. Roads also **contribute to people's wellbeing and social and human capital through socio-economic services**. Since roads equally contribute to livelihoods, **they directly affect people's resilience in the face of climate hazards**.

Livelihoods based on the road/transport system
- repair workshops, tractor and car maintenance workshops

[6] According to participants, economic activities that are the most affected by road disruptions are agriculture, bricks making as well as those related to the local administration. But in the end, all activities depend on roads and are affected.

- 10 lines of *Mashrutkas* (400 private small busses) - Phone taxis.
Livelihoods highly dependent on roads - Agriculture (cotton, wheat, horticulture…): 360 collective farms plus private farms - Rearing livestock ("officially"14,000 heads of sheep and 1,000 cows)[7] - orchards (apples, apricots, quinces, peaches, lemons…) - brick factories (11) - carpet production factories - mulberry trees for silk worms - processing factories - borrow pit/quarry for silica; exported to Uzbekistan - shops, building material, that support part of the district (200 shops), restaurants - two markets - short-term labour migration to Kyrgyzstan
Socio-Economic services dependent on roads - 12 schools, hospital, clinic, and physiotherapy, health centre - marriages - birth delivery in Kyrgyzstan (closer for villagers of Qurgoncha and beyond)
Livelihoods not dependent on the road (or less dependent on roads) - long-term and distant migration (30% of the workforce)

Table 3: Livelihoods, socio-economic services and road dependency

All roads are served by *mashrutkas* (private regular small busses) and taxis. And **both types of roads - Republican and non-Republican (i.e. Feeder and Departmental) are important for income generating activities in the district**. The population of Golakandoz as a whole owns more than 4000 vehicles (population: 46,000). Exchanges with Kyrgyzstan are also very well developed, and depend on cross-border roads.

In facts, participants confirmed that "all income-generating activities are dependent on the road". One episode illustrates this: when Kyrgyzstan closed the border crossing in 2014/5, people in Qurgancha who used to cross through Kyrgyz territory to access the rest of the valley found themselves deprived of road connection. They collected Tjs 60,000 to build the 30 km long dirt track connecting their village to the rest of the road network.

Gender impacts

The road affects equally men and women, as both sexes are involved in income generating activities for which the use of roads is required. At the same time, because **women mostly work as daily agricultural labourers, and need to travel to their places of work on a daily basis, their livelihood is comparatively more vulnerable to road disruptions**. Participant also mentioned that the crossing of rivers and blockages is more difficult for women and young children.

[7] Rearing livestock is arguably less dependent on roads, but roads become critical in case of water and fodder scarcity, when these need to be carried by truck.

3. Contribute to Impact chain of risk components and potential adaptation options with M&E indicators

Roads in a CRVA assessment.

Roads are often thought of in terms of vulnerable assets when exposed to potential hazards. **Roads feature prominently in climate risk assessments due to their many different functions, which result in complex effects on impact chains:**
- in terms of exposure;
- as vulnerability factors: with positive and negative impacts;
- in terms of risks per se, or climate impacts when those materialise (and mediating climate impacts);
- as adaptive measures, and mediating the range of adaptive measures available to societies.

Exposure Roads are part of the most at risk infrastructure, especially by water related hazards (e.g. floods, mud-flows, rock-falls). They are costly to build, maintain, and repair, and it is difficult and costly to reduce their exposure.
Vulnerability **Positive factors**: - Roads are an essential element of livelihoods and service delivery, and contribute to increased resilience of the population and region. - Roads are essential in enabling quick response and recovery during and after a disaster, and are essential for reconstruction efforts after disasters. - Road (re-)construction and maintenance directly contribute to employment and incomes. - If used for rainwater harvesting and ground-water recharge, they can contribute to the mitigation of droughts. **Negative factors:** - Roads may have negative impacts on water availability and distribution, erosion, pollution, dust, and exacerbate the impact of climate hazards. - The impacts of road disruptions are proportionately more deleterious when they are essential to peoples' livelihoods and service delivery
Climate risks and impacts - Roads are impacted by climate hazards. - Roads will be subjected to increased hazards linked to climate change impacts (heatwaves, precipitations, floods, extreme temperatures, etc.). - Roads deeply influence/mediate climate impacts on socio-ecological systems, due to the role they play as vulnerability factors. For instance, the impact of extreme precipitations will be different if the water is allowed to flow evenly, or if it is canalised along the road and culverts and into the fields/village: in that case, roads exacerbate the consequences of climate impacts in some areas, while protecting others. Disrupted road connectivity also has profound social, economic and political impacts for affected populations.
Adaptive measures - Roads can have many unintended consequences, which if harnessed, can positively contribute to adaptation and resilience. - Roads can be an essential element of socio-economic systems' resilience. - In general, roads affect many aspects of socio-ecological systems, and largely define and contribute to the range of adaptive measures (and coping strategies) that are available to societies.

Table 4: Roads in a CRVA assessment

The fact that roads are both exposed to climate risks, decisive for the vulnerability context and essential to the adaptation strategies available implies that roads need to be made as resilient as possible and built in a way that maximises positive externalities and minimizes negative ones.

Possible indicators

(non-exhaustive list):
- km of degraded roads;
- km of degraded road drains;
- km of roads with shelterbelts;
- number/% of culverts leading to erosion;
- number/% of valleys where erosion has been stopped through gully plugging;
- surface reforested/resown/fenced-in at degraded areas above the road;
- quantity of silt/mud/sediments deposited in the river at river crossing every year.

4. Ecosystem-based or green-grey infrastructure related measures to increase resilience of critical roads infrastructure

General recommendations

A number of approaches would contribute to a better integration of roads, water and climate risks, and making roads more resilient to climate risks and climate change. Among these approaches are the closely related concepts of **multifunctional roads/roads for water** and **green roads**. Both concepts are very similar and convergent in terms of design, the difference being that multifunctional roads insist on the use of the roads, whereas green roads insist on construction methods (typically labour-intensive) and on the use of local materials. **Both approaches are compatible with EbA and make full use of its methods**.

Multifunctional roads

The concept of multifunctional roads takes as a starting point that the two distinctive objectives of improving road connectivity and water availability for irrigation are interlinked and can be served by the same infrastructure (Demenge et al. 2015). In addition to securing transport functions, roads can also:
- be instruments for water management;
- be used for flood protection;
- stem erosion and promote good land management;
- through roads side vegetation, control dust and filter effluents.

Advantages of multifunctional roads

"A multifunctional approach to road building increases the chances that the road infrastructure brings fundamental improvements to the conditions faced by the rural poor, notably by improving access to water, and therefore bringing positive impacts to their livelihoods. Such positive impacts could include, among others, improved physical assets (road, irrigated land, new land under cultivation, ponds); livelihoods diversification (sale of water, commercial agriculture, fish farming, increased demand for labour); reduced vulnerability (seasonal water variability reduced, climate change resilience); and saved time in transport/travelling/irrigation/chores. These are very likely to improve people's livelihoods and well-being and contribute to poverty reduction and increased resilience." (Demenge et al. 2015: 12)

Table 5: Multifunctional roads

Green roads approach (developed in Nepal). Relevant elements: • Use of labour based methods – working through local construction teams and avoiding the use of mechanical equipment or imported materials (such as gabions or concrete); • Preference for maximum road slopes: (where possible) 2% or less, and not exceeding 10% so as to ensure road remains passable and safe; • Preference for down sloping road crowns rather than road drainage canal networks – as the latter have a tendency to concentrate run-off and create uncontrolled spill-over when blocked whereas down sloping crowns dispose of the run-off evenly; • Mass balance method whereby the material from the road excavation is as much as possible reused to make the downslope toe of the road. In this way the road width is not fully excavated from the hill slope – causing less excavation and less disruption to hill-sides; • Use of bio-engineering methods to stabilize hill-sides; • Down slope protection, among others with breast walls Adapted from (Van Steenbergen and Yakami 2018)

Table 6: Green roads

As mentioned by UNIQUE/GIZ, “typical infrastructure planning normally does not consider ecosystem services and climate risks in the planning which bears a high risk of ecosystem damage and negative impacts on peoples' livelihoods“ (UNIQUE/GIZ 2018: 1). Moreover, if hard engineering techniques are usually considered to fix water/road issues (For hard or grey engineering measures, see: (ADB 2014)), this is not necessarily the case when applying the green roads and roads for water approaches: these also consider green engineering techniques. Also, **such approaches attempt to look at environmental issues in context, considering the whole ecosystem in terms of impacts and potential solutions**. Roads can impact the ecosystem, the circulation of people, materials and water; they can change the volumes and directions of water flows, the albedo and permeability of the soil, the value and therefore use of the land and local resources, location of settlements, etc. At the same time, roads are highly impacted by the ecosystem, the climate, geological processes and protecting the road infrastructure often requires interventions elsewhere in the watershed. Countering erosion and siltation, for instance, may require reforestation and pasture restoration higher upstream. These approaches make use of the full potential of roads to harness positive effects for the hydrological regime.

Hence the purpose and impacts of roads are not limited to accessibility and transport. Roads can contribute to restoring ecosystem services by:

- Water provision, water storage (soil, vegetation);
- Slope stabilization;
- Soil fertility;
- Water retention (flood protection);
- Fodder provision;
- Crop production

Therefore, such approaches are fully compatible with EbA interventions, which “use biodiversity and ecosystem services to increase the resilience of exposed elements of the system (people and roads) by stabilizing the soil, increasing the vegetation cover, increasing the water retention function, decreasing the water run-off” (UNIQUE/GIZ 2018).

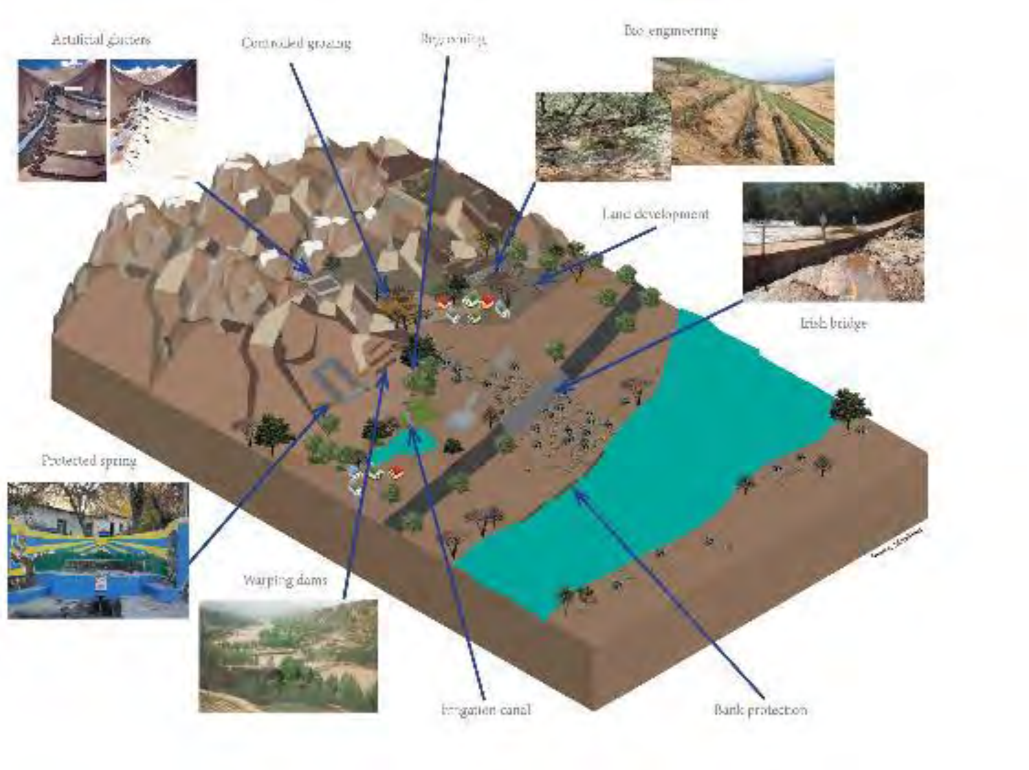


Illustration: Example of multi-functional roads/roads for water approach making use of green/grey methods at the watershed level (Source: MetaMeta. Unpublished).

Specific recommendations

Specific recommendations are made in Annex 1 (field visit) and Annex 2 (technical guidelines). Here is a summary.

Hazards and associated risks and impacts	Recommendations
1. Mudflows: overflow of the canal, erosion of the river-bed and agricultural land, siltation, destruction of the water and road infrastructure.	- Re-enforcement of the road embankment (Concrete blocks attached/boulders to protect the bank, and concrete slabs in the bend). - Correction of the river trajectory. - Flow-through dam for flood control. Higher in the watershed: - Reinforcement structures and vegetation would be required to protect the riverbanks. - Study the possibility to increase water recharge through infiltration ponds and trenches to increase the amount of groundwater available for irrigation and drinking purposes from the wells.
2. Road and land erosion due to insufficient run-off management.	- Consolidation on a priority basis of damaged sections of roads to limit further destruction (spot maintenance).

	- Refilling ditches with gravel. - Scour checks: small “check dams” (consisting of bigger stones or stone walls) to reduce the velocity of the water and enable the sediments to settle. - Cleaning the channel from garbage to avoid clogging /stagnating water on the road. Generally, canals and drains should not be used to dispose off garbage. - Potential change to road design: downslope road crowns to limit stagnation of water and limit the size of ditches. - Roadside plantations to maintain the soil in place, provide livelihoods, decrease wind erosion and limit dust (Note that this measure was mentioned by participants during the workshop). - Generalise the use of turnout ditches: diverting systems to enable road water harvesting and use of supplementary water for irrigation.
3. Overgrazing leading to: - erosion; - reduced productivity of pastures; - siltation; - mudflows; - destruction of assets.	**-** Fencing of critical areas to enable regeneration (plus sowing pastures and pasture management). - Re-forestation of degraded areas (in Tajikistan and Kyrgyzstan) and fostering sustainable land management. - Check dams in erosion gullies (gully plugging) to limit the flow of water and enable the slopes to stabilise.
4. Insufficient water management/poorly planned culverts leading to: - unchecked erosion of pastures and loss of topsoil; - irreversible damage to the road; - more siltation and erosion downstream.	Alternative options for the evacuation of the runoff: - more dispersed culverts, with a cemented apron under the gully and a settlement pool to spread the water and decrease the amount of water flowing or - rolling dips on the road to enable the runoff to be evacuated on the road; or - **fords/ that would spread the water over a larger area, depending on the amount of runoff.** This would indeed be the **best option**, intercepting the runoff to irrigate pastures and potential reforested areas. Downstream: - gully plugging: stone walls in the gully to decrease the flow of water and keep the soil in place, potentially with trees and roots (“green gabions”).

	- revegetation (trees and sowing) of degraded slopes. Upstream: - Above the road: check dams/stone walls in the erosion gullies to slow down the flow of water and enable sedimentation, creating greener and potentially fertile areas for plantations. - Revegetation of degraded slopes and enclosures in critical areas. Note: these measures would not only protect the road infrastructure, but potentially highly reduce the amount of sediments that make it into the canal and contribute to mudflows.
5. Erosion of bridge pillars and land adjacent to the flow.	- Modified bridge design. - Extend the concrete slab with stones to prevent erosion after the slab. - Revegetation on the banks to limit erosion to the fields downstream of the bridge. - Potentially (green) gabions in adequate locations before the riverbed to protect the embankments and slow down the river flow and facilitate infiltration. On the dirt track: - stone (or other type of) pavement to protect the dirt road while not decreasing the permeability of the surface. - rolling dips to direct the flow to one side of the dirt-track.

Table 7: Hazards, associated impacts and recommendations

5. Recommendations for further increasing climate resilience in the Fergana Valley by upscaling Ecosystem-based solutions for Adaptation and Disaster Risk Reduction in the framework of a larger project.

Which hazard: Mudflows or Droughts?

Based on the conclusions of the CRVA workshop, expert knowledge, and field observations, the three main climate related risks/hazards affecting the region and population are by order of importance mudflows, droughts and strong winds. If mudflows are deemed the most important (and therefore should be dealt with on a priority basis), both mudflows and droughts are linked to the same vulnerability factors - land erosion and poor water and flood management –, re-enforce each other, and require similar and complementary interventions. Among these interventions, an EbA approach aiming at restoring degraded ecosystem services seems to be very appropriate. In fact, mudflows and droughts are two faces of the same coin, and it seems difficult to address one issue without addressing the other.

Roads

Given the importance of roads for livelihoods, climate adaptation, and disaster recovery on the one hand, and given the current condition and vulnerability of the road infrastructure on the other hand, an intervention aiming at reducing road infrastructure vulnerability by using ecosystem based solutions would potentially carry high benefits for the populations of the region, and therefore seems highly justified. The road centered interventions could function as entry points and as necessary elements for broader adaptation planning encompassing the whole watershed. Because of their compatibility with and large applicability of EbA tools and methods, multi-functional roads/roads for water seem particularly appropriate. Examples include shelterbelts, largely endorsed by participants, but also pasture sowing and pasture management, gully plugging, etc.

Besides technical solutions, institutional measures would be required:
- better coordination between roads and water authorities;
- more inclusive and participatory processes (integrating local populations, local knowledge and needs, and therefore increasing ownership);
- technical guidelines for roads and water management.

Scale

Since solutions at the level of the watershed are necessary, and part of the interventions lie in Kirgiz territory, a regional approach is required and a high degree of trans-border cooperation will be necessary. In addition, roads also carry the potential to be used to foster cooperation between the countries more easily than the extremely contentious issue of water management.

The importance of feeder roads

"The vision behind the CAREC transport corridors is that the priority investments in road and transport infrastructure along these corridors will eventually transform transport corridors into logistic corridors, and ultimately into economic corridors" (UNIQUE/GIZ 2018: 5). So that these roads do not become just transit points with no or only limited benefits provided to local populations, attention to feeder roads in combination with wider adaptation measures are required to enable the local population's full participation within the regional economy.

The assessment shows that roads – both local and national highways ("Republican roads") – are used and are essential from a socio-economic point of view. Both should be taken into account. However, the most neglected ones are the local ones. It is also easier to achieve cooperation at a local level and it should therefore be a considered as a useful starting point for any intervention (Demenge and Mehta 2017). Note that local roads in the Fergana Valley also have an international dimension. National/International highways could be addressed differently, via national guidelines and capacity building, for instance. Local roads would benefit from more direct support and interventions. Generally, there would be a need to harmonize practices.

Adaptation and development

International climate funding requires that the intervention is not development but **adaptation related**. Although the type of intervention previously described carries development implications, it is mostly adaptation relevant:
- It is highly urgent to adapt roads and the way they are built to climate related risks and impacts, or the infrastructure will be lost.

- Roads play and essential role in adaptation. Roads are not the only factor that matter, but they are an essential one for any adaptation plan for the region. Another factor is access to water, and both issues are interlinked through the concepts of *roads for water* and through the restoration of ecosystem services. Also, hazards like erosion and mudflows cannot be addressed unless roads are better constructed and made climate resilient.
- Roads contribute directly to adaptation through drought mitigation, recovery and by increasing people's resilience. In more general terms roads can support a wider agriculture adaptation project (e.g. agriculture diversification based on the export of high value crops instead of water-intensive cotton). Roads directly increase the range of adaptation measures available.
- Measures taken to protect the road infrastructure are practically the same as those that contribute to ecosystem adaptation and recovery, to control mudflows, reduce the impact of droughts and wind erosion.

