Multi-Hazard Risk Assessment for the Schools Sector in Mozambique

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Keywords
Safe schools, earthquakes, coastal flooding, river flooding, cyclones, landslides, risk assessment, retrofitting options, awareness raising

Summary
To address the issue of school safety globally, the World Bank / Global Facility for Disaster Reduction and Recovery (WB/GFDRR) launched the Global Program for Safer Schools. As part of this initiative in Mozambique, the WB/GFDRR has given an assignment to Deltares to better understand the risk to the school sector through a multi-hazard (riverine floods, coastal floods, cyclone winds, earthquakes, landslides) disaster risk assessment. A cost-benefit analysis of retrofitting options is also conducted for each identified building typology.

In this assignment, hazard, exposure and vulnerability information is available from previous studies such as the R5 project and the Safer Schools project itself. The execution of the multi-hazard risk assessment is done with the Delft-FIAT model. At national level, the annual expected damage is estimated to be 2,125,000 $/year and 39,000 $/year for conventional and unconventional classrooms, respectively. For conventional classrooms, the highest contribution is from coastal flooding (43%), followed by river flooding (37%), cyclone wind (16%) and earthquakes (3%). For unconventional classrooms, the contribution of cyclone wind is more significant and increases to 29%. Further, coastal flood is responsible for 36% of the annual damages, the riverine flood for 29% and the earthquakes for 6%.

Five retrofitting options are presented, consisting of dry flood proofing, retrofitted roof (additional fixations), fully retrofitted roof (additional fixations and pillars), fully retrofitted buildings (additional fixations and pillars, and entrances protection), and earthquake-proof reinforcement of the building (strengthening of roof and walls). A cost-benefit analysis of the retrofitting options is conducted showing that retrofitting for reduction of the damages from flood risk is economically feasible, as classrooms prone to flooding can be easily identified. Only one option for retrofitting against wind hazard by reinforcement of the roof is economically feasible. All other retrofitting options are not economically viable, unless exposed classrooms can be more precisely identified. For earthquakes there is no economic rationale for retrofitting of the buildings as the risk is very low.

Version	Date	Author	Initials	Review	Initials	Approval	Initials
	May 2018	Christophe Briere		Tony Minns		Frank Hoozemans	
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This Multi-Hazard Risk Assessment for the Schools Sector in Mozambique (Risk Assessment for Schools) has been conducted by Deltares within the scope of the assignment and is funded by the World Bank / Global Facility for Disaster Reduction and Recovery (WB/GFDRR) and the European Union (EU)–funded Africa Disaster Risk Financing (ADRF) Initiative, managed by the Global Facility for Disaster Reduction and Recovery (GFDRR). The ADRF Initiative is part of the larger EU–Africa, Caribbean, and Pacific (ACP) cooperation program Building Disaster Resilience in Sub-Saharan Africa, which aims at strengthening the resilience of Sub-Saharan regions, countries, and communities against the impacts of natural disasters, including the potential impacts of climate change, to reduce poverty and promote sustainable development.

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Sumário executivo

Introdução

Moçambique é um país exposto a várias ameaças naturais, sendo secas, inundações e ciclones tropicais os mais frequentes. Inundações e ciclones são ameaças recorrentes que afectam severamente as infraestruturas, os serviços e a economia. Moçambique também está em risco de terramotos devido à sua localização na intersecção da placa Nubiana africana a oeste e a placa da Somália africana a leste.

Devido ao fraco desenho, à baixa qualidade da construção, bem como localização inadequada, os edifícios escolares são altamente vulneráveis aos efeitos combinados de inundações, vento forte e terramotos. Estima-se que mais de 70% das escolas em Moçambique estejam em áreas de alto risco para uma ou mais ameaças naturais (UN-Habitat, 2015)[1].

O Banco Mundial / *Global Facility for Disaster Reduction and Recovery* (GFDRR) lançou o Programa Global das Escolas Seguras, com o objectivo de tornar as instalações escolares e as comunidades que estas servem mais resistentes aos desastres naturais. Lançado em Julho de 2012, a iniciativa Escolas Seguras em Moçambique foi criada em resposta às graves inundações que afectaram mais de mil salas de aula nas províncias de Maputo, Gaza e Zambézia. O principal objectivo da iniciativa é desenvolver directrizes para construção de escolas resistentes às ameaças naturais e produzir recomendações para sua implementação efectiva.

Como parte da iniciativa Escolas Seguras e seguindo outros programas e projectos, neste estudo a Deltares realizou uma avaliação de risco a múltiplas ameaças naturais [sismos (*Earthquake*, EQ), inundações costeiras (*Coasta Flooding*, CF), inundação fluviais (*River Flooding*, RF), ventos ciclónicos (*Ciclone Winds*, CW) e deslizamentos de terra (*Landslides*, LS)] da infraestrutura escolar e uma análise custo-benefício de soluções de reforço ("retrofitting") para cada tipologia de construção identificada. Como parte da verificação das soluções de reforço no terreno, foram realizadas visitas a 22 escolas por engenheiros da Consultec.

Metodologia

A classificação da *UN Habitat* dos tipos de construção *convencional* ou *não convencional* foi adoptada para classificar salas de aula e atribuir as melhores funções de vulnerabilidade disponíveis para cada ameaça natural. As salas de aula convencionais são aquelas construídas com cimento e tijolos, enquanto as salas de aula não convencionais são construídas com materiais locais como maticado, pau-a-pique e outros.

[1] UN-Habitat. (2015). Safer Schools Project in Mozambique "Developing Guidelines in School Safety and Resilient School Building Codes in Mozambique", Ministry of Education and Human Development (MINEDH), Project Financing World Bank – Global Fund for Disaster Risk Reductions, Maputo, January 2015

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Pesquisas de campo a 22 escolas foram realizadas, para avaliar a vulnerabilidade dos edifícios escolares em relação ao risco sísmico, inundações costeiras, inundações fluviais, ciclones e deslizamentos de terra. Durante as pesquisas, foi identificado um conjunto de questões problemáticas recorrentes nos edifícios escolares, evidenciando os inadequados modelos de construção escolar actualmente aplicados em Moçambique quando relacionados aos perfis de risco existentes nas áreas visitadas.

A avaliação de risco foi realizada usando o modelo Delft-FIAT[2], que calcula os impactos de cada ameaça natural e os expressa em valores monetários ou número de entidades afectadas. Aqui o risco é descrito como o produto da ameaça natural, da exposição e da vulnerabilidade. A intensidade da ameaça natural é considerada para diferentes períodos de retorno, para o clima actual e para cenários climáticos futuros. Os dados de exposição consistem na informação espacial sobre os edifícios escolares e numa descrição dos seus atributos: tipo de escola, material de construção, número de alunos, etc. A vulnerabilidade é expressa usando funções de dano para cada categoria de danos e informações sobre danos máximos por tipo de objecto (custo de substituição). A informação da ameaça natural, da exposição e da vulnerabilidade está disponível em estudos anteriores; CIMA e Deltares (2016)[3], Deltares (2017)[4], CIMA (2016)[5], RED e ERN (2016)[6], ARUP (2017)[7].

Neste estudo, apenas as soluções de reforço para edifícios convencionais são consideradas, consistindo em actualizar a infraestrutura existente para aumentar a resistência contra os desastres naturais. Isso é feito através de intervenções técnicas no sistema estrutural de um edifício para optimização da força, ductilidade e capacidade de carga.

Para determinar a lógica económica das soluções de reforço, realizou-se uma análise custo-benefício (*Cost-Benefit Analysis*, CBA) das várias soluções de reforço. Para esta CBA, as diferenças nos riscos entre as salas de aula originais e as reforçadas são calculadas com base nas curvas de vulnerabilidade ajustadas. Para a CBA, os custos para o reforço de uma sala de aula são comparados com a redução de danos que resulta do reforço.

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[2] *Delft-FIAT. Flood Impact Assessment Tool provides information on the possible effects of a flood extent: https://publicwiki.deltares.nl/display/DFIAT/Delft-FIAT+Home*

[3] *CIMA and Deltares (2016). Final Report - Development of National Disaster Risk Profiles for Sub-Saharan Africa, Project selection no. 1175393, CIMA – Italy, Deltares, VU-IVM, PRI – The Netherlands*

[4] *Deltares (2017). Mozambique - Coastal Flooding Hazard Assessment, World Bank contract number 7180360, Reference 1230818-000-ZKS-0007*

[5] *CIMA. (2016). Final Report Tropical Cyclone Risks – RISK Computation, Mozambique and Cape Verde, 1230818-000, World Bank contract number 7180360, July. 2017*

[6] *RED and ERN. (2016). Final Report, National Level Earthquake Risk Profiles for Sub-Saharan Africa, Stage 2 Countries; Risk Engineering and Design (RED) and Evaluación de Riesgos Naturales (ERN)*

[7] *ARUP (2017). National-Level Landslide Risk, Profiles for Sub-Saharan Africa, (Stage 2 Countries: Cabo Verde, Malawi, Mali and Mozambique), Ove Arup & Partners International Ltd, Final Report, Job number 245630-10.*

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Resultados

Os Danos Estimados Anualmente (*Annual Expected Damages, AED*) para salas de aula convencionais e não convencionais estão ilustrados, a nível nacional, na tabela abaixo. O dano anual total estimado para Moçambique é de 2.125.000 $/ano para salas de aula convencionais e 39.000 $/ano para salas de aula não convencionais.

Tabela: Danos médios monetários estimados anualmente (salas de aula afetadas) a nível nacional

	Annual expected monetary damages for Mozambique				
	RF [$/year]	**CF [$/year]**	**CW [$/year]**	**EQ [$/year]**	**Total [$/year]**
Conventional classrooms	800,000	900,000	350,000	75,000	2,125,000
Unconventional classrooms	11,000	15,000	11,000	2,000	39,000

Para as salas de aula convencionais, a contribuição mais alta para o dano anual total estimado (ver Figura abaixo) é de inundações costeiras (43%), seguido de inundações fluviais (37%), vento ciclónico (16%) e terramotos (3%). Para salas de aula não convencionais, a contribuição do vento ciclónico é mais significativa e aumenta para 29%. Estima-se ainda que inundações costeiras sejas responsáveis por 36% dos danos anuais, inundações fluviais por 29% e terramotos por 6%.

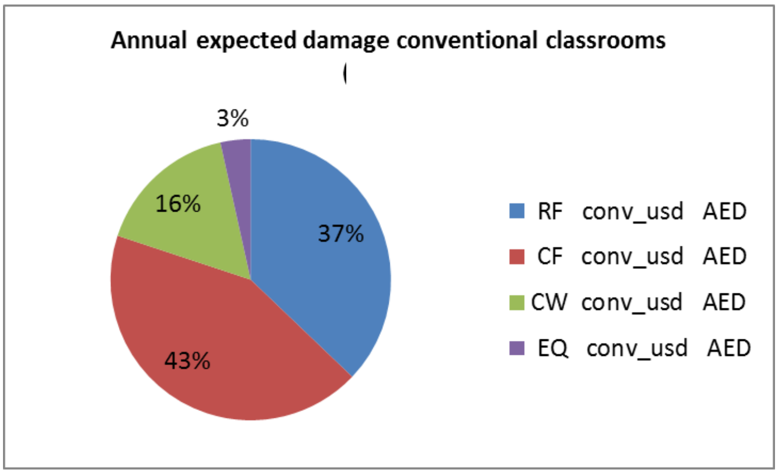

Figura: Dano estimado anual para salas de aula convencionais, distribuição por ameaça natural

Tornar edifícios convencionais completamente à prova de cheias, “impermeabilização *a seco*” (selando a parte da estrutura abaixo do nível de inundação e fechando as portas e janelas com válvulas permanentes ou removíveis) foi proposta como solução de reforço RF1 em caso de inundações fluviais ou costeiras. O reforço de edifícios convencionais para ciclones foi proposta em 3 níveis diferentes: melhorando a conexão entre parede, quadro e telhado e incluindo fixações adicionais para a cobertura do telhado e para a estrutura do telhado (RF2); Além do anterior, colocando pilares para apoiar a extensão do telhado (RF3); e, finalmente, além do anterior, fortalecendo e protegendo portas e janelas introduzindo vigas e coberturas protectoras (RF4). O reforço do edifício contra terramotos (estrutura de telhado e parede) foi proposto como solução de reforço (RF5) para edifícios convencionais em caso de terramotos. Para edifícios não convencionais, recomenda-se a substituição de edifícios escolares.

Os custos das várias soluções de reforço são apresentados na tabela abaixo.

Tabela: Custos para as diferentes soluções de reforço (“*retro-fitting*”).

Soluções de reforço	**Custo por sala de aula (USD)**
1. *Tornar edifícios completamente à prova de cheias, “a seco” (RF1)*	443
2. *Telhado reforçado para ventos ciclónicos (RF2)*	677
3. *Telhado reforçado extra, com pilares e extensões (RF3)*	2.375
4. *Telhado reforçado extra, e com reforço portas e janelas (RF4)*	2.760
5. *Reforço sísmico para edifícios convencionais (RF5)*	3.584

Para a CBA (Análise Custo-Benefício), é utilizado um valor de dano máximo para salas convencionais de 575 $\$/m^2$. Com base em funções de vulnerabilidade ajustadas para as diferentes ameaças e níveis de perigo, os danos ajustados foram calculados para inundações, vento e terramotos. Os danos calculados são combinados para determinar os Danos Estimados Anualmente (AED), incluindo a exposição ao desastre natural específica para cada sala de aula individual. Os AED calculados por sala de aula são usado para determinar a viabilidade económica para as diferentes soluções de reforço.

Os resultados da CBA mostram que o reforço que torna edifícios convencionais completamente à prova de enchentes (*a seco*) é economicamente viável para todas as salas de aula, pois os benefícios para salas velhas (com cerca de 12.5 anos de uso previsto) e para salas novas (com cerca de 25 anos de uso previsto) são maiores do que os custos estimados para o reforço da sala de aula. Também a opção com telhado reforçado para vento é sempre viável para todas as salas de aula expostas. No entanto, nenhuma das outras soluções de reforço é economicamente viável, porque para todas as outras soluções de reforço os custos reforço são superiores aos benefícios obtidos. Apenas na província de Inhambane, a solução de reforço RF3 (telhado totalmente reforçado) é economicamente viável para salas de aula mais novas.

Conclusões

Neste estudo a Deltares procurou quantificar o risco de ameaças naturais para o sector escolar em Moçambique através de uma avaliação de risco a múltiplas ameaças. As actividades do projecto consistiram em: (i) avaliação de risco a sismos, inundações costeiras e fluviais, ventos ciclónicos e deslizamentos de terra; (ii) a identificação de soluções de

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reforço para proteger as escolas para cada tipologia de construção identificada e a estimativa de custos e benefícios de opções selecionadas; (iii) a consciencialização sobre a importância de aumentar a resiliência das escolas.

Informação sobre as ameaça naturais, exposição e vulnerabilidade estava disponível em estudos anteriores. A avaliação de risco a múltiplas ameaças naturaisfoi feita com o modelo Delft-FIAT. A análise custo-benefício das soluções de reforço mostra que o reforço para redução dos danos causados pelo risco de inundação é economicamente viável, pois as salas de aula propensas a inundações podem ser facilmente identificadas. No entanto, a identificação de salas de aula para reforço contra ventos ciclónicos é mais difícil. Apenas uma solução de reforço contra efeitos de ventos ciclónicos através do reforço do telhado é economicamente viável. Para terramotos, não há motivos económicos para o reforço dos edifícios escolares.

O estudo mostrou que a nível nacional, anualmente cerca de 57,000 alunos são afectados e 540 salas danificadas por ameaças naturais. Concluiu-se que o dano estimado anual é de 2.125.000 $/ano e de 39.000 $/ano para salas convencionais e não-convencionais, respectivamente, e que o custo estimado para as soluções de reforço economicamente viáveis seria de US$ 28.1 milhões.

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Executive summary

Introduction

Mozambique is a country threatened by several natural hazards, the most frequent of which are droughts, floods and tropical cyclones. Irregular and limited rainfall results in water scarcity. Floods and cyclones are recurrent hazards that severely impact infrastructure, services and the economy. Mozambique is also at risk of earthquakes due to its location at the intersection of the African Nubian plate on the west and the African Somalia plate on the east.

Due to inadequate design, poor construction quality, as well as inappropriate location and orientation, school buildings are highly vulnerable to the combined effects of flooding, wind and earthquake hazards. It is estimated that more than 70 percent of schools in Mozambique are in high-risk areas for one or more hazards (UN-Habitat, 2015)[8].

The World Bank / Global Facility for Disaster Reduction and Recovery (GFDRR) launched the Global Program for Safer Schools, with the aim of the program is to make school facilities, and the communities they serve, more resilient to natural hazards. Launched in July 2012, the Safe Schools initiative in Mozambique was created in response to the severe flooding which affected more than 1,000 classrooms in the provinces of Maputo, Gaza and Zambézia. The main objective of the initiative is to develop disaster resilient school building guidelines on school safety and to produce recommendations for their effective implementation.

As part of the Safe Schools initiative and following other programmes and projects, in this study Deltares performed a multi-hazard risk assessment (seismic hazard (EQ), coastal flooding (CF), river flooding (RF), cyclones (CW) and landslides (LS)) of the school infrastructure, and a cost-benefit analysis of retrofitting options has been also conducted for each identified building typology. As part of the verification of retrofitting options, Consultec's engineers visited 22 schools during the study.

Methods

The UN Habitat's classification of either *Conventional* or *Non-Conventional* building types has been followed to classify schools and to assign the best available vulnerability functions for each hazard. The conventional classrooms are the ones built with cement and bricks, while the non-conventional Classrooms are built with local materials such as maticado, pau-a-pique (wattle and daub) and others.

Field surveys of 22 schools were carried out primarily to assess the vulnerability of school buildings with regard to seismic hazard (EQ), coastal flooding (CF), river flooding (RF), cyclones (CW) and landslides (LS). During the surveys, a set of recurrent problematic issues

[8] *UN-Habitat. (2015). Safer Schools Project in Mozambique "Developing Guidelines in School Safety and Resilient School Building Codes in Mozambique", Ministry of Education and Human Development (MINEDH), Project Financing World Bank – Global Fund for Disaster Risk Reductions, Maputo, January 2015*

in the school buildings has been identified, providing evidence of the inadequacy of the school construction models currently applied in Mozambique when related to the existing risk profiles of the areas visited.

The risk assessment has been carried out using the Delft-FIAT[9] model, which calculates the impacts of a hazard and expresses them in either monetary values or number of affected entities. In this study, risk is described as the product of hazard, exposure and vulnerability. The hazard intensity is considered for different return periods, for current climate and if available for future climate scenarios. The exposure data consists of the spatial information on the available school buildings, together with a description of their attributes: type of school, building material, number of pupils, etc. Finally, the vulnerability is expressed using damage functions for each damage category and information on maximum damages (stock values) per object type, i.e. replacement costs. Hazard, exposure and vulnerability information is available to a large extent from previous studies, e.g. CIMA and Deltares (2016)[10], Deltares (2017)[11], CIMA (2016)[12], RED and ERN (2016)[13],[14] ARUP (2017).

In this study, only retrofitting options for conventional buildings are considered, consisting of upgrading the existing building for increasing the resistance against natural hazards. This is done through technical interventions in the structural system of a building for optimization of the strength, ductility and load capacity.

In order to determine the economic rationale of the retrofitting options a cost-benefit analysis (CBA) of the retrofitting options has been conducted. For the CBA the differences in risks between the original and retrofitted classrooms are calculated based on the adjusted vulnerability curves. For the CBA the costs for retrofitting of a classroom is compared to the reduction in damages that is the effect of the retrofitting.

Results

The annual expected damage for conventional and unconventional classrooms is illustrated at national level in the table below. The total annual expected damage for Mozambique is 2,125,000 $/year for conventional classrooms and 39,000 $/year for unconventional classrooms.

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[9] *Delft-FIAT. Flood Impact Assessment Tool provides information on the possible effects of a flood extent: https://publicwiki.deltares.nl/display/DFIAT/Delft-FIAT+Home*

[10] *CIMA and Deltares (2016). Final Report - Development of National Disaster Risk Profiles for Sub-Saharan Africa, Project selection no. 1175393, CIMA – Italy, Deltares, VU-IVM, PRI – The Netherlands*

[11] *Deltares (2017). Mozambique - Coastal Flooding Hazard Assessment, World Bank contract number 7180360, Reference 1230818-000-ZKS-0007*

[12] *CIMA. (2016). Final Report Tropical Cyclone Risks – RISK Computation, Mozambique and Cape Verde, 1230818-000, World Bank contract number 7180360, July. 2017*

[13] *RED and ERN. (2016). Final Report, National Level Earthquake Risk Profiles for Sub-Saharan Africa, Stage 2 Countries:; Risk Engineering and Design (RED) and Evaluación de Riesgos Naturales (ERN)*

[14] *ARUP (2017). National-Level Landslide Risk, Profiles for Sub-Saharan Africa, (Stage 2 Countries: Cabo Verde, Malawi, Mali and Mozambique), Ove Arup & Partners International Ltd, Final Report, Job number 245630-10.*

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Table: Annual expected monetary damages of affected classrooms at national level

	Annual expected monetary damages for Mozambique				
	RF [$/year]	**CF [$/year]**	**CW [$/year]**	**EQ [$/year]**	**Total [$/year]**
Conventional classrooms	800,000	900,000	350,000	75,000	2,125,000
Unconventional classrooms	11,000	15,000	11,000	2,000	39,000

For conventional classrooms, the highest contribution to the total annual expected damage (see Figure below) is from coastal flooding (43%), followed by river flooding (37%), cyclone wind (16%) and earthquakes (3%). For unconventional classrooms, the contribution of cyclone wind is more significant and increases to 29%. Further, it is estimated that the coastal flood is responsible for 36% of the annual damages, the riverine flood for 29% and the earthquakes for 6%.

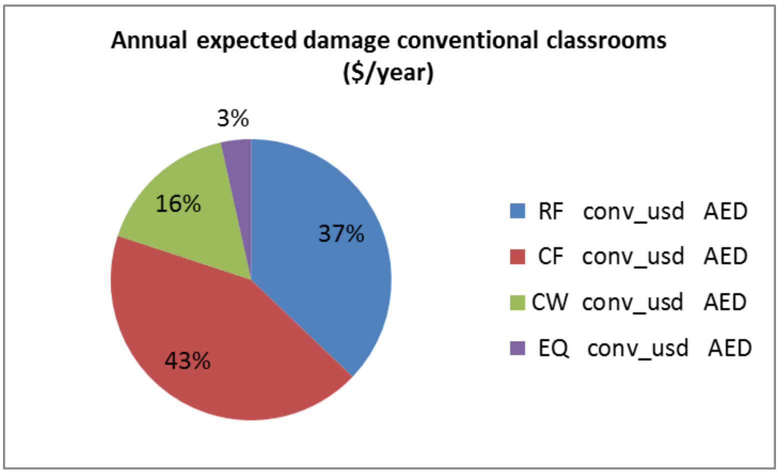

Figure: Annual expected damage for conventional classrooms, hazard distribution

Dry flood proofing (i.e. by sealing the portion of structure below flood level, and by closing of the doors and windows, etc. with permanent or removable vales) has been proposed as the retrofitting option (RF1) for conventional buildings in case of riverine and coastal flooding. Retrofitting of conventional buildings for cyclones has been proposed in 3 different levels: by improving connection between wall, frame and roof and including additional fixations for the roof cover and for the roof frame (RF2); in addition to the previous, by placing pillars to support roof extension (RF3); and finally, in addition to the previous by strengthening and protecting doors and windows introducing protective beams and covers (RF4). Earthquake-proof reinforcement of the building (roof and wall structure) has been proposed as the retrofitting option (RF5) for conventional buildings in case of earthquakes. For non-conventional buildings, substitution of school buildings is recommended.

The costs for the retrofitting options are presented in the table below.

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Table: Costs for the different retrofitting options

Retrofitting options	**Costs per classroom (USD)**
1. *Dry flood proofing (RF1)*	443
2. *Retrofitted roof (RF2)*	677
3. *Fully retrofitted roof (RF3)*	2.375
4. *Fully retrofitted buildings (RF4)*	2.760
5. *Earthquake-proof reinforcement of building (RF5)*	3.584

For the CBA, a stock value for conventional classrooms of 575 $/m2 is used. Based on adjusted vulnerability functions for the different hazards and hazard levels, adjusted damages have been calculated for floods, wind and earthquakes. The calculated damages are combined to determine the Annual Expected Damages (AED) by including the actual hazard exposure for each individual classroom. In this way the calculated AED per classroom is used to determine the economic feasibility for the different retrofitting options.

The CBA results show that retrofitting with dry proofing of classrooms for floods is economically feasible for all classrooms, as both the low (12.5 years) and high (25 years) benefits are higher than the estimated costs for retrofitting of the classroom. Also the option with retrofitted roof for wind is always feasible for all exposed classrooms. However, none of the other retrofitting options are economically feasible, as for all of the other retrofitting options the costs for retrofitting are higher than the obtained benefits. Only for Inhambane province retrofitting option RF3 (fully retrofitted roof) is economically feasible for newer classrooms.

Conclusions

In this study Deltares quantifies the risk to the school sector in Mozambique through a multi-hazard disaster risk assessment of school infrastructure. Activities consisted of: (i) a multi-hazard risk assessment with regard to seismic hazard, coastal flooding, riverine flooding, cyclone winds and landslides; (ii) the identification of retrofitting options to protect schools from natural hazards for each identified building typology, and the estimation of costs and benefits of selected options; (iii) awareness raising about the importance of enhancing the resilience of safer schools.

In this project, hazard, exposure and vulnerability information is available from previous studies. The execution of the multi-hazard risk assessment is done with the Delft-FIAT model. The cost-benefit analysis of the retrofitting options shows that retrofitting for reduction of the damages from flood risk is economically feasible, as classrooms prone to flooding can be easily identified. However, identifying classrooms for wind retrofitting is much more difficult. Only one option for retrofitting against wind hazard by reinforcement of the roof is economically feasible. All other retrofitting options are not economically viable, unless exposed classrooms can be more precisely identified. For earthquakes there is no economic rationale for retrofitting of the buildings as the risk is very low.

This study shows that at national level, every year about 57,000 pupils are affected and 540 classrooms are damaged by natural hazards, and that the annual expected damage is

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estimated to be 2,125,000 $/year and 39,000 $/year for conventional and unconventional classrooms, respectively. The cost to implement the economically viable retrofitting options was estimated at USD 28.1 million.

Contents

Appendices

1 Introduction

Mozambique is a country threatened by several natural hazards, the most frequent of which are droughts, floods and tropical cyclones. Irregular and limited rainfall results in water scarcity. Floods and cyclones are recurrent hazards that severely impact infrastructure, services and the economy. Mozambique is also at risk of earthquakes due to its location at the intersection of the African Nubian plate on the west and the African Somalia plate on the east, at the southern end of the East African Rift, which is the source of many major African earthquakes.

Due to inadequate design, poor construction quality, as well as inappropriate location and orientation, school buildings are highly vulnerable to the combined effects of flooding, wind and earthquake hazards. It is estimated that more than 70 percent of schools in Mozambique are in high-risk areas for one or more hazards (UN-Habitat, 2015).

To address the issue of school safety globally, the World Bank / Global Facility for Disaster Reduction and Recovery (GFDRR) launched the Global Program for Safer Schools. The aim of the program is to make school facilities, and the communities they serve, more resilient to natural hazards. The Program's development objective is to save lives, reduce the physical impact of disasters on school infrastructure, and minimize the negative educational outcomes caused by natural disasters.

Significant progress has been made in supporting the Government of Mozambique to better understand the drivers of disaster risk and to develop tools for resilience increase in the education sector. Launched in July 2012, the Safe Schools initiative was created in response to the severe flooding which affected more than 1,000 classrooms in the provinces of Maputo, Gaza and Zambézia. The main objective of the initiative is to develop disaster resilient school building guidelines on school safety and to produce recommendations for their effective implementation.

As part of the Safe Schools initiative and following other programmes and projects, the World Bank / GFDRR has given an assignment to Deltares to better understand the disaster risk to the school sector in Mozambique through a multi-hazard (seismic hazard (EQ), coastal flooding (CF), river flooding (RF), cyclones (CW) and landslides (LS)) disaster risk assessment of the school infrastructure. A cost-benefit analysis of retrofitting options should also be conducted for each identified building typology.

This report presents the results of the risk assessment and the cost-benefit analysis of retrofitting options. Chapter 2 discusses the specific objectives of the project. Chapter 3 provides details of the surveys done during 22 school visits. Chapters 4, 5, 6 and 7 detail the methodology and results for the main components of the project, respectively, i.e. for the risk assessment, the cost-benefit analysis, the analysis of representative events and the outreach component. Chapter 8 concludes the report.

2 Project objectives

The main objective of the project is to improve the understanding of the risk to the school sector in Mozambique, through a multi-hazard disaster risk assessment of the school infrastructure. Further on, this study aims to inform about retrofitting options to protect schools from natural hazards for each identified building typology.

More specific, the project objectives are:
1. To identify school typologies that require retrofitting, with regard to seismic hazard (EQ), coastal flooding (CF), river flooding (RF), cyclones (CW) and landslides (LS) affecting the school sector on a national level;
2. To assess the risk to the school sector, for multiple hazards as listed above, and for current climate and under climate change projections;
3. To identify retrofitting options and to inform about the associated costs;
4. To raise awareness about the importance of, and build capacity on enhancing the resilience of safer schools.

As part of the inception phase, a school building assessment was carried out, to support the activities conducted to address the objective 1. Moreover, the project has been structured with three other distinct components, which are the multi-hazard and risk assessment of school infrastructure, the cost-benefit analysis of retrofitting options, and the training and outreach components, to address the objectives 2 to 4, respectively.

In order to perform successfully the activities, and more especially to have access to local knowledge, and carry out school surveys in Mozambique, Deltares was supported by Consultec, a Mozambican private company providing consultancy in engineering and environment.

3 School building assessment

3.1 Purpose

Field surveys were planned primarily to assess the vulnerability of school buildings with regard to seismic hazard (EQ), coastal flooding (CF), river flooding (RF), cyclones (CW) and landslides (LS).

For this assignment, the UN Habitat's classification of either Conventional or Non-Conventional building types has been followed to classify schools and to assign the best available vulnerability functions for each hazard. The surveys could be therefore used to confirm or disprove a school classification based on two main building typologies: conventional, or local/traditional.

During the surveys, a set of recurrent problematic issues in the school buildings could possibly be identified, which may provide evidence of the inadequacy of the school construction models currently applied in Mozambique when related to the existing risk profiles of the areas visited. On the other hand, best practices of school construction adapted to specific hazards may also be identified.

When combined with desk studies, these surveys finally help in identifying adequate retrofitting options to protect schools from natural hazards for each identified building typology.

3.2 Visit planning

The list of schools to be visited has been discussed with the DIEE (Direction of Infra-structures and School Equipment), a Department/National Direction from the Ministry of Education and Human Development (MINEDH).

A selection of 22 schools has been made from the following provinces:
- Maputo province with proposed Namaacha, Marracuene and Manhiça districts, for the visit of 6 schools in total,
- Gaza province with proposed Xai-Xai, Chokwé and Guijá districts, for the visit of 5 schools in total,
- Inhambane province with proposed Inhambane city, and districts along the coastal stretch, for the visit of 4 schools in total,
- Manica province with proposed Chimoio City and Gondolas district, for the visit of 7 schools in total.

This selection is based on the following criteria:
- Populated provinces and easy access (Maputo)
- Districts subject to flooding (Manhiça, Chokwe,Guijá)
- Province subject to cyclones (Inhambane)
- Province subject to seismic activity (Manica)

In addition, a selection of schools with conventional and non-conventional building types has been made, resulting in the visit of 15 conventional schools, 3 non-conventional ones and 4 mixed constructions.

In each province, the schools have been selected given a relatively good access to it (paved or tar road in good conditions) and a short distance from the capital of the province, in order to shorten the duration of the surveying activity. In total, 22 school visits have been performed given the project timeline and available budget.

Finally, it should be noted that a sample of 22 schools represents about 0.1% of the total number of schools in Mozambique. As such, the visited schools should not be considered as representative of the school building condition at national level.

3.3 Surveys

The school visits and surveys took place from 23rd October to 3rd November 2017. Before each visit Consultec contacted the provincial directors, to guarantee proper communication at the districts levels. For each school visit, a member of the provincial or district education directorate joined the survey team. In some cases, the provincial education director was even present.

As complementary information, it should be noted that the UN-Habitat's assessment (UN-Habitat, 2015) considered in a quite detailed manner a set of components of classroom buildings that directly influence the sensibility of schools, contributing to the increase or decrease of the vulnerability of schools and consequently affecting risk. These components are listed below (UN-Habitat, 2015):

1. Location of the building or deployment - Orientation of buildings, physical characteristics of the land.
2. Foundation or base of the building - Elevation pavement, pavement quality.
3. Structure of Building and Walls - Distancing between the pillars, material type closure (blocks, bricks, poles, maticado, etc) and condition, dimensions of the structure- this construction materials were further organized to classify the classrooms in 2 typologies that could allow a comprehensive risk assessment: Conventional and Non-Conventional Classrooms.
4. Structure of coverage - type structure, conservation and treatment of roof structure, linking the various elements of the roof structure and strengthening of linkages.
5. Coverage - Storage conditions of coverage, thickness of the cover plate, fixing of roofing sheets.
6. Windows, Doors and Openings - Existence of Frames in vain, frames quality, accessories and operationalization of the frames.
7. Capture System and Water Storage - Existence of a system to capture and store rainwater, operationalization of these systems and the elements that comprise these systems as cover, gutter and tanks.

Obviously, the seven components listed above are less technically sound (and more sensitive to hazards) in non-conventional classrooms, largely due to the lack of technical capacity and observance of techniques and norms that can improve resistance to hazards (UN-Habitat, 2015).

The surveys carried out in the present study aimed at collecting similar type of information in order to be complementary and not contrast too drastically from the existing and available information.

The assessment data have been collected according to a template including:
- General aspects of the school,
- Quantities (buildings, classrooms, areas),
- Topographical conditions of the school location,
- Preparedness and response characteristics to disasters,
- Existing infrastructure,
- Type of building materials (for foundations, roof, walls),
- Suggestions for safety upgrading options,
- And pictures.

The survey reports are presented in Appendix A.

3.4 Main findings

Despite a selection made to ensure the visit of schools prone to all hazards, it should be noted that, based on the information collected regarding the experienced past event, the 22 visited schools are located in cyclones and strong local wind storms-prone areas as well as in riverine floods-prone areas.

During the field assessment, the main common shortcomings identified among the inspected buildings are linked to four areas that are often highly overlooked by local builders and communities that use local material for classrooms:
1. Under-design. Detailed design was not available for any visited school. In addition, the visual inspection usually highlighted that the structural elements are under designed, with incorrect dimensions/sizes regarding the anticyclone construction techniques. The usual and accepted rules for building are usually not used in the design.
2. Quality of execution. There is a lack of skill to build roofs and to install sheets. It seems that the local contractors are not following the supplier instructions.
3. Poor quality of the material used, especially for the walls, roofs, etc. The sheet thickness is usually less than the estimated 0,6 mm.
4. Lack of a perimeter beam, not allowing a proper fixing of roof elements

Schools visited in cyclone hazard areas:
In general, all the schools visited in the cyclone hazard area need the roof to be reinstalled, including structural frames and sheets. In some cases, there is no guarantee that, if reinstalling properly the roof, damages will be avoided in the future. It may be assumed that the construction quality, at foundation level, is not of high standard either.

Schools visited in flood prone areas:
Some of the visited schools are located in areas prone to flooding. In most of the cases, retrofitting options seem not to be an efficient risk reduction solution. For the existing schools, to build a safe point (at least one floor high) seems to be a more plausible solution to mitigate the present problem. This safe point would be used to keep any valuable equipment (computers, copy machines, etc.) and important documents (books, grades, etc.). New buildings and school complexes should be located at the highest point of the village, similar to other public buildings (e.g. hospital, governmental services building, etc.), and/or to be built on a high platform.

Non-conventional schools

The non-conventional schools that have been visited do not have the conditions to withstand a cyclone nor a flood of significant level. In some cases, a few buildings have not even been repaired after the last cyclone or strong wind, and the community is currently building additional non-conventional classrooms due to a lack of roof-covered classrooms. It is however not expected that these more recent buildings would withstand the next cyclone event.

4 Multi-hazard and risk assessment for schools

This chapter describes the steps taken in the multi hazard risk assessment. The first step of the analysis consists of the preparation of the already available hazard, exposure and vulnerability data to obtain a consistent data set (section 4.2). This information is used as input for the Delft-FIAT model, which calculates the impacts of a hazard and expresses them in either monetary values or number of affected entities (section 4.3). The results of the analysis are first presented at national level, by relating different hazards to each other (section 4.4.1). Sections 4.4.2 to 4.4.5 describe the results for each hazard individually. In the following sections, the risk assessment for each hazard is individually described. However, it is important to be aware that the impacts of cyclone wind, coastal flood and possible river floods may occur simultaneously. This aspect has direct influence when investments are being considered for schools upgrade: such investments should be designed to assure resilience to multiple hazards simultaneously.

4.1 Introduction

Risk is generally described as the product of hazard, exposure and vulnerability (see Figure 4.1), and is often expressed in monetary terms.

- The hazard is defined as the probability and magnitude of an event that causes negative impacts (IPCC, 2012).
- Exposure refers to the elements or assets that could potentially be adversely affected by the hazard, due to their location within the hazard prone area. Exposure can include for example people, objects, infrastructure and the overall economy, as well as intangible assets such as environmental resources or ecosystems and cultural or social assets (IPCC, 2012).
- Vulnerability is determined by estimating to what degree the exposed assets are affected or damaged by a certain hazard characteristic, for instance the water depth. The vulnerability or degree of damage can vary according to the composition or material of the exposed assets (e.g. building material of different building types). We note that other factors can have an influence on the vulnerability, for example the awareness and preparedness of people living in hazard prone areas (Messner et al., 2007).

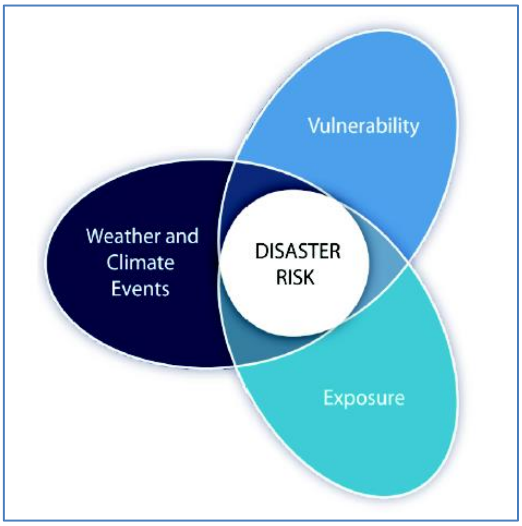


Figure 4.1 Concept of risk (IPCC, 2012)

Given this definition of risk as a product of hazard, exposure and vulnerability, risk assessment can be divided into four main parts: (1) hazard assessment, (2) the exposure assessment, