INTEGRATING CLIMATE CHANGE ADAPTATION AND WATER MANAGEMENT IN THE DESIGN AND CONSTRUCTION OF ROADS

Assessment of Opportunities in Mozambique

ANE
ADMINISTRAÇÃO NACIONAL DE ESTRADAS
WORLD BANK GROUP
Roads for Water
META META

1. Introduction

This report[1] assesses the scope for making use of roads for building climate resilience and improved water management in Mozambique. With 30,121 kilometres of roads in Mozambique the more systematic integration of road maintenance/ improvement and water management presents an important opportunity to increase climate resilience.

There is a range of opportunities that can be systematically introduced in road development, rehabilitation and maintenance. This report aims to give an overview of the most promising opportunities in Mozambique and discusses the way forward.

The report starts with a brief understanding of the road sector in Mozambique, followed by an assessment of current climate and expected climate change (section 2 and 3). The report then discusses the scope for the systematic integration of road maintenance/ improvement and water management in section 4 and section 5. It describes the way forward in section 6.

The report is complemented by a number of other outputs:

- Draft Guidelines on Beneficial Road Water Use for Climate Resilience and Road Asset Management
- Brochure on Using Water Bars to Preserve Low Volume Roads and Divert Water to Farm Land
- Brochure on Using Drainage Cuts (Sanjas) to Provide Water to Farm land
- General Brochure on Opportunities for on Beneficial Road Water Use for Climate Resilience and Road Asset Management.

The assessment is undertaken as part of the program "Integrating Climate Change Adaptation And Water Management In The Design And Construction Of Roads", supported by the World Bank Group. This program aims to introduce road water management for climate resilience in four countries. Mozambique is the first country visited. As part of the assessment the following activities were undertaken: preparatory work; a mission to Mozambique from 22-30 June 2017[2] ND. The mission consisted of fieldwork/ transect visit to six road sections in Gaza and Inhambane Provinces, discussion with regional representatives; bilateral meetings with national level stakeholders and a National Workshop (29 June 2017). Though Gaza and Inhambane are two areas that are on the cutting edge of climate change, having a combination of recurrent floods and droughts, opportunities for beneficial road water management are abound elsewhere in Mozambique too and discussed in this report. The National Road Agency (ANE in Portuguese) had already made a start in envisioning the harmonization of roads and water resources management, in particular in studying the reuse of borrow pits. Besides the converting of borrow pits, however, there are many more opportunities to be developed.

2. Road sector in Mozambique

Of the 30,121 kilometres of roads in Mozambique, 22,700 is classified- either as Class 1 (6,087 kilometres), Class 2 (4,755 kilometres) or Class 3 (12,589 kilometres). These classified roads are in the custody of ANE. In addition there are 6,690kilometres of unclassified roads and 3,300 kilometres of urban roads. These unclassified roads are developed by local district governments and municipalities. ANE often becomes the service provider for these roads as well, though generally it is not directly responsible. The classified roads are categorized according to their national, provincial and local importance. All in all, an estimated 25% of roads are

[1] This assessment is undertaken by MetaMeta. The Mission was undertaken by Frank van Steenbergen (Team Leader), Fabricio del Rio Valdivia (Water Management Expert) and Janeiro Avelino (Climate Change Adaptation Expert).

[2] The mission program is given in annex 1; the workshop program in annex 2 and list of persons met in annex 3. The persons are registered as part of the Learning Alliance on Roads for Water.

paved.

There is relatively little new road development in Mozambique. The challenge in fact is in the maintenance of the existing roads. Funding comes from the Road Fund that is funded by a fuel surcharge as well as from a number of other sources, including international donor funding. Reportedly in the past two years financial allocations for maintenance have been reduced. They always fell somehow short of requirements but the gap has increased from approximately one quarter to one half. This comes down hard especially on Class 3 Roads, some of which are very labour intensive to maintain. Even though there is a short fall, compared to other countries in SSA there is still considerable financial allocation for road maintenance. According to the slightly outdated data:

- Financial disbursement of road maintenance and rehabilitation amounts to 1% of GDP, or 100 M USD – spent on rehabilitation (43%); periodic maintenance (33%) and recurrent maintenance (25%)[3].

- The funding of maintenance of the road network rely on the Road Fund revenues. These funds have grown from US$ 210 million in 2007 to US$ 688 million in 2015. The portion allocated to maintenance operations can only cover fully the routine maintenance needs and about 60% of periodic maintenance (a growth from around 50% ten years ago)[4].

- The road network density in Mozambique is relatively low at 37 kilometre per 1000 kilometre compared to 132 for low income, non-fragile countries – this reflects the size of the country and the low population density.

- Rural road access is estimated at only about 32.7 percent. About 17.3 million people are still left unconnected to the road network[5].

Mozambique's Gross Domestic Product (GDP) dropped from 6.6% in 2015 to 3.3% in 2016. The rapid deterioration of the economy was caused by the revelation of previous undisclosed borrowing. Foreign direct investment declined by 20% indicating a decline in confidence in the economy. Tight monetary policy and high prices also contributed to growth deceleration. With the economy poised to grow over the last ten years and many mining and agriculture projects in the making, one may expect road development to continue in the future, even though it is paused for now. There are already signs of recovery. For instance, inflation has started to decelerate.

According to a road condition survey, conducted by the Network Management Department of ANE (DIPLA), the condition of the classified roads network of mid-2015 is given in Table 1. In general, Mozambique is facing challenges in particular in the maintenance of the tertiary roads.

In 2015, 71% of the roads in Mozambique were in very good to good condition, 16% in bad condition, 7% in very bad condition and 5% were in not passable condition.

This may be compared with the result from the preceding year. In 2014 74% of the roads in Mozambique were in very good to good condition, 16% in bad condition, 14% in very bad condition and 9% are in not passable condition.

There is a difference between the different Provinces with regards the condition of the roads. The provinces of Tete, Niassa and Manica have a distribution of above 50% for roads in "very good" road conditions. Most provinces however have 30% or less of their roads in "good/very good" road conditions. Gaza, Maputo and Nampula have large portion of their roads (>30%) in bad or worse conditions.

As many be expected the roads that are in non-satisfactory condition are largely unpaved roads. In Table 2, the condition of the roads is explained by type of road.

On the next 3 graphs, the condition of the roads is explained nationally including all types of roads, paved roads and unpaved roads.

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[3] AICD Data Base
[4] AfDB. 2016. https://www.afdb.org/fileadmin/uploads/afdb/Documents/Project-and-Operations/Mozambique-AR-Mueda-Negomano_Road_Project_Phase_I.PDF
[5] IDA. 2015. https://www.gfdrr.org/sites/default/files/documents/Mozambique%20-%202012%20Cyclones,%202013%20Limpopo%20Valley%20Flooding%20-%20PAD%20Restructuring.pdf

Table 1: Condition of the classified roads network Mozambique

CONDITION OF THE CLASSIFIED ROADS NETWORK											
	Total	Very good		Good		Bad		Very bad		Not passable	
	(Km)	(Km)	%	(Km)	%	(Km)	%	(Km)	%	(Km)	%
Primary	6087	4226	69.4	1327	21.8	504	8.3	5	0.1	20	0.3
Secondary	4755	2338	49.2	2373	49.9	700	14.7	175	3.7	71	1.5
National	10842	6564	60.5	3700	34.1	1204	11.1	180	1.7	91	0.8
Tertiary	12589	4216	33.5	3789	30.1	2067	16.4	856	6.8	729	5.8
Local	6690	1320	19.7	1941	29.0	1677	25.1	938	14.0	695	10.4
Regional	19279	5536	28.7	5730	29.7	3744	19.4	1794	9.3	1424	7.4
Total	30121	12100	40	9430	31	4948	16	1974	7	1515	5

Source: *Modified from "Relatório: condições de transitabilidade da rede de estradas classificadas, ANE 2015".*

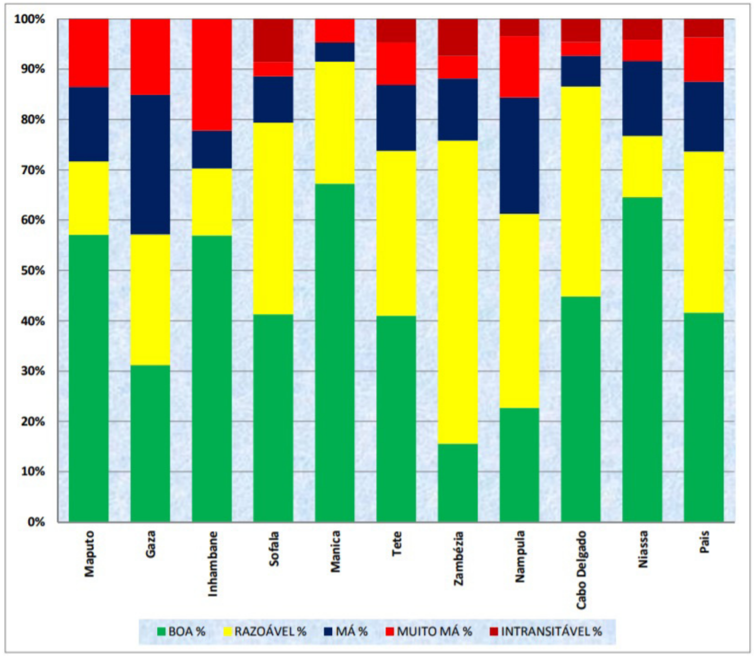


Figure 1: Province distribution of road transitability conditions. Source: Modified from "Relatório: condições de transitabilidade da rede de estradas classificadas, ANE 2015".

Table 2: Road conditions for 2015 according to type of road

Road	Mozambique										
	Total length	Very good		Good		Bad		Very bad		Not passable	
	(Km)	(Km)	%	(Km)	%	(Km)	%	(Km)	%	(Km)	%
Paved	6817	4719	69	1646	24	434	6	20	0	0	0
Not paved	23305	7381	32	7785	33	4514	19	1953	8	1515	6
Total	30122	12100	40	9430	31	4948	16	1973	7	1515	5

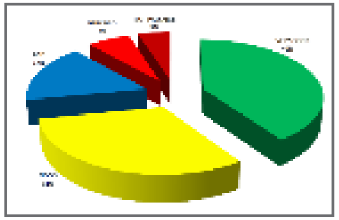


Figure 2.1 Results from the entire surface run-off (Chokwe)

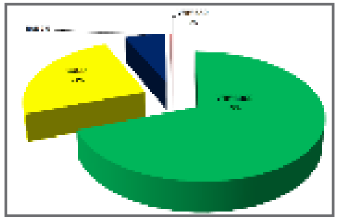


Figure 2.2 Results from paved roads

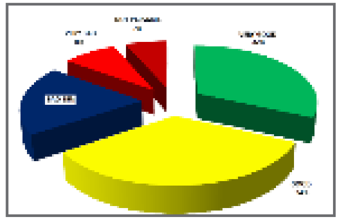


Figure 2.3 Results from unpaved roads

Source: *"Relatório: condições de transitabilidade da rede de estradas classificadas, ANE, 2015"*

3. Water related challenges and climate change

Mozambique has its fair share of droughts and floods in the past years. Being at the lower part of major river systems, flooding is a recurrent event. There is the normal seasonal inundation of the flood plains of Incomati, Limpopo, Zambezi and smaller rivers – but also the recurrent unusual events. Mozambican rivers are expected to exceed the flood alert level every 2 to 3 years with extreme flood events once every 15 to 20 years. Flooding usually occurs during the rainy season in river basins, low-lying coastal areas or areas with drainage problems. On average, 100km of roads and 33,000 households are impacted by flooding every year resulting in estimated direct losses of US$700,000 and US$17.5 million respectively. Drought make an appearance in the dry season, but in the past years the impact has been more severe, especially during the 2016 El Nino year. El Niño conditions resulted in Mozambique experiencing the worst drought in 30 years[6].

The weather extremes are expected to increase with climate change. A summary of climate change over the past decades and in the coming decades is given in table 3.

Table 3: A summary of climate change over the past decades and expected future changes

Change 1960-2006	Expected future changes
Increase in temperature 0.6 degrees	Temperature rise 2010-2100 1.0 to 4.6 degrees
Increase in number of hot days (6.8%) and hot nights (8.4%)	Mainly for inland and Southerns regions (3.0 degrees by 2055)
Most pronounced in South	No of hot days to increase from 10 to 20/53%
Decrease in rainfall 3.1%	Higher EY combiend with erosion, deforestation and climate ro
Proportion of rain falling in heaving events increass 2.6% per decade	North rainfall increase: 1-8% in North, mainly in rainy season
Level of preparedness	West/south/central rainfall decrease esp at onset of rainy season
142 out 178 on ND-Gain index (dropped five places) which measures CC preparedness	More rain to fall in heavy rainfall events (10%)
36th on vulnerability; 144th on readiness	More floods expected with implication for damage esp in South – Limpopo average increase in magnitude of flood peaks 25% bit on other hand Limpopo will also be dry most of year and Zambezi flows drop 15%
	Combined with population increase 26 M (2014) to 60 M (2050) per capita water availability will decrease from 1900 (2000) to $500m^3$
Source: *Netherlands Commission for Environmental Assessment, 2015)*	

The impact of emergencies – in particular uncontrolled flooding – is substantial, with 2015 as the peak year as shown in Table 4.

Given the size of Mozambique the water related road challenges differ between the different areas. In the North rainfall is higher with steep slopes bringing risks of erosion (see figure 3.2). Soil erodibility is also a main contributor to erosion. The Western part of the country is also at high risk of erosion The Southern Provinces are more prone to drought and floods (Figure 3.1). In general, given the relatively flat nature of large parts of

[6] UNRCO (2016) Mozambique: Drought, Situation Report No. 4 https://reliefweb.int/sites/reliefweb.int/files/resources/Mozambique-UNRCO-Situation%20Report%204_Drought%202016_Final_June.pdf

Table 4: Impact of emergencies on infrastructure (2013 - 2017)

	2013					2014				
Province	Infrastructure affected				Total cost (1000 Mts)	Infrastructure affected				Total cost (1000 Mts)
	Road Km	Bridges	Drifts	Channel		Road Km	Bridges	Drifts	Channel	
Maputo	30	0	0	0	81,549	43		1		4,000
Gaza	90	0	0	5	369,727	52				12,970
Inhambane	50	2	0	4	27,750	20			3	10,238
Sofala	250	0	0	2	38,383	333	3		17	298,113
Manica	161	1	0	0	13,400					0
Tete	90	0	0	2	45,930	20	2			25,000
Zambézia	120	2	0	3	29,504	154	3		3	62,577
Nampula	50	2	4	7	37,006	102	1		3	24,350
Cabo Delgado		0	0	0	19,150					14,426
Niassa	888	2	0	0	16,620			1		30,287
Total in Mts	1729	9	4	23	679,019	724	9	2	26	481,961
Total in USD					22,509,480					15,803,501

	2015					2016					2017
	Infrastructure affected				Total cost (1000 Mts)	Infrastructure affected				Total cost (1000 Mts)	Total cost (1000Mts)
Province	Road Km	Bridges	Drifts	Channel		Road Km	Bridges	Drifts	Channel		
Maputo	185	0	1	5	43,600						10,000
Gaza	305	2	3	1	82,060						90,000
Inhambane	0	0	0	0	0						71,775
Sofala	453	2	0	5	79,930						9,834
Manica	206	1	1	2	33,000						41,831
Tete	844	0	0	2	164,700	175	1	1	1	23,700	7,200
Zambézia	3798	36	12	11	8,082,170						85,606
Nampula	838	8	11	113	663,250	206	1		2	17,000	31,165
Cabo Delgado	0	1	0	5	86,870	394	1	3	3	28,290	7,812
Niassa	1873	7	0	6	305,100	185	3	1		47,500	10,000
Total in Mts	8501.3	57	28	150	9,540,680	960	6	5	6	116,490	365,223
Total in USD					318,023,000					1,595,913	5,869,134

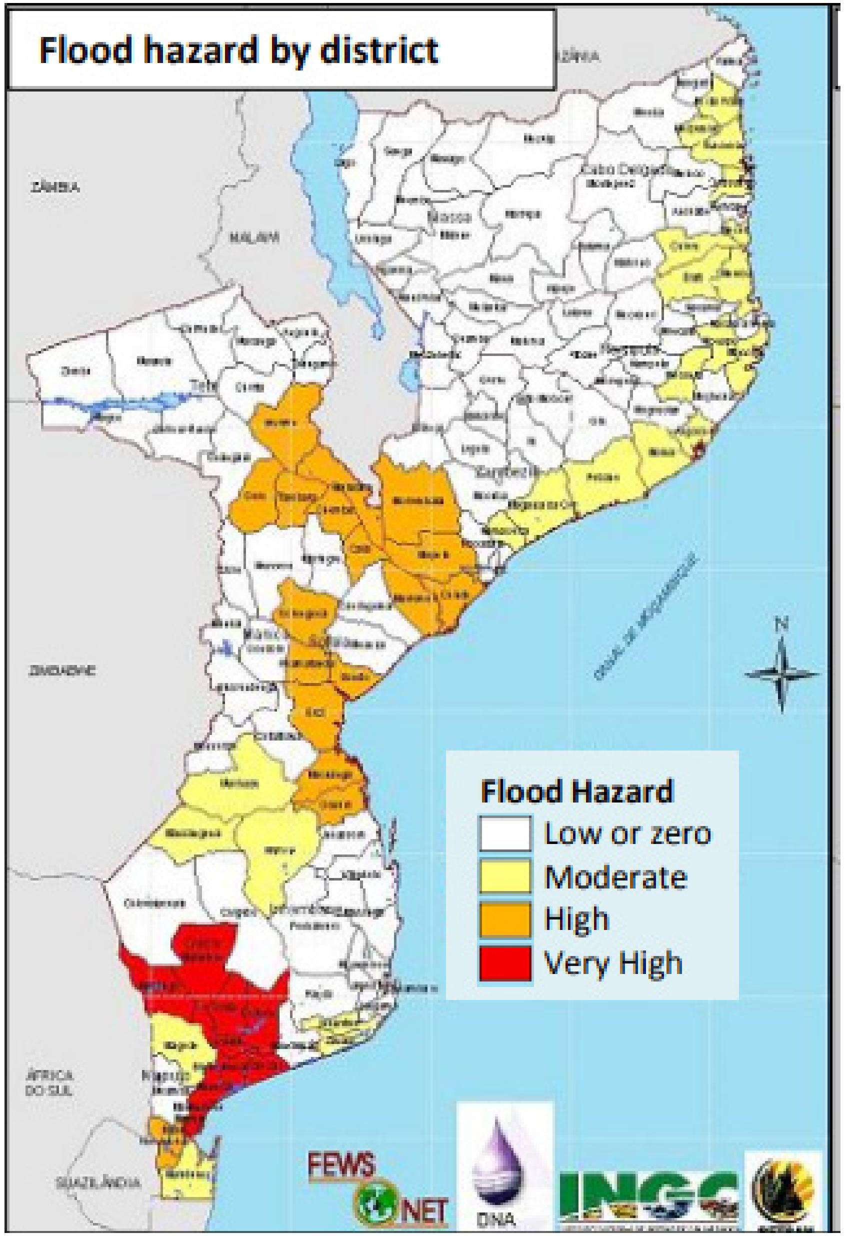


Figure 3.1: Flood hazard map of Mozambique (Source: INGC, 2010)

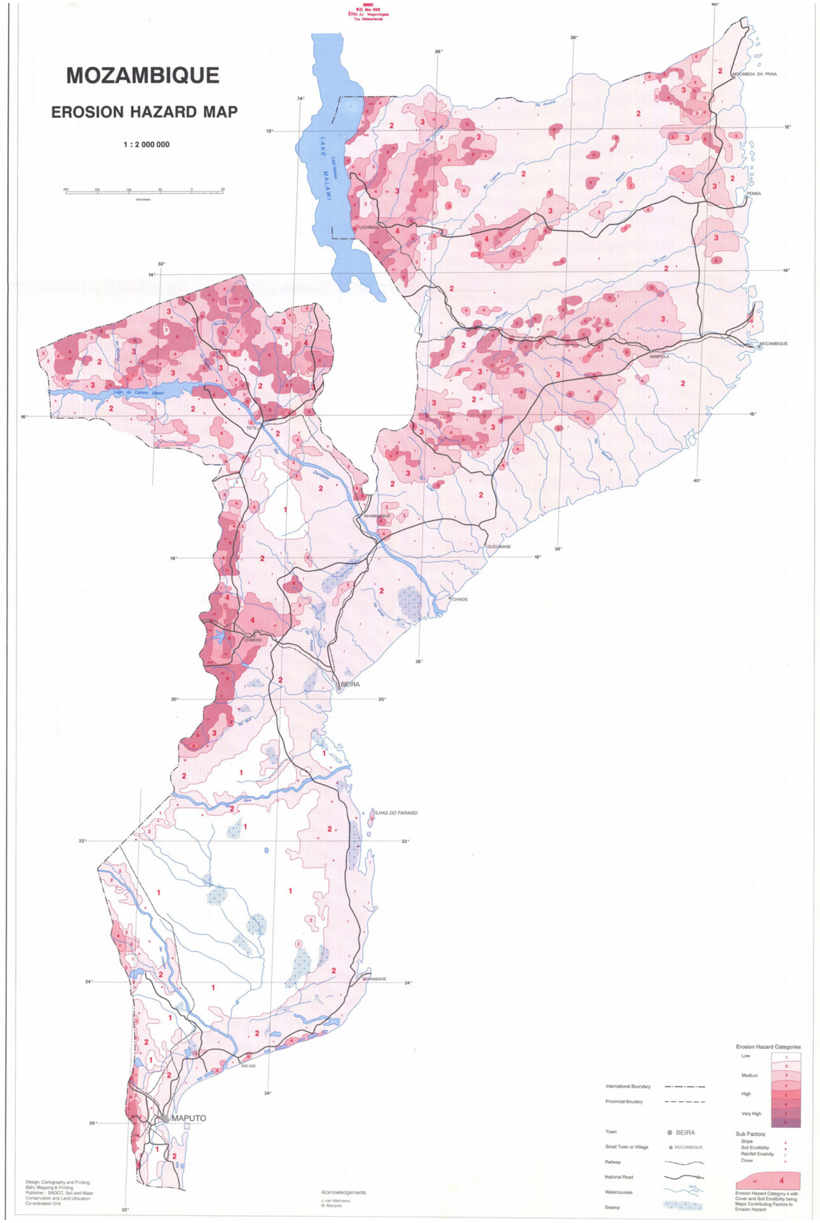


Figure 3.2: Erosion hazard map of Mozambique (Source: European Soil Data Centre)

the country and the occurrence of large areas with permeable soils, the drainage pattern is not so articulate and there are relatively few road-water crossings.

Two major road-water challenges emerge:

- Managing droughts with roads
- Management of floods and flood plains with roads

The options for beneficial water management in these two categories of areas are described respectively in section 4 and 5. Section 6 discusses the way forward, based on among others the National Workshop.

4. Managing droughts with road water harvesting

Several parts of Mozambique suffer from seasonal water shortage – in particular Gaza and Inhambane, but droughts are common elsewhere too (Figure 4). The exposure to long dry periods can be observed from the popularity of self-financed roof top water harvesting in rural areas. A roof top water harvesting system consists of a catchment roof, conveyance pipes, and a storage tank. The pipes include a gutter system made from a polythene pipe with a flushing system that allows the system to be periodically flushed clean. Besides these private roof water investments, however, there is no water harvesting at scale in Mozambique. This is unlike other countries in SSA, such as Ethiopia, Rwanda or Niger, where water harvesting has been implemented at scale combining public leadership and private contribution.

The systematic use of roads for water harvesting however could change this and be a first opportunity to introduce water harvesting at scale in Mozambique for productive use such as livestock or farming. The introduction of road water harvesting is cost effective as it makes use of the existing infrastructure. Moreover, the use of roads for water harvesting in many

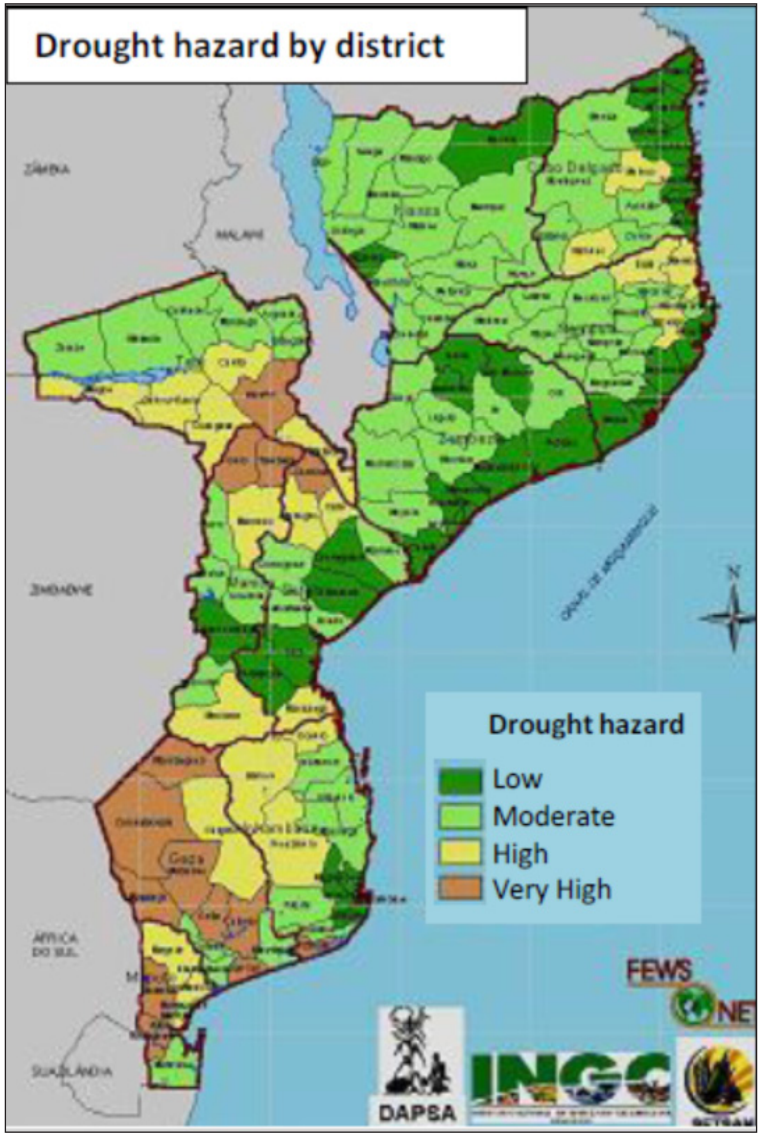


Figure 4: Province distribution of road transitability conditions. (Source: INGC, 2010)

instances (use of road side trenches, water bars and drifts as sand dams) is likely to reduce the maintenance burden on roads. Given the challenge of funding road maintenance this is much required.

The following main opportunities exist:

(4.1) Converting borrow pits for water storage
(4.2) Connecting road side trenches to farm land
(4.3) Using water bars on unpaved roads
(4.4) Making systematic use of road drifts for water storage
(4.5) Other water harvesting measures

4.1 Converting borrow pits for water storage

There are a large number of abandoned borrow pits that are not intensively used or not used at all in Mozambique. Based on the data from 7 out of 10 Provinces (see table 5) the number of borrow pits probably amounts to 800. The exhausted borrow pits may be converted into water storage ponds. The non-exhausted borrow pits could be also converted unless there are plans to re-use the pits in the future

The sourcing of good road building material is challenging in Mozambique. There is also a practice of re-opening borrow pits, because identifying new suitable source locations is often difficult. As a result borrow pits in Mozambique – in comparison to other countries – tend to be very large – with the more than 65% of the borrow pits being larger than 5000 m^3 and 30% larger than 10000 m^3 – see table 5.

Usually these borrow pits are not landscaped. Moreover, not all borrow pits are suitable for conversion. In some cases (for instance along the R902 and R481 in Inhambane) the borrow pits are located too high to collect substantial amounts of water. In other cases the borrow pits are far from habitation. It may also be that the areas surrounding the borrow pits have sufficient other sources of water and there is no need for additional storage locally.

Nevertheless, there are many areas where it would be interesting to rehabilitate the borrow pits. For instance, one borrow pit visited (Mavanza in Inhambane) was lined with geomembrane by ARA-SUL and surrounded by a fence. The borrow pit was also equipped with an Afridev pump, leading among others to some distant animal drinking troughs to avoid livestock

Table 5: Distribution of borrow pits per volume m^3 based on figures of seven provinces

	0≤2500	2501≤5000	5001≤7500	7501≤10000	>10000
Total	113	83	114	86	172
				TOTAL	568

Source: *ANE*

coming near to the open water source. In Mavanza the management of the reservoirs and the pump was no longer in place. Even so, the use of the borrow pits was very intensive. Water was collected by a population in a radius of 4 kilometer from the pond. The storage pond, with an estimated storage capacity of 20,000 m^3, was storing water throughout the year. Though the cost of upgrading the borrow pit to a full-fledged reservoirs was high, in the Mavanza area it served an important purpose as there was no other source of water.

Several opportunities for converting borrow pits for water storage were identified during the transect surveys. There is a strong case to make an inventory of borrow pits and see if where conversion makes sense. For instance, along the N212 in Gaza a large number of promising opportunities for borrow pit conversion exist – at minimum for stock water and to recharge groundwater. Better water management and retention could benefit this area, which suffered from extensive livestock deaths because of the El Nino-triggered drought. Also there is already the practice of collecting water for domestic use from open ponds. What is required in this area is to do basic landscaping of the borrow pits by avoiding potentially dangerous heaps and sides and ensuring stable slopes. Overflow channels should be protected to prevent wash-out. Next, the borrow pits have to be supplied by the cross drainage from the N212 and the railway track running parallel to it. The location of the culverts on the railway and the road is not synchronized, yet this would be simple to do and place culvert on both the road and railway in the same position. As there are a large number of borrow pits (one every 5 kilometer) with different shapes and depth it would make sense to select the borrow pits that are most promising to rehabilitate and provide with proper management, protection and measures to ensure water of acceptable quality. Borrow pits (for development or conversion) should be close to areas where people reside or where there is interest in irrigation or possibility to recharge wells. In pastoralist areas in general it is useful to plan the location of water resources taking into account the grazing resources. Ensuring water quality can be done by providing sand filters in the converted borrow pit. Such sand filters can be equipped with hand pumps: if immersed the sand filter will remove large part of the harmful bacteriological contamination. An alternative option for ensuring good water quality from the converted borrow pits is to make wells that collect the groundwater recharged from the borrow pits or to place the so-called 'village pump' that combines pumping with filtering and automated cleaning of the filters.

Based on the data sets of the ANE, it is proposed to make a systematic inventory of the borrow pits that can be converted in the different provinces, looking at the following criteria:

- Water pits that can be connected to a water source
- Water pits located in areas of water shortage with no access to viable alternative sources
- Water pits that are not excessively large and that do not need extensive relandscaping
- Borrow pits that are located close to area of usage – by human or livestock
- Borrow pits have relatively impermeable soils (not requiring costly lining) or where the local geohydrology makes it possible for the borrow pits to recharge wells.

On the basis of this inventory a priority plan could be developed in cooperation with the Ministry of Water of setting aside abandoned borrow pits for conversion into water ponds.

(1) Example of abandoned borrow in Gaza

(2) Collecting water from pond at railroad crossing along N212

(3) Landscaped borrow pit along N1 – unused as there are other sources of water

(4) Mavanza upgraded borrow pit – with geomembrane lining and fencing – intensely used

4.2 Connecting road side trenches to farm land[7]

A common practice observed in Mozambique on both class 1 roads (such as the N1) and class 2 and 3 roads is to provide short road side trenches, called sanjas. During rain, these trenches take road run-off of the road surface in order to preserve the road body. The road side trenches are usually placed at very short distance from one another. During the transect visits to Inhambane Province, it was found for instance that there were 10-16 such road side trenches per kilometer. Ideally the trenches align with the road slope, though this is not always the case. They are in most cases made by the grader working on the road surface. The length of the trenches is very short: typically 3-5 meter.

Heat photos shows that several of the trenches store considerable moisture. This is obvious from the cooler temperature at the bottom of the trench. Because of the short length of the sanjas, this moisture at the moment does not reach the adjacent farmland where it could contribute to higher crop production. There is scope in drought prone areas to extend the road trenches to the adjacent farmland. Such is already done in Kenya and Malawi. It helps to increase soil moisture and store water in the soil profile. To move this forward the following steps may be taken:

- select one or more roads that can serve as a test case – the Maxixe to Chiquoke Road in Inhambane could be a candidate place to undertake such a trial
- engage local ANE staff to connect to community leaders along the road and discuss the opportunities
- make standard design (see draft Guidelines and brochure)
- make agreement with interested famers on liabilities and mutual responsibilities for making the extended road side trenches
- engage graders and farm labour to make the trenches
- monitoring of impact and sharing the results.

In the box below some do's and don'ts are given.

Box: do's and don'ts

Do's

- Run-off collected on the road surface can be diverted into to farm trenches to increase soil moisture
- The trenches can be connected with the road-run off outlets now commonly made among roads
- The trenches should be developed by farmer-land owners in cooperation with local roads staff
- To guide the water to the farm trench a water bar may be made across the road. Water bars are narrow structures akin to speed breakers used to divert water away from the unpaved road surface
- In some case a trench is not necessarily but a simple diversion canal may be sufficient
- To improve soil moisture or water availability the trench may be provided with infiltration pits
- Alternatively some small low cost lined ponds can be integrated in the farm trench

Don'ts:

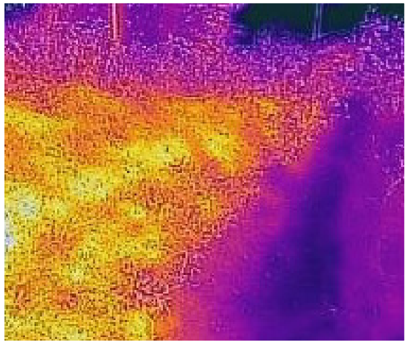
- Ensure the amount of water entering into the farm trench is not too much: this can be done by closing the trench with small soil bund.
- Ensure trench entrance is in direction of the flow and that backflow does not occur

[7] A special brochure is developed on this opportunity.

An asset for introducing a road trench farm land program are the local field staff. ANE employs maintenance staff that are often well-known in the area. These field staff have strong knowledge of the people living along the road and often excellent relations.

Having the water used in the farms moreover would give an incentive for ANE and farmers to keep the unpaved roads and the trenches in place. In some areas the trench may be supported with water bars, whereas in other areas this could be in the shape of a surface channel. This could be a massive program, starting the implementation in a number of vulnerable Class 3 roads.

(1) Short road trench – standard practice now



(2) Heat photo showing cold temperature and ample moisture in the trench

(3) Improved practice in Kenya – trench and pond

(4) Improved practice in Kenya – farm road trench filled with water

4.3 Use of water bars

The maintenance of un-sealed roads, especially Class 3 roads, is a major challenge – financially and technically. Section 2 gave an overview: The challenge is compounded by the fact that in several areas there is no suitable sub-base and base material available. This was observed in Inhambane in road R905 for instance where the main material is highly erodible red sand. Under the impact of traffic movement and water run-off the material disintegrates and is washed away in large quantities, requiring substantial maintenance efforts.

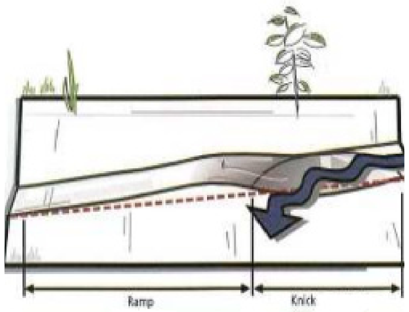
Part of the solution here is the use of water bars, i.e. slanted water breakers that slow down the speed and force of water run-off on the road by diverting it to the surrounding land at regular intervals. Normally such water breakers are made from the road material but given the extremely soft nature of the road material, the use of small slanted pre-cast concrete road ridges is proposed. Apart from breaking the speed of road run-off and diverting water to the land where it can be used productively, the concrete water bars will also fixate the road material. This is particularly important in steeper areas where run-off get high velocity. Special precast designs may be tested. In the Guidelines that are part of this assignment the design for the water bars are worked out.

The outflow end of the water bars should remain open to avoid accumulation and preferably lead to land where it is utilized. Erosion control measures should be put in place to protect adjacent land. These measures include grass strips, check dams, rock mattress and sediments traps.

(1) Massive gullying on red sand road slope

(2) Road lowered 90 centimeter due to wash out

(3) Large deposits of washed away road material



(4) Water bar placed at angle to divert water of the road

4.4 Systematic use of drifts for water storage

In Gaza and Inhambane there are relatively few road river crossings and where these occur, the crossing is often small and steep and small bridges are used. In other parts of Mozambique this is different and vents are frequently used.

For wider crossings of small streams and rivers in dry areas of Mozambique, non-vented drifts are strongly suggested – instead of 'vented' drifts. i.e. drifts with culverts. The advantage of the non-vented drifts is that they spread water gently over the length of the drift and avoid rutting of the river bed or uncontrolled flooding. In case of vented drifts, it is common for the culverts to be blocked by flotsam and hence create uncontrolled flooding. By having no vents/ culverts on the road drift, the water flows over the drifts in a controlled way using the width of the drift, reducing maintenance needs. By lowering the middle section of the drift water is guided towards the middle of the stream. It is important that the drift body extends wide enough in the river – to avoid that the drift is circumvented in high floods.

The second major advantage of the use of non-vented drifts – provided the river is sandy – is that a package of sand and gravel will be deposited immediately upstream of the non-vented drift. This sand and gravel deposit forms a local new mini-aquifer, storing water in the river bed that will feed the nearby wells. The river bed can also be drained with a slotted pipe to provide relatively safe water.

Some such drifts doubling up a sand dams exist in Mozambique, but they are not yet standard practice – unless many counties in Kenya. It is proposed to make the use of non-vented drift for water retention a standard practice. As part of road rehabilitation some vented drifts may be converted into non-vented drifts.

(1) Non-vented drift doubling up as sand dam in Kenya

(2) Road crossing doubling up as dam/sand dam in Mozambique

4.5 Other water harvesting measures

There is a large range of other road water harvesting techniques that may be considered. Many of these are in practice in other countries but not yet applied in Mozambique. These techniques will make use either of the water from the road surface or from the road culverts/ drains. In general it was observed that road drains are not commonly used in Mozambique, at least not in the parts of Gaza and Inhambane visited. Yet the opportunities to make better use of culverts and run-off from the road surface are plentiful. This can be done by:

- Floodwater spreaders from paved road surface – these spread road surface run off to adjacent land
- Floodwater spreaders from culverts – these take water from road culverts and spread it widely over the land, avoiding the development of gullies in the process. Important – as in all these measures – is that the drainage water is removed to a safe distance from the road subgrade
- Road side infiltration trenches – these collect run-off obstructed by roads into recharge structures
- Road side infiltration or storage ponds – this sees road drainage filling ponds used either for surface storage or infiltration and recharge of groundwater

(1) Flood water spreader from paved road surface

(2) Flood water spreader from culverts

(3) Infiltration trenches fed by road water

(4) Road side infiltration trenches – all pictures from Ethiopia – note that the distance to the road is too small

5. Managing floods and flood plains with roads

One major additional use of road infrastructure is to alleviate water shortage, discussed in section 4. A different angle is to manage floods and flood plains with roads. More than other countries, Mozambique has extensive flood plains – both flood plains fed by permanent rivers and flood plains fed by seasonal flows.

The location of the road bodies and the cross drainage of roads may have a large impact on the nature of these floodplains. There are two main effects:

- Roads divide the flood plain areas in two – with one side remaining as active flood plains and the other side protected and drier
- Roads affect the flood patterns – with elevated road bodies in particular acting as dikes.

The impact of roads on flood plains should be taken into account prior to the design of roads in flood plains. This is first to prevent unwanted negative impact (water logging, drying up of areas). But going a step further: if done well, roads in low-lying areas can contribute to the management of floods and flood plains as well. There are three important areas of interaction that should be explored in Mozambique.

(5.1) Considering low embankment roads in flood plains to control flooding and manage flood plains
(5.2) Using cross drainage to manage the water retention in flood plains
(5.3) Using roads to undertake water spreading in flood plains

5.1 Considering low embankment roads with overflow areas to guide floods

In many cases roads have been built on relatively high embankments in flood plains. This is to avoid them being overtopped during floods. Yet even with such high embankments, flood water however still had to get its way, which leads to uncontrolled flooding – putting life, infrastructure and connectivity at risk. The damage experienced in 2015 floods owes itself to high embankments to a large extent. The damage happened once when the floods water crossed towards the higher area and then once it receded. Quite often the receding flood was more damaging. Also the high embankment roads have often dissected the flood plains – causing waterlogging on one side and dry areas on the other side.

Rather than having high embankment roads that may breach or overtop in an uncontrolled manner, having low embankment roads with a lowered overflow section should be considered, especially in low traffic areas when the flooding is for a limited period or happens only occasionally. The floods rather than causing unplanned breaches escape through in a planned way through the lowered sections acting as spillways. Such low embankment sections (also called floodways) will conserve floodplain functions, reduce road-building costs (as embankments are lower so less fill material is required) and avoid unpredictable damages around the road. There are a number of things to keep in mind:

- The lowered overflow section should be armoured (for instance with stone pitching).
- Trees on either side will provide further protection against scour of the overflowing water.
- The overflow should leads to an area where it does not do harm but serves useful purposes – for instance the recharge of groundwater, the improvement of grazing land or the preservation of a wetland.
- In general roads in floodplain have a huge effect on the floodplain functions – the alignment of the road, the height and cross-drainage should be carefully considered.
- Do not make the overflow section (floodway) too short or narrow: it has to accommodate substantial quantities of water in a gradual manner. A careful assessment of height of the floodplain road and the overflow area is necessary. The dimensions (width and height) of the floodway should be chosen so at to ensure that: floodwater can spread widely across the floodway. This should bring velocity to acceptable levels (reducing scour) and the level of the water level passing over the waterway body during the flooding period in line with the accepted down time.

The practice is not common in Mozambique but merits wider application. It has been applied successfully in Lindella in Inhambane – where the wetland is preserved including its functions for grazing and reed collection – by including a 100 meter overflow section in the road traversing the flood plain.

(1) Example of Limpopo flood plain dissected by road – dry downstream side with termite hills

(2) Same flood plain on river side – with extensive water logging

(3) During floods the same road was overtopped and wash away – with extensive damage

(4) Good practice of low embankment road in Lindella – with armoured overflow area complete with flood velocity reducing trees along the overflow area

5.2 Using cross drainage to manage the water retention in flood plains

Following the above, the roads and the cross drainage structure along the roads can be used to manage the flood plains. Whereas in principle the roads divide the flood plain in an active/ wetter and a protected/ drier part, the exact level of water retention and 'wetness' in either side of the dissected flood plain can be regulated by the cross drainage provided in the flood plain road, i.e. the number of culverts and bridges and importantly also the bed level of the culverts or of the bridge sills. Lowering or raising these bed levels has a tremendous impact on the water levels in the flood plain.

(1) Dissected flood plain – with different moisture levels and land use on either side of the road

(2) Bridge on N1 – bridge sill level determining moisture levels in sugercane growing area

5.3 Using flood water spreading with roads

Thirdly, especially in flood plains fed by ephemeral streams, roads can be used to spread short term flood water flows over a large areas – this improving its beneficial use. Spreading such short term floods can improve recharge, soil moisture for farming and the opportunities for grazing. The technique of flood water spreading weir is common in Niger and Ethiopia. Two possible locations were noticed in Inhambane too – that would need furhter study, Pembara along the N1 and the floodplain area along the R481.

(1) Road cum flood water spreading weir in Niger

(2) Potential area along R481

6. Way forward

6.1 Validation of findings

During the National Workshop on 29 June the preliminary findings from the assessment were validated. The comments of the Workshop has been reflected in the above in the sections above.

The Workshop also discussed the way forward. It identified the following opportunities to systematically introduce beneficial road water management in Mozambique:

- In general using roads in in arid and semi-arid areas for water diversion, storage and retention
- Using roads in flood prone areas for the management of low lands and floodplains
- Align with current programs for maintenance, rehabilitation and improvement of roads to integrate the water management element.
- Start working on a number of specific opportunities:
    - Making a systematic assessment of borrow pits and see how they can be converted into water storage reservoir
    - Introduce the use of road side trenches (sanjas) for farm trenches.

The proposed way forward consisted of:

- Creation of a steering committee (including all stakeholders)
- Mapping of areas with potential for road water harvesting and road floodplain management opportunities
- Identify priorities: identification of vulnerable areas
- Widely disseminate information on road water harvesting potential and options
- Sensitize communities living in the vicinity of roads
- Development of technical specifications – contribute to manuals

- Integrate in ongoing road for water programs
- Identify trial activities with secure funding or limited cost implications
- Get going: start some immediate activities in short term.

Finally, mechanisms for coordination were discussed. What was recommended was:

- Interinstitutional coordination: making a coordinated management of projects between related sectors (roads, health, water, environment, local governments, agriculture and fishing)
- Provide responsibilities to each institution at different phases
- Avoid complexity – focus on getting things going.

6.2 Follow up

The discussions above have led to the following agreed follow up under the program of "Integrating Climate Change Adaptation And Water Management in The Design And Construction Of Roads" – as given in the table below. The table gives the actions proposed and the current status.

Table 6: Actions proposed for follow up, and their current status

		Actions	Current status
1	**Complete assessment of opportunities report (this report)**	Provide data from ANE on emergency and maintenance, number of borrow pits	Finalized (this report)
2	**Guidelines/ guidance note on road water harvesting specific to Mozambique**	Preparation of guidance note – making sure there is connection to manuals being developed by TRL.	First version of Guidelines prepared and reviewed by ANE. New version to be completed by 11 Sept – should be reviewed for finalization, Made assessment of where link can be made to the manual under preparation, in particular: - Site investigation - Rehabilitation Design - Hydrology and drainage - Specification for roads and bridge
3	**Guideline on borrow pits development**	Generic guideline: To be reviewed by ANE, MoW, MoA and RHDHV	First version completed and ready for circulation and review (was included in Guidelines) Discuss plan on how to identify borrow pits
4	**General Brochure in Road Water Opportunities**	Reviewed and finalized	Can be printed - preferably with all logos (MoW and MoA) and be distributed widely
5	**Trial on road site cuts (sanjas)**	Flyer prepared and circulated for comments	Flyer can be printed and circulated. Discuss interest and scope of trial.

6	**Trial on water bars**	Flyer prepared and circulated for comments	Flyer can be printed and circulated. Discuss interest and scope of trial.
7	**Initiate discussion on flood management, flood plain management and roads**	Meeting with MoW and ANE (same ministry) and maybe others)	Make a link; prepare note, make connection with EKN formulation of basin projects
8	**Coordination within ANE**	Core group in place	
9	**Coordination – meeting between Directors/ Steering Committee**	At ministerial level – plus directors and other staff On occasion of guidance note	Need to operationalize
10	**Training package – make available 5 key translated PowerPoint**	Training package is ready	National consultant can be available to do small sessions on ANE events and others
11	**General documentation**	Three short videos prepared	Finished, shared and placed on www.thewaterchannel.tv

Annex 1 Mission Program

Activities		
Arrival, kick-off briefing	21 June	Logistical arrangements
Transect road visit in two different areas (each visiting feeder road and highway) to make first assessment and documentation of the opportunities for road water harvesting/ management for resilience	22-26 June	Visit to: Gaza Province Inhambane Province Some one from ANE accompany Also make visit to Provincial Offices
Discussion with stakeholders at national level and at regional level (the latter combined with transect road visits) to explore issues and opportunities and identify on-going programs in which better integration of roads and water management can be promoted	27-28 June	Suggested names/organisations to visit: - disaster risk reduction - water department - agricultural department - World Bank office - Forestry department - Department in control of sand mining
Workshop for a day with main stakeholders discussing and agreeing on the opportunities of road water management in Mozambique	29 June	Venue Persons to invite: - ANE (different sections) - Environmental Dept - Emergency Unit - Water Ministry - Agricultural Dept - World Bank ANE is inviting Objective of workshop - present field assessment - explore scope for beneficial road water use for resilience - ideas on guidelines
	30 June	Wrapping up

Annex 2 Program National Workshop 29 June 2017, Hotel Cardoso Maputo

09:00-09:30	Welcome	Irene Simoes
09:30-10:00	Introduction to the Program Getting to know each other	Janeiro Avelino Fabrizio del Rivo Valvida
10:00-1045	Roads for Water: International Experience	Frank van Steenbergen
10:45-11:00	Coffee break	
11:00-11:30	Developing and Maintaining the Road Network in Mozambique: Main Challenges	Rubina Normahomed
11:30-12:00	Climate Change in Mozambique: the Challenges and the Opportunities	GIMCC (to confirm)
12:00-12:30	Roads for Water – Roads as Instruments for Resilience : Opportunities in Mozambique	Frank van Steenbergen
12:30-13:30	Facilitated Plenary Discussion and Wrap up	Janeiro Avelino Irene Simoes
13:30-14:30	Lunch	
14:30-15:30	Follow up discussion in smaller groups and closure	

Annex 3 List of persons met

Name	E-mail	Institution	Position
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Tapaca	ialfinete@gmail.com	ANE/GE	

Annex 4

As part of the assessment, MetaMeta consultants together with ANE National, Gaza and Inhambane staff members visited several roads and borrow pits.

To analyze the current state of roads and think about opportunities with the Roads for Water program, two transects were conducted.

The first Transect included the road from Chowne to Mabalane. For this road, the main goal was to visit borrow pits and possible interventions to use them to collect water. See Figure 2.

The second transect from Maxixe to Chiquoke was elaborated in more detail. The main goal was to look for damages in the road produced by water, which can be easily improved by using different techniques from the Roads for Water program such as Farm trenches" (sanjas), water bars, infiltration ponds, flood water spreaders and tree planting.

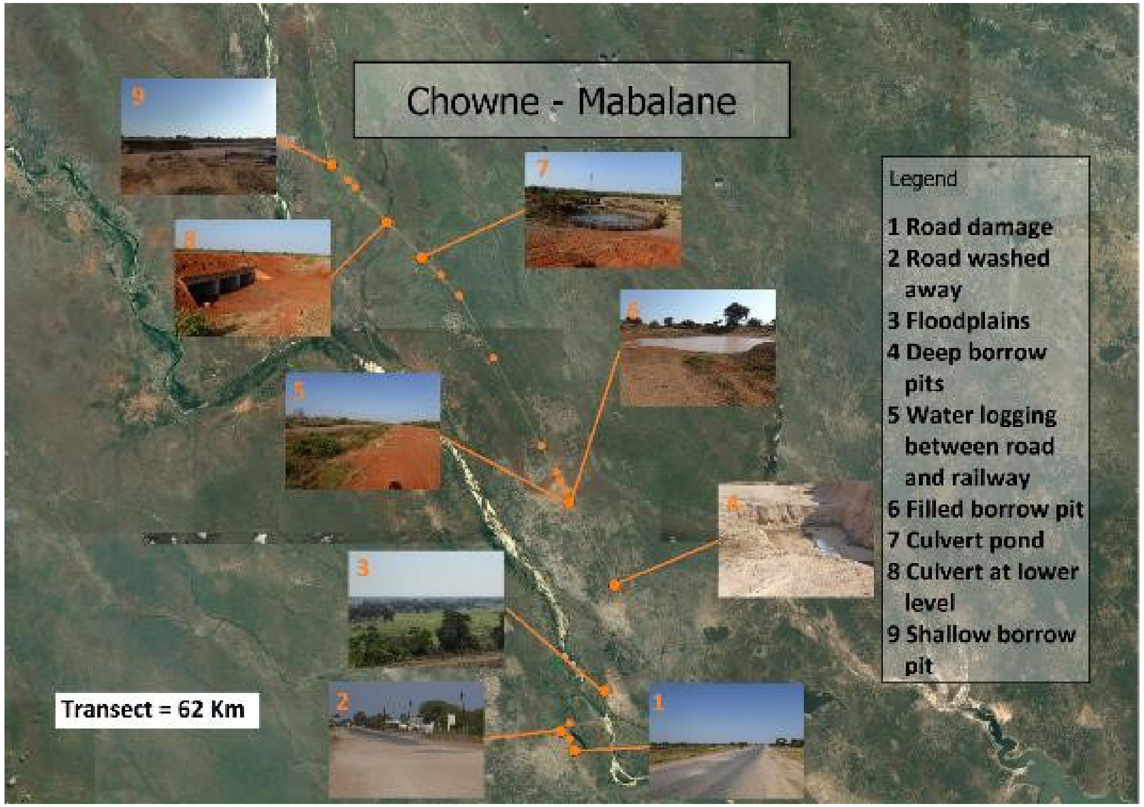

Figure 2: Transect Chowne-Mabalane (Source: prepared by MetaMeta)

The transect (see Figure 3) results are:

- Covered length, 10Km long: 5,7 Km of unpaved road and 4,3 paved road
- The area has a slow slope
- The area is sandy and might have good infiltration capacity
- The top side of the slope has a good potential for water harvesting, which is currently taking place in some houses
- There is potential for tree planting along the road, to mitigate large quantities of dust produced by cars
- The bottom side of the slope is too narrow In the area next to the paved road
- The road is currently maintained with a grader at least 3 times a year

Annex 4

- The area was severely damage by a cyclone last year
- The areas next to the road have cashew, coconut and banana trees

The inventory results are:

Table 3: Inventory of transect Maxixe-Chiquoke

Inventory	
inland trenches	23
cyclone damage	4
culverts	11
gullies	3
borrow pit	1
Potential improvements	
water bar	4
infiltration pond	5
flood water spreaders	1
tree planting	2

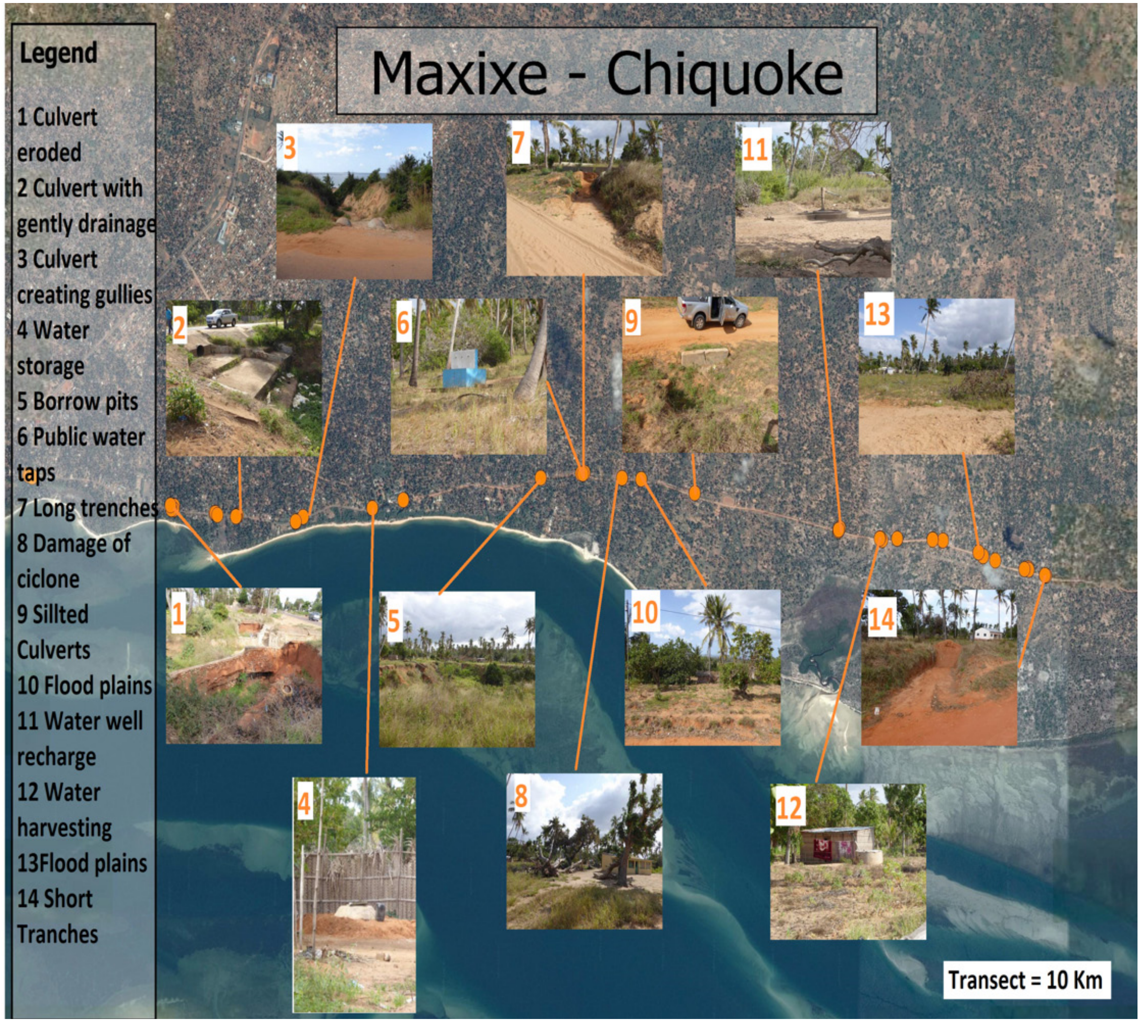

Figure 3: Transect Maxixe-Chiquoke (Source: prepared by MetaMeta)

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