Specific suggestions for potential project proposals linked to climate-resilient infrastructure:

1. Systematically link roads to livelihood adaptation strategies: roads are required from a regional integration perspective, and can accompany adaptation strategies. In fact, one cannot expect people and the region to adapt without road access and resilient roads.

2. Keep roads at the centre, but link them to a wider adaptation project (away from water intensive cotton and towards high value and resilient crops).

3. If framed in the terms suggested here, the project would contribute to
- Ecosystems and ecosystem services; but also to
- Health, wellbeing, and food and water security.

4. To the problem setting, add the fact that poorly planned roads may increase the impacts of climate related hazards, as road construction methods and techniques that would integrate better water management into their design and could contribute to increased resilience of communities in face of climatic hazards (including droughts) are not yet considered in practice.

5. An intersectoral approach as well as trans-border cooperation are required.

Further questions to be explored

In order to design the best possible interventions, a few questions remain. For instance:

1. How much do CAREC guidelines take climate risks and adaptation into account?

2. Additional data would be required on the origin and quantity of water and silt, eroded sites, etc. in order to prioritise the interventions.

3. It would also be necessary to have a better understanding of local groundwater flows. Irrigated areas depend on wells, which may be fed by the canal: catchments upstream of Khitoy suggest so. Recommendations: focusing on ground water recharge - instead of surface flows - could allow filtration of run-off water and limiting evaporation. This depends on the geology of the area, which requires further investigations.

4. The sharing of responsibilities for building and maintenance between the different levels of government entities and the population is quite complex, and evidence suggests that the practice differs from the theory (communities seem to maintain roads even when authorities are in charge). Further inquiry is required. It will be important to ensure that every intervention is accompanied by clear rules in terms of ownership and maintenance.

Additional useful Resources

1. World Road Association (PIARC) International Climate Change Adaptation Framework for Road Infrastructure (Van Steenbergen and Yakami)
2. Potential for Spate irrigation (van Steenbergen et al. 2010)
3. Community Based Participatory Watershed Development: A Guideline (Desta et al. 2005)
4. INTEGRATING CLIMATE CHANGE ADAPTATION AND WATER MANAGEMENT IN THE DESIGN AND CONSTRUCTION OF ROADS: Assessment of Opportunities in Tajikistan (World Bank and MetaMeta Research 2018)

Annex 1: Field Visit Isfana River. Jamoats of Golakandoz and Hayoti Naw, consisting of villages of Khitoy and Qurgancha.

Date of the field visit: 24.11.2018

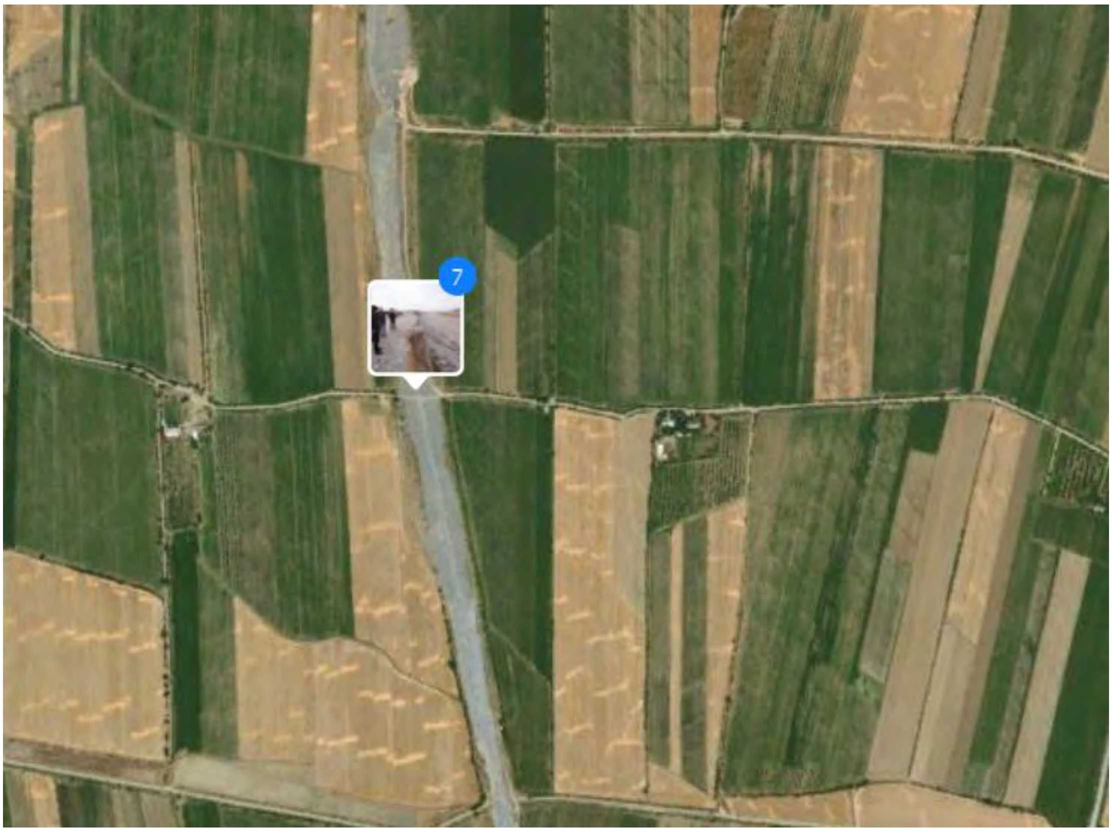
The purpose of the visit was to better understand climate risks associated with mudflows along the Isfana river, understand how the road infrastructure interacts with climate risks (i.e. is affected by climate hazards and contributes to their impacts) and look at the potential for climate resilient roads. We followed the Isfana River upstream, driving South towards the Kyrgyz border beyond which the river and most of its tributaries originate.

1. Stop along the canal built during the Soviet period (1960s)

We cross Proletarsk, the district headquarter, Golakandoz and the outskirts of the city where individual houses seem to be equipped for roof water harvesting to irrigate the small plot in front of them (an interesting practice that contributes to climate resilience and could be generalised). We cross the fields – mostly cotton[8] - largely bordered by mulberry trees (used for silk). Fields are irrigated through water pumped from wells (probably fed by the Isfara water system), while gravity does the rest.
After a while, we cross a dike and literally plunge into the canal: all dry in surface. The Canal is about 50 m wide and 1.5 meters deeps, while it used to be much narrower and around 8 meters deep. We are told the canal was mainly built to evacuate the mud coming from Kyrgyzstan, mostly during the summer months. Apart from stones and soil ("mud" carried by the mud flows), the riverbed is littered with garbage (which is an issue when water from the canal is used for drinking purposes.
Mud flows here are often 60 m3/s, but can reach up to 150 m3/s during peak time. They usually start in KG when it rains there, and take around 1 hour to reach this spot. People are informed by the inhabitants of Qurgancha (about 25 km upstream). But there is no early warning system and no protocol for communication in place to inform them on the Kyrgyz side.
When the level of the river goes up, the vibrations of the river can be felt from a distance, it increases progressively, the muddy river remains unpassable for an hour, further eroding the river banks, carrying garbage and sometimes small animals ("1000s of livestock are washed away", exceptionally human victims) and threatening to overflow, and then recedes after an hour to become again passable, and dry after a few hours. The way is then cleaned and compacted with the head of machinery to facilitate crossing.
The canal used to be cleaned and emptied regularly during the Soviet period, but it is not maintained anymore, hence the shallow and wide aspect. Funds are collected (100 Som/year/hh) for maintenance

[8] Cotton yields in the Kolkhoz used to be 60t/ha; today they are only 15 t/ha. The reason seems to be the lack of water and access to agricultural outputs.

it but this is not sufficient. Dykes have been built to contain the mudflows and protect the fields.
When the level is low, the water can be used to irrigate the fields (if pumped the turbidity must seriously damage the pumps…). Otherwise people mostly use wells (40 were built in the area) for irrigation. Other rivers are used, although we are told villages in Kyrgyzstan use most of the water for their own needs in summer (cabbage, tomatoes and tobacco are cultivated), so that small rivers and canals often run dry.



Map 1. The canal

Plate 1: the riverbed (Source: Author).

2. Stop at the bend, where the river was redirected to the North-North-West to develop the city of Proletarsk.

During Soviet times, the river was redirected from the North-East to the North-North-West, in order to develop the city of Proletarsk/Golekandoz. The ancient bed of the river is still visible on the aerial view, and when mudflows happen the river has the tendency to go back to its original riverbed. Along the canal are:

- few remaining patches of a tarmac road that has been washed away by the river (and the soil with it). It is beyond repair.
- next to it, a lined irrigation canal (see Plate 2), partly open, partly consisting of a pipeline
- adjacent to the canal, a dirt road (local road) that was built 20 years ago as an alternative to the original one with community's money (TjS 60'000).

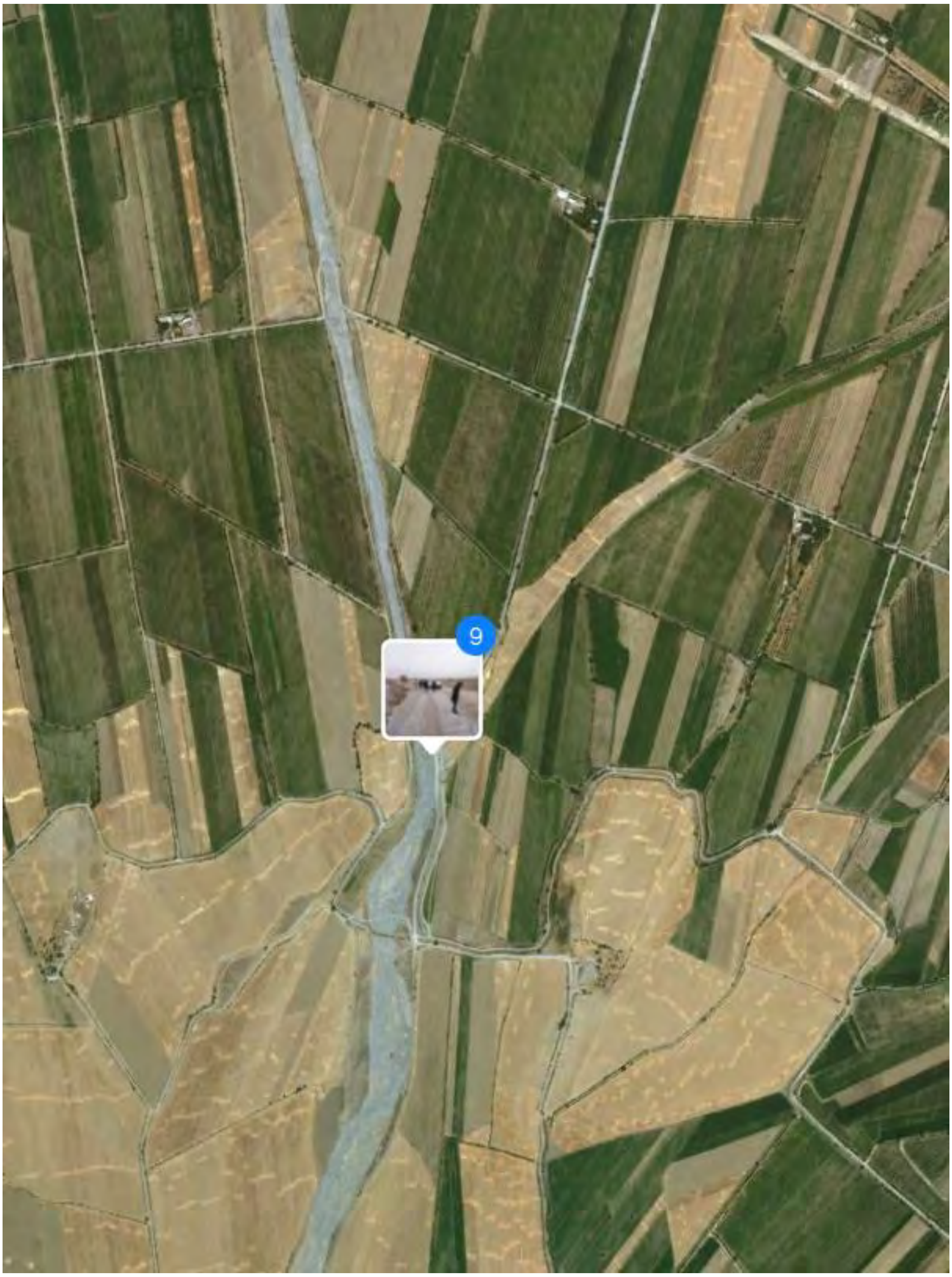
Risks: - overflow, erosion of agricultural land and siltation (already happening in places) - erosion/loss of the water canal, leading to loss of infrastructure and loss of irrigation facility for the irrigated land and trees bordering the canal. If the canal cannot be repaired quickly, conditions could include loss of the harvest (short term consequence), loss of trees (medium- to long-term consequence: if non-irrigated for a whole season, assets are lost) as well as long-term inability to irrigate the fields (in case the canal is damaged beyond repair). - permanent damages to the road, requiring a realignment of it and further loss of agricultural land. - Potential threat to the city nearby in case the mudflow is big enough and allowed to flow freely towards it.
Measures taken: - elevated banks (soil) - gabions on the river-bed to redirect the flow: they have been washed away - Gravel accumulated in the bend every year to protect the banks: also washed away every time.

Suggestions: - Concrete blocks attached/boulders to protect the bank, and concrete slabs in the bend. The irrigation channel is very vulnerable and will soon be damaged. - correction of the river trajectory on the inside of the curve to diminish the action of the river on the outside of the curve, upstream of the bend and on the right bend to increase the radius of the curve and dragging inside the curve to concentrate the flow on the inside of the curve (at the moment, the trajectory of the river is such that the flow is directed on a small portion and on its weaker point: see map 2, aerial view). Although it is a massive intervention, it would probably diminish the erosive action of the river at its weaker point. - The road embankment need to be re-enforced, in order to help contain the river when the level is high. **Substantive and urgent measures are required on this spot to address the issues and risks associated with mudflows. Given the potential risk for the cities of Proletariask and Golakandoz, the mobilization of resources beyond the *jamoat* would be clearly justified.**

Table 8: Risks and corrective measures

Plate 2: from the left: the river-bed, remaining patches of an elevated road, the irrigation canal, the local road pointing toward the ancient riverbed and the city of Proletarsk/Golekandoz (Source: Author).

Plate 3: the external bend of the river, 8m above the canal. Observe the buried (rusty) pipeline linking two portions of the irrigation canal at the feet of the team, on right bank. On the left bank (the inside of the bend), some concrete slabs remain (Source: Author)..



Map 2. The "bend". The river flows South to North: notice the "S-shaped" curve, bouncing back the flow of water and increasing the erosive power of the river where the original river-bed once was.

3. Road to Khitoy

On the way to Khitoy, the ditch along the road is seriously eroded. The runoff has dug as deep as one meter along the road, which is starting to collapse.

Risks: **-** Further erosion and damage to the road and loss of agricultural fields
Measures taken:

- Diverting the water towards from the ditch to the fields drain (temporary solution)
Suggestions: - Consolidation on a priority basis of damaged road bits to limit further destruction (spot maintenance) - Refilling the ditch with gravel - Scour checks: small "check dams" (consisting of bigger stones or stone walls) to reduce the velocity of the water and enable the sediments to deposit. - Cleaning the channel from garbage to avoid clogging it (stagnating water on the road). Generally, canals and drains should not be used to dispose of garbage. - Potential change to road design: downslope road crowns to limit stagnation of water and limit the size of the ditch **"Roads for Water suggestions"** - Roadside plantations to maintain the soil in place, provide livelihoods, decrease wind erosion and limit dust (Note that this measure was mentioned by participants during the workshop). - Generalise the use of turnout ditch: diverting systems to enable road water harvesting and use of supplementary water into rain-fed fields.

Table 9: Risks and corrective measures

Plate 4. Erosion due to the runoff, threatening the stability of the road, and the fields (Source: Author)

Plate 5. Erosion due to the runoff, threatening the road; garbage management issue (Source: Author)

4. Khitoy

A stop in the new residential area of Khitoy, under construction, enables us to spot the impact of mudflows in the river below. These destroy the irrigation channels upon which irrigated agriculture depend. Hence after each mudflow the initial part of channels has to be rebuilt.

The impact of overgrazing on the hills and slopes around are clearly visible, on both sides of the river, leading to degrades pastures and erosion gullies that seem to contribute to lower productivity, mudflows and siltation. Officially, the district has 60’000 sheep and 20’000 cows, for a population of 140’000 inhabitants, although in reality numbers are much higher; in addition, transiting flocks visit the area, triggering further degradation. Later, a fenced cemetery with long grass enables us to see the difference between grazed land and non-grazed land.

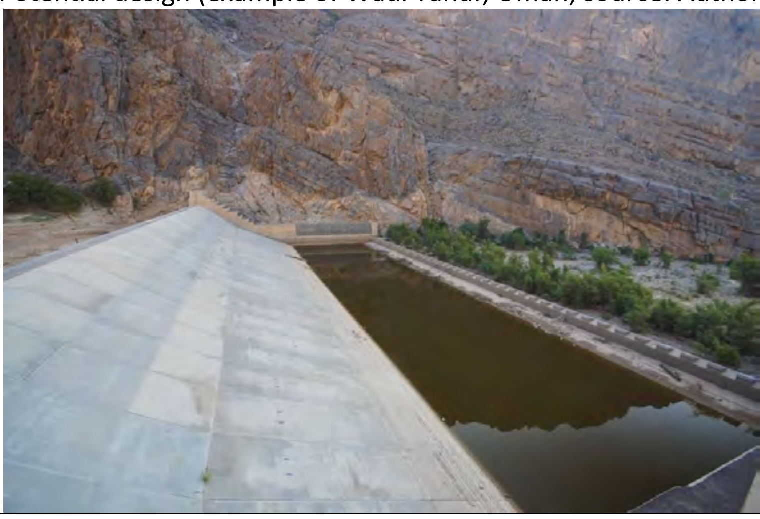
Risks: - land erosion - reduced productivity of pastures - siltation - mudflows - destruction of assets
Measures taken: - apparently none so far
Suggestions: - fencing of critical areas to enable regeneration (plus sowing pastures and pasture management). - Forestation of degraded areas (in Tajikistan and Kyrgyzstan) and sustainable land management in particular. - check dams in erosion gullies (gully plugging) to limit the flow of water and enable the slopes to stabilise.

Table 10: Risks and corrective measures

5. Stop at the site of planned dam

We now borrow the alternative road that was built up when the Kyrgyz authorities closed the border crossing in 2015. The gorge gradually narrows down along the river into a small canyon. ADB has invested US$ 1 million to make “captages” (underground water catchment) in 2008, although these were destroyed by mudflows and had to be rebuilt. An irrigation dam was planned at this site, but never constructed due to the collapse of the USSR. At a planned cost of US$ 10 million, it was meant to hold 10 million m3 and irrigate a surface of 4’000 ha. A 300m long diversion tunnel was built and is now used for the road.

The dam would certainly help regulate the flow of the river, although with peaks of 150 m3/s and given the amount of sediments carried by the river, the feasibility should be studied, and regular cleaning would be required. However, the topography would certainly make a good location for a reservoir to store water for the dry season and a mean to regulate the flow of the river. Coupled with other measures, it could be contributing to climate resilience of the socio-economic system by addressing mudflows, droughts and protecting the infrastructure. A feasible alternative could be a flow-through dam (see below).

Risks: - mudflows, - erosion of agricultural land and siltation (already happening in places) - destruction of the infrastructure
Measures taken: - captages
Suggestions: - Flow-through dam for flood control. Potential design (example of Wadi Tanuf, Oman; source: Author): 

Map 3: the canyon along which the irrigation dam was planned (North side). The map shows the secondary erosion channels that contribute to siltation and building up high water levels in the Isfara River.

6. Erosion along the road threatening the road

Culverts that concentrate the runoff have triggered significant erosion through the pastures next to the road. Deep gullies (up to 3 m deep) have formed, eroding the pastures and potentially the road.

Risks: - unchecked erosion of pastures and loss of topsoil. - irreversible damage to the road. - more siltation and erosion downstream.
Measures taken: - none

Suggestions: **Alternative options for the evacuation of the runoff:** - more dispersed culverts, with a cemented apron under the gully and a settlement pool to spread the water and decrease the amount of water flowing or - rolling dips on the road to enable the runoff to be evacuated on the road; or - fords/ that would spread the water over a larger area, depending on the amount of runoff. This would indeed be the best option, intercepting the runoff to irrigate pastures and potential reforested areas. **Downstream:** - gully plugging: stone walls in the gully to decrease the flow of water and keep the soil in place, potentially with trees and roots ("green gabions") - revegetation (trees and sowing) of degraded slopes. **Upstream:** - Above the road: check dams/stone walls in the erosion gullies to slow down the flow of water and enable sedimentation, creating greener and potentially fertile areas for plantations. - Revegetation of degraded slopes and enclosures in critical areas. **Note: these measures would not only protect the road infrastructure, but potentially highly reduce the amount of sediments that make it into the canal and contribute to mudflow.**

Table 12: Risks and corrective measures

Plate 6. Gullies triggered by the culvert (Source: Author)


Plate 7. Erosion gully upstream (Source: Author)

7. Culverts triggering erosion

At five different spots when approaching Qurgancha, the road crosses small ephemeral streams that have shaped the landscape into narrow but deep valleys. In order to protect the road, 3 years ago each crossing was equipped with a large (1m wide) culvert that concentrates all the runoff into one spot. Since there is no pan at the exit of the culvert, the runoff exiting the culvert cascades down the slope with a lot of energy and has dug a 10m deep canyon. It destabilises the slope, and the proximity of gully and eroded slope to the road threatens the road.

Risks: - unchecked erosion of pastures and loss of topsoil. - irreversible damage to the road. - more siltation and erosion downstream.
Measures taken: - none
Suggestions: - Equip the culvert with a proper pan, followed by a check dam and a settlement pool in the end (although it is likely that culverts are just not the right solution in such configuration) or - preferably replace the road and culvert by a cemented ford that would spread evenly the water over the whole surface, and keep the moisture in the soil **In addition: upstream and downstream** - revegetation of the slope (shrubs, grass sowing, reforestation) - check dams, depending on the flow of water - Gully plugging: stone walls/gabion boxes/green gabions in the erosion gully to limit the velocity of water and create sedimentation; - The canyon could be temporarily transform into water pounds, until the siltation fills in the ponds.

The proximity of houses (about 15 houses, part of Qurgancha but 1km before) would make the presence of water ponds and vegetated areas easy to maintain and profitable. **Note: Given the amount of destruction done in only 3 years, urgent action is required on these spots, or massive damages will occur on the road infrastructure. This would also contribute to reduce siltation and mudflows.**

Table 13: Risks and corrective measures

Plate 8. The catchment area leading to the culvert (Source: Author)

Plate 9: The erosion gully formed, and aggravated by the culvert (Source: Author)


Plate 10. The erosion gully seen from inside the culvert (height: approximately 10m; Source: Author)

Map 4. The map shows the five erosion gullies where the road intersects seasonal streams, while the slopes above are severely eroded

8. Qurgancha

The issue of droughts, high temperatures and water shortages is confirmed by the local authorities. In addition to the Isfana riverbed, our respondents also confirm the presence of 26 sites where local mudflows occur. They mention that mudflows were not so much of a problem in the past, but have become a big issue over the last decades.

In addition, they mention that sheep died in the pastures last summer, as there was not enough fodder due to water scarcity. Also, the price of fodder doubled last year (fodder from KG used to be cheaper). Wells are stilted and also need to be repaired. They have also identified a site for a reservoir (which would not need to be lined, as the soil is not too permeable according to them).

They also mention that the biggest problem is the lack of drinking water. Irrigation channels are used but the water is polluted.

Further, we go to see the bridge at the centre of the village, where due to flash floods the level sometimes rises 1 m above the banks. The bridge was rebuilt in 1985. The German Red-Cross is involved in the emergency response, and has built hazards maps and plans for the village. An excavator is used to drag the river, and mounts of soil have been put in places to protect the road and houses.

Suggestions - Reinforcement structures and vegetation would be required to protect the river banks - Study the possibility to increase water recharge through infiltration ponds and trenches to increase the amount of groundwater available for irrigation AND drinking purposes from the wells

Table 14: Possible adaptation measures

Plate 11. The bridge in Qurgoncha (Source: Author)


Plate 12. The river embankment (Source: Author)

At the entrance of the village, a bridge is under construction to cross a seasonal stream that flows on top of a dirt road that comes down from the hill (or rather: the dirt road follows the river bed…)

Suggestions: **Bridge and stream:** - extend the pillar on the left to prevent erosion around the pillar - extend the concrete slab with stones to prevent erosion after the slab. - revegetation on the banks to limit erosion to the fields downstream of the bridge. - potentially (green) gabions in adequate locations before the riverbed to protect the embankments and slow down the river flow and facilitate infiltration. **On the dirt track:** - stone pavement (or other type) to protect the dirt road while not decreasing the permeability of the soil. - rolling dips to direct the flow on one side of the dirt-track

Table 15: Risks and corrective measures

Plate 13: bridge under construction (Source: Author)

For technical information and guidance, a useful resource is: Community Based Participatory Watershed Development by the Government of Ethiopia (2005).

Additional data requirements:
- Data on Isfana River discharge in Qurgancha and downstream is required.
- Data on erosion along secondary erosion channels: mudflows start in Kyrgyzstan, but it seems also very likely that overgrazing, erosion and bad land management in Tajikistan also contribute to the mudflows; also, a large degraded areas upstream but situated in Tajikistan seem visible on the map. Further inquiry is required.
- Transect drive in Kyrgyzstan (along with Tajik citizens to that they understand the process)
- Data on fodder scarcity and death of livestock.

Addition suggestions:
- In general, roadside plantations to address water erosion and soil degradation, wind gusts and wind erosion, limit dust, provide shade, increase moisture content, and provide additional livelihoods.
- Early warning system in Kyrgyzstan, cross-border cooperation.
- Better roads-water integration at the institutional level, cross-sectoral cooperation between agencies and between jamoats/district.
- Cross-border resource management groups.
- Separate drinking water systems (using wells rather than irrigation channels, captages, spring capture). Road water harvesting could contribute to better groundwater recharge.
- Proper garbage management would also limit the contamination of river flows and of the canal.

Annex 2: Road water management measures Tajikistan – Additional Technical Guidelines

By Frank von Steenbergen - Meta Meta Research

Additional information on:

- Road tree side plantations
- Water/mudflow spreading to revive pasture and add to recharge
- Sowing of pastures
- Lowered ford for water crossing and water retention in the river bed - in many places better than culverts
- downslope road crowns
- Water spreading from culverts and better protection
- Gully plugging
- Dissipation blocks
- Checkdams and downstream protection
- Revival of some of the captages
- Using roads for recharge in general.

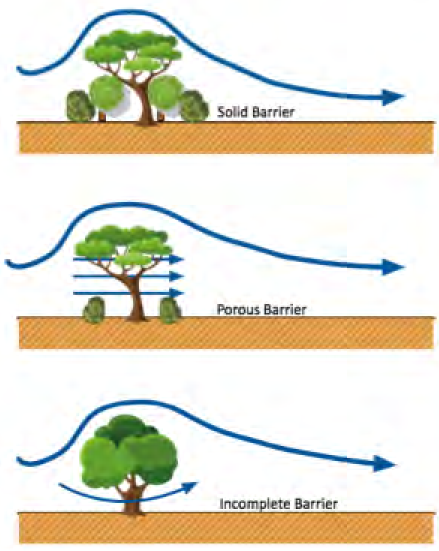
Road side tree plantations (shelter belts)

The scope for road side plantation is enormous. The benefits of roadside vegetation are multiple. Foremost they can serve as shelter belts. They reduce the erosive effect of wind across a landscape, especially when placed in the dominant wind direction. They create barriers against road dust. Trees and shrubs especially can trap the dust with their leaves, minimizing the amount of dust reaching farms and houses. Moreover, trees provide shade and contribute to the beautification of the area. This is a significant service because in many countries a large number of people walk alongside the road.

Roadside vegetation can also protect the road. Grasses can especially help to reduce runoff velocity and trap sediments, thus reducing roadside erosion. In some waterlogged areas, trees that use large quantities of water (such as eucalyptus) can be used to dry the road subgrade and help protect the road. Furthermore, roadside plantations will not only check the deterioration of roads and the environment but will also create productive assets for local communities. This can be from the direct benefits of trees—timber, fruits, and bee pollination—or by acting as windbreaks that reduce desiccation and wind erosion.

Roadside plantations can also improve road visibility and break the monotony. Care should be taken not to disturb views. A very special use of roadside tree planting is to reduce speed. Along roads in long stretches of land, where speeding can be common, trees can be planted at irregular distances along the road. The makes it more difficult for drivers to assess their speed and the effect is that they will be more cautious and will slow down.

Roadside plantations must have some porosity to allow the wind pass through the plantation and increase the filtering effects. Optimal porosity: 35-50%.



above: closed element (eg dense hedge)
SMALL FILTERING EFFECTS

middle: porous element (eg half open hedge or row of trees with undergrowth.)
GOOD FILTERING EFFECTS

below: incomplete element (eg line of trees without undergrowth)

Plate 14: Using tree planting to capture dust: best is to have porous shelter belts with undergrowth (Source: Author*)*

Water/mudflow spreading to revive pasture and add to recharge

Vegetation degradation in the dryland pastoralist environments is a widespread phenomenon. Changes in the composition of the herbaceous vegetation cover, grasses and herbs are short-term indicators of vegetation degradation, but they are reversible.

Grass reseeding has been used successfully as a means of restoring degraded drylands/ As a rule of thumb, the best grasses for reseeding program are those that are native and found on range sites similar to those to be reseeded.

Reseeding programs aim at improving existing ground cover and pasture biomass to an extent or in a manner not possible by grazing management. This can be accomplished by over-sowing into existing vegetation with a superior species, reseeding a denuded land and establishing a completely new pasture, with or without the aid of irrigation. Flood based irrigation and road water harvesting are two viable and low-entry methods to boost fodder production in drylands. A high soil moisture content and prolonged plant growth can be ensured by spreading water on the field or by capturing it through trenches. These will allow water time to infiltrate slowly, this water will move in both vertical and lateral directions, thus recharging groundwater and soil moisture. Systematically introducing the spreading of short term floods from ephemeral rivers and from road drainage combined with water retention in trenches will lead to increase of soil moisture levels. This can revitalize drylands into a highly productive production system – in terms of return to labour. Growing fodder with flood and road drainage water has several advantages: (1) it turns a threat (flood/drainage water) into an asset; (2) it reliefs the pressure on the dry rangelands and creates an economically rewarding production system, and (3) it requires almost no land preparation and hence it can also be applied in areas that are short in skills and labour.

Lowered ford for water crossing and water retentions

Where roads cross the dry bed of ephemeral streams, reinforced causeways or drifts may be used. Besides their functions as traffic conduits, they help stabilize the unstable gravelly stream beds in mountain environments. They may also help to retain water in the sand and gravel of the river bed. For this, the drift may be reinforced beyond normal specifications so as to withstand the pressure of the torrential flows and the impact of rolling boulders. The drift should not be equipped with culverts. Besides the body of the drift itself, the drift consists of the approach road, the upstream protection of the stream, and the downstream apron. Because of the heavy natural armoring of mountain streams, they may not need a downstream apron

Plate 15: Non-vented drift stabilizing dry river and acting as sand dam (Source: Author)

Non-vented drifts also provide other water management benefits. The first is the stabilization of the upstream riverbed. Depending on the lay of the land, non-vented drifts make it possible to divert water from the riverbed—either perennial flows or short-term floods or spates—using gravity upstream of the drift. This would be difficult where the riverbed is not stabilized and smooth but is instead rutted and incised.

Culvert less drifts also cause less damage to the riverbed immediately downstream of the road crossing since water will not spout through the culverts during flood events to erode the area downstream of the drift. Water now has the chance to cross over the entire width of the drift, thus reducing damage to land downstream. As river crossings, non-vented drifts are therefore more reliable and predictable and much cheaper compared to bridges in their function as low-volume roads. During flood events, however, they are impassable for the duration of the flood, whereas vented drifts are passable (unless they are affected by blocked flotsam and uncontrolled flooding). This downtime on non-vented drifts can be reduced by placing pointed markers alongside the drift to guide vehicles across during low floods.

Water spreading from culverts

The road drainage systems concentrate runoff. Culverts in particular are the embodiment of the changed drainage pattern that comes with road development. Because they concentrate runoff, there is always the risk of erosion downstream of the culverts. Gullies so created may even “creep” upstream and destroy the road body. Therefore, both to protect downstream land and to make beneficial use of water, runoff should be diverted from the culverts.

Different auxiliary structures may be constructed to gently divert flow from culverts to where water will be used or conserved. The structures may be constructed from different materials with different alignment, width and height. V-shaped flood diverters are in most circumstances most appropriate because they dissipate energy from the culvert runoff. If the flow from the culvert comes at low velocity, a diversion structure will be sufficient. The structures should also be placed at a reasonable distance of at least three meters from the culvert outlets to avoid their creating sedimentation inside the culvert.

Plate 16: V-shaped diversion structure constructed from soil and stone to spread water from culvert, Ethiopia (Source: Author)

On steep slopes, the flows from the culverts have high scouring potential and should ideally be provided with energy dissipators at a safe distance (to avoid full flow condition in the barrel of the culvert). The flow diversion structure should then be placed next to the energy dissipator.

The purpose of cross and side drains is to evacuate water away from road structures. This is often done without taking into consideration the opportunities for water storage or recharge. Water from road drains, either culverts or lead-out ditches (or mitered drains), can be guided directly to groundwater recharge structures. Most common are infiltration trenches, recharge wells, and infiltration ponds.

Plate 17: Infiltration trenches along roads: note these should be placed at distance for road safety and road integrity. the trench on the right (in Malawi) is too close to the road (Source: Author)

Gully plugging and water spreading from gullies

Around roads, particularly downstream of culverts, gullies may develop, especially when run off is concentrated in a few mountain drains and when there are no dissipating provisions. The description above describes the development of gully plugs that will retain sediment in the gully and hence stabilize the gully and transform its productive capacity.

TECHNICAL INFORMATION KIT

Sediment Storage and Overflow earth dams (SS Dams) for productive gully control

(1) Period/phases for implementation

. Only during dry season and min. one month before rains likely to occur. Should be completed within one season.

(2) Objectives/remarks

• SS dams are water harvesting and conservation systems that convert unproductive large and active gullies into productive areas (fertile cultivated or fodder producing areas, mixed plantations, and fruit tree orchards).

• SS dams are stone-faced earth dams constructed across medium/large size gullies to trap sediments, collect water and divert excess runoff. SS dams accommodate the runoff generated by the catchment located above the gully. The structures are often constructed in series along the gully. It is just like creating a land that does not exist.

• Contribute significantly to protect cultivated lands, arrest gully expansion and recharge water tables

• Huge potential in Ethiopia - can provide tens of thousand Km of gullies to poor households (small land holders and landless).

(3) Suitability, agroecology, adaptability to local knowledge

. Traditional structures similar to SS dams are common in several parts of drylands in Ethiopia (Dire Dawa, Tigray/Erob, Wollo, Hararghe, etc). SS dams can be easily introduced in those areas, particularly where local structures are damaged by excess runoff. In other areas, start small scale and develop local interest by introducing high value crops and allocating SS dams to needy farmers - SS dams can become a "food ensurance" site for food insecure households. Deep rooted perennials/annuals make use of the moisture and nutrient available in the accumulated soil behind SS dams.

(4) Main land use and agro-ecology

. Highly eroded gully areas in all land uses. Not suitable for large gullies without catchment treatment and protection.

(5) Technical preparedness

. Training required (DAs and HHs).
. Agree with farmers on location, user rights, size, production area, catchment protection works and on-the-job training. Test measure first.

(6) Potential to increase/sustain productivity and environmental protection

. Very high - for cash and staple crops, introduction of fruit trees in gullies, valuable trees, etc.
. Provide opportunities for income generation to small land holders and landless.
. Drought proof activity - even when rainfall is low SS dams collect sufficient moisture.
. Promote fertility management (compost, etc) and watershed protection, raise water table.

(7) Minimum surveying and tools requirements

. Survey: long rope and wooden pole, measuring tape or marked string Tools: crow bars, shovels, pick axes, local stretchers (barella) to carry soil, sledge hammers.
. 10-20 workers per SS dam site.

(8) Design & technical standards (fig 1)

A) Site Selection:

. Inside gullies and natural depressions that you wish to convert into productive fields.
. Below catchments with less than 40 ha max. because of the increased costs for larger structures.
. The site should allow the maximum formation of a cropped field area (wide portions of a given gully are preferred to narrow and deep portions).
. One side of the gully needs to have suitable hard structure to put the spillway (stony areas, limestones, very hard pans and soft rocks).
. When suitable soil conditions do not exist, reinforcement of spillway is required (riprap and drop structures).

B) Design/size: Estimate the size of the structure

(1) With a meter tape and a graduated long pole (5-7 m) measure the base width and length, height and top width and length of the structure.
(2) Select the best emplacement of the spillway. Estimate spillway construction standards (see below) including gradient and length.
(3) Dimensions and volume of the structure: they are selected based on the area of the catchment, the width of the gully and specially its depth. Apply the following criteria to **approximately estimate the dimensions of the SS dam** (simplified for trapezoidal design).

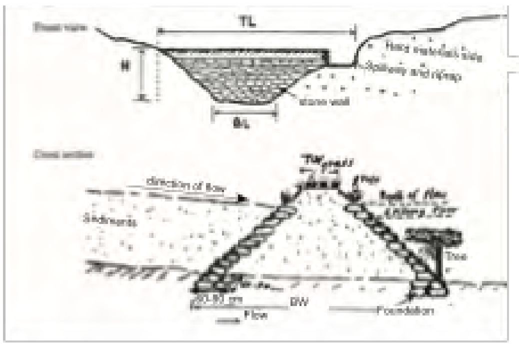
Height = H,
Base width = BW,
Top width = TW,
Top length = TL,
Bottom length = BL

H < 2m	H:BW is 1:2-2,5	TW = 1,5m
H = 2-3,5m	H:BW is 1: 2,5-3	TW = 1,5m
H = 3,5-5m	H:BW is 1: 3	TW = 3 m

(4) V1 = Volume of embankment earth/stone work (m^3) = $H \times \frac{(TW+BW) \times (TL+BL)}{4}$

V2 = Volume of spillway (SP) earth work = Length SP (equivalent to BW) x base width of SP (see table) x total depth of channel (see table)

V1 + V2 = Total volume of earth work (including foundation)



C) Construction standards and phases:

(1) Scrape and **remove grass** and vegetation from the whole bottom width and sides of the gully where the dam is to be constructed (structural continuity).
(2) Proceed with construction of the **key & foundation** of the downstream wall (called riser or lower retention wall) in front of the structure. A second stone wall or rip-rap is placed on the upstream side of the dam (upper retention wall).
. Large flat stones used for the key foundation, side keys (abutments) and retention walls. Make this key & foundation 60-90cm deep x 100cm large and start filling it with large stones. Fill the space between stones with small stones. The first 2-3 lines of large stones inside the foundation inclined 10-20% uphill (stability of foundation).
(3) Erect retention walls with care **following the correct H:BW ratio**:
. Use a rope and a water level placed across the entire gully to adjust the position of the stones of the retention wall (straight level).
. The retention walls are then carefully constructed ladder-shaped.
. Fill space between stone lines with soil and compact. Soil is taken from reshaping the gully or (if not suitable) nearby suitable site and spillway canal. Compaction should be carefully done by repeated passes of oxen over the piled layers of soil (use oxen-pulled compactors-rollers or manual compactors such as buckets filled with heavy soil & stones, wood beams, etc.).

(8) Design & technical standards (fig 1)

D) Spillway design and construction

. Start digging the spillway at the desired height (see total height of the structure and deduct the total depth of the spillway = maximum permissible depth of the flow (d) + free board).
. Length of spillway equivalent to base width of dam or more.
. Slope of the spillway is 0,4-0,8% and outlet with drop structure and apron if necessary.
. Construct the spillway at the appropriate side (hard materials) of the gully.
. If both sides are of hard materials, construct the spillway at the side which is facing the direction of the water flow.
. The size of the spillway is determined by the catchment area and runoff estimations.
. The side of the spillway looking towards the dam should be stone faced & reinforced (see fig 2 and fig 3). Shape is trapezoidal.
. The dimensions of the spillway (see table 1 below) have been computed based on "safe standards" for rainfall intensity of 100-150 mm/hour.

CATCHMENT AREA (hectares)	BASE WIDTH (b)		DEPTH OF FLOW (d)	TOTAL DEPTH (D)
	medium/low runoff coefficient (0,4)	high runoff coefficient (0,7)		
2	0,8	1,1	0,30	0,70
3	0,9	1,4	0,30	0,70
4	0,9	1,4	0,35	0,75
5	1,0	1,6	0,35	0,80
6	1,0	1,6	0,40	0,90
8	1,0	1,8	0,50	1,00
10	1,0	2,1	0,55	1,05
12	1,0	2,3	0,60	1,10
14	1,1	2,5	0,60	1,20
16	1,1	2,7	0,60	1,20
18	1,1	2,8	0,60	1,20
20	1,3	3,2	0,60	1,20
24	1,6	3,6	0,60	1,20
28	2,0	4,4	0,65	1,25
32	2,3	5,1	0,70	1,30
36	2,7	5,5	0,70	1,30
40	3,2	6,1	0,75	1,35
45	3,7	7,0	0,75	1,35
50	4,3	7,8	0,75	1,35
60	5,1	9,6	0,75	1,35
70	6,1	11,3	0,75	1,40
80	7,1	13,0	0,75	1,45
90	8,1	14,8	0,75	1,50
100	9,1	16,5	0,75	1,50

Figure 2 Section of a spillway

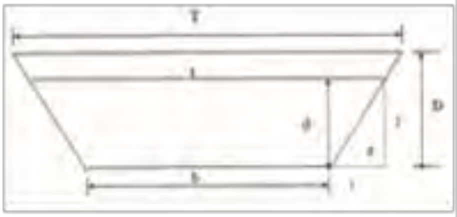
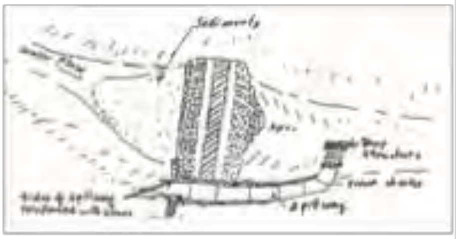


Figure 3 Aerial view SS dam and spillway



(9) Work norm

Estimate labour requirements based on the following work norms:

. The work norm for the SS dam embankment (inclusive of all elements) is estimated of 0,75 m³ of volume work (earth & stone fill) per person per day.

. The work norm for the spillway is 0,5 m³ of spillway excavated soil & stone work (including drop structure and rip rap if necessary) per person per day.
. The work norms for Gully cut & fill/reshaping/leveling: 1PD/1m³/day

(10) Integration opportunities/requirements

. SS dams are part of a sub-watershed treatment. This is required to allow fine and fertile sediments to be trapped behind the SS dam and avoid coarse materials accumulation. SS dams are then constructed simultaneously or preferably after closure and treatmment of fragile/unstable parts of the catchment with conservation measures (trenches, eyebrows, etc.). Smaller gullies feeding into the main one where SS dams are placed should be laso treated with checkdams.
. This activity is integrated with revegetation of gully sides after sedimentation is completed. Hand-dug wells often possible at lower side of embankment for irrigation.
. This activity is also integrated with conservation works on cultivated lands adjacent to the gully sides (bunds, grass strips, etc.).
. Apply compost in sedimented areas. Apply ring cultivation following receding moisture in large SS dams that fill slowly (few years).

(11) Management requirements

. Check conditions of the spillway (enlarge it if necessary, check scouring, apply paved systems, side protection, etc.).
. Continue gully reshaping for filling SS dams and check quality of sedimentation from catchment and apply additional protection measures (expand closure, SWC, etc.) as required.
. After 1-3 years try hand-dug well close to lower side of embankments (2-3 meters from the wall)
. Check stability of retention walls, riprap and embankment.
. Make sure that each households owning/using their own SS dams along a common gully agree to form a group for management of SS dams (mutual help).

(12) Planning and implementation arrangements

. Agree with the land-owners/users (or those that have lands on both sides of the gully) where to place the structure (s). If SS dams are constructed in series start from the top of the gully. Sample soil profile cuttings to check soil/parent material conditions in order to decide best placement of the dam and spillway.

(13) Limitations

. Labour intensive and needs thorough follow-up - difficult in areas with limited expertise.
. Not suitable in sandy and sodic soils

(14) Institutional responsibility

. Fully on individuals/groups +/- community (commitment to management).
. DAs and wda experts - technical support and follow-up/management.

Plate 18 : Developing a gully plug (Source: Desta et al. 2005)

Dissipation blocks

Streams and torrents during the rainy season, especially where rain concentrates and flow, have high tendency erode the surfaces. In steep slopes the eroding capacity of torrents increases multifold, as the velocity is very high. Where the stream descends on the road, the use of dissipation blocks is recommended (Van Steenbergen and Yakami, 2019).

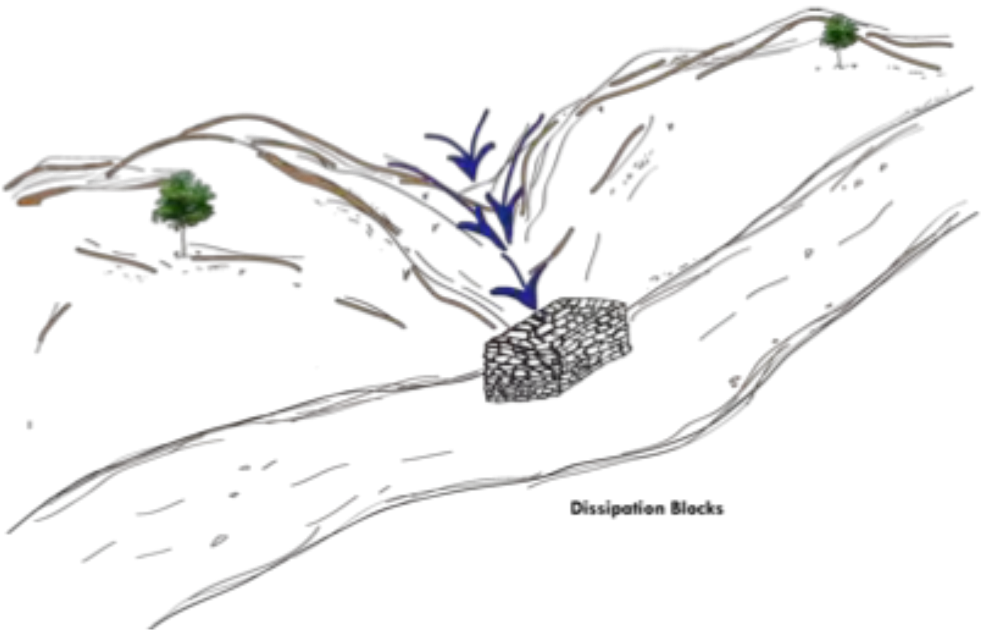


Plate 19: Dissipation blocks protecting the roads (van Steenbergen and Yakami, 2019: 17)

Roads are traversed by several streams. Prior to the construction of the road such stream followed their natural course. With the construction of the roads the stream flows are interrupted and the gradient is broken. Depending on the local topography and the nature of the stream, a hydraulic impact is created on the road surface. The streams differ – some are perenial, some seasonal -, but they will all increase their discharge, velocity and erosive/ torrential power

Checkdams and downstream protection

In mountainous terrain, most streams will flow at high velocity. The development of a road section creates a hydraulic jump in these chutes that can do considerable damage to the road surface and side slopes. Making checkdams in the upstream section of these road streams will reduce the velocity of water crossing the road. The spare stone blocks from road construction may be used to build up small checkdams in the upstream part of the streams (figure 8). The excess material may also be used to armour the down road part of the stream by placing some stones there. This will prevent damage from erosion to the landscape and avoid upward gully development that could affect the road body.

Plate 20: Series of check dams reducing erosion (Van Steenbergen and Yakami, 2019: 20)

Revival of captages

In hilly areas, the development of roads - either though the removal of unconsolidated material or the cutting of rock formations - will affect the occurrence of seeps and springs. Different from a spring, a seep does not have a clear orifice and water exits over the entire water bearing strata. The management of such springs and seeps is important: they are in many regions the main source of domestic water supply and small irrigation. The table shows the effect of the opening of a new road alignment on different spring types. The development of roads may distort existing springs but may also create new ones. Given the importance of springs for domestic water supply or for agricultural use, the management of springs in road development should be integral part of road construction. Particularly where springs are sources of drinking water they may be captured and protected by building captages. The springs and seeps are also main sources of road damage, either by affecting the road surface directly or by creating (minor) depressions in the roads that enlarge during rainstorms and cause the uncontrolled and erosive exit of run-off water from the road bodies.

Plate 21: A seep opening up and damaging the road surface (Source: Author)

There are several types of springs. Geomorphology, rock type, and tectonic history determine the type of springs that occur. There are two broad categories– springs with concentrated discharge through one or more clear orifices and those springs with more diffuse discharge. The different springs and the effect that road development will have on these springs are given below.

Effect of road development on different type of springs

Springs' Type	Description	Effect of road development
Springs with concentrated discharge (through one or more orifices)		
Fracture springs	Fault, fractures and cleavage in semi-permeable and permeable formations connected with a water source (seepage, flow, shallow or deep aquifer)	Road development may expose the spring; rock cutting may change the location of the orifices – either blocking old or creating new ones
Contact spring	Permeable layer overlays an impermeable layer, forcing water to come out – often in a line of springs	Road may distort the outflow of the spring, causing orifices to be blocked or new ones to be created – much dependent on the geological faulting
Fault spring	Due to geotectonic movement a permeable layer is moved on top of a impermeable layer	Road may distort the outflow of the spring, causing orifices to be blocked or new ones to be created – much dependent on the geological faulting
Depression springs	The groundwater table reaches the surface in topographical	Road may create new depression springs where the

	low	roads are made in cut or dry existing one by lowering the groundwater table
Karst springs	Relatively large flow from large openings – typically in karst areas where water erodes the calcium formation	Roads may expose new springs and expose new cavities
Springs with diffuse discharge		
Seep	Diffuse direct discharge of water usually from soils or unconsolidated sediments (sand or gravel)	Road development may create many seeps, especially where roads are developed in areas with deep soil profiles
Secondary springs	Water issued from a primary spring that is typically covered by debris or rock fall	Road development may expose springs or change the outlet, in particular where unconsolidated material is removed

To manage the springs along roads is important hence to safeguard road quality and ensure water supply for domestic and agricultural use. It is recommended that before the road is made, the geology must be understood and the areas where springs occur or are likely to occur should be mapped. When roads are being made, they effect the location of the spring, if not handled carefully. The use of bulldozer or excavators in the areas of high potential springs should be avoided and preferably manual labour should be used to excavate the road in such sections.

Once the road is developed the presence of springs and seeps will be evident. A choice has to be made whether the spring or seep will be used or not. In areas with a low population density, springs may not be utilized but they should still be managed to prevent that their discharge will damage the road body. The following table suggested methods for managing different types springs in different circumstances

Recommended practices for spring management along roads

Springs' Type	**Description**	**Spring management**
Spring with concentrated discharge	Not used	Retaining wall with weep holes or with longitudinal drain to collect excess water and traverse drains (French matrasses) underneath road
	Used for agriculture	Retaining wall with longitudinal drain to collect excess water and traverse drains (French matrasses) underneath road
	Used for domestic water supply	Spring box (captage) and conveyance to benefitting community or tap fitted on protected spring
	Used for domestic water supply and storage	Spring box (captage) and conveyance to benefitting

		community. Include possibility of spring closure (tap) to store water inside the mountain aquifer (esp. in karst areas)
Spring/ seep with diffuse discharge	Not used	Develop road drainage in up road section to collect seepage and convey to safe place
	Used for agriculture	Use gravel section in road to have water conveyed to agricultural land

By controlling the outflow of the springs, water can be better retained in the area. Equipping the orifice of a spring with a gated outlet and even a tap makes it possible in some cases (especially karst springs or fracture springs) to store spring water in the mountain aquifer. The outflow is regulated and retained in a controlled spring, creating storage in the mountain aquifer and prolonging the time during which water is available.

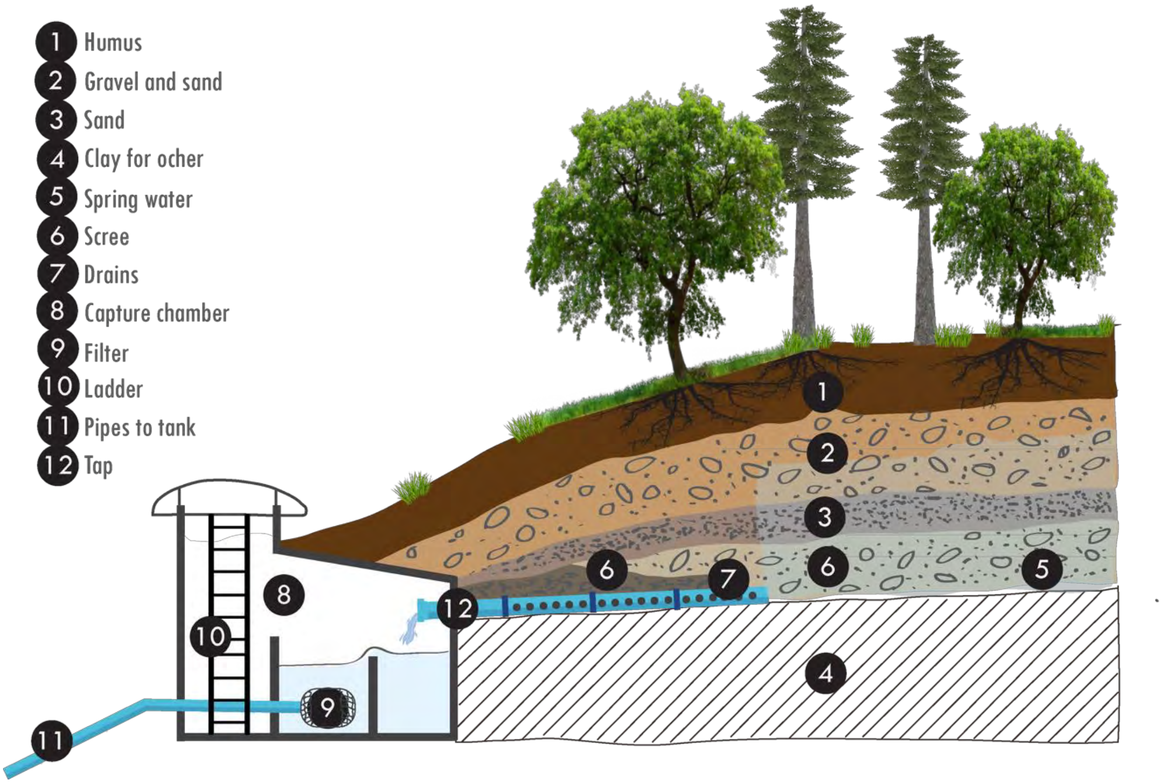


Plate 21: Spring captage - capturing spring water in a mountain slope (Source: Author)

Using roads for recharge in general

The water accumulated by the road can be used for recharge, by routing it to areas where water can easily infiltrate. The purpose of cross and side drains is to evacuate water away from road structures. This is often done without taking into consideration the opportunities for water storage or recharge. Water from road drains, either culverts or lead-out ditches (or mitered drains), can be guided directly to groundwater recharge structures. Most common are infiltration trenches, recharge wells, and infiltration ponds.

Infiltration trenches are quite popular in Ethiopia and have contributed to rising groundwater levels. Wells are in use in several areas where there never was groundwater before. Infiltration trenches consist of a chain of individual percolation ponds with water overflowing from one pond to the other. This keeps trenches in steep terrain from being scoured out but instead allows water to overflow from one pond to the next one in the trench. Typical dimensions for a single percolation pond in a trench are 1.5 m long x 0.4 m wide x 0.5 m deep. The infiltration trenches should be placed at a safe distance of at least 20 m from the road body on the downhill side to keep them from soaking the soil and affecting the road subgrade. Alternatively, the infiltration trench is led away from the road body.

Plate 22: Series of roadside infiltration trenches with bund to intercept additional surface runoff, Tigray, Ethiopia (Source: Author)

An alternative is that runoff can also be guided to recharge wells or percolation ponds. These collect the water for recharge in the shallow aquifer. In some cases these may be abandoned dugwells or out-of-use borrow pits. What is important is that these recharge structures penetrate a water-bearing layer with good transmissivity (ability to convey water) and spare storage capacity (not saturated). Such conditions are easily found in most semiarid areas.

Plate 23: Collecting road water for groundwater recharge:
Recharge well (Ethiopia) and abandoned borrow pit (Mozambique) (Source: Author)

A further sophistication to improve infiltration is the use of special tube recharge wells, or *bhungroo* as they are called in Gujarat, India. These recharge wells collect excess water during the rainy period and are best situated in areas that are temporarily inundated. The land is slightly tilted toward the recharge well, so that it "feeds" it with water. The bhungroo are equipped with small cemented collection structures measuring 1.5 by 2 m. The top of the recharge pipe sticks out from the bottom of the collection unit to prevent the entry of sediment and dirt. The recharge pipes are between 30 and 100 m deep, and between 10 and 15 cm in diameter. They should penetrate into a sandy layer within this depth: the slotted screen will be placed here. In the case of groundwater use, in shallow aquifers the cost of pumping up water for agriculture may be prohibitive.

Plate 24: Tube recharge well collecting excess water for recharge (Source: Momentum4Change.org)

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Front cover photo: Erosion triggered by poor water management on the road to

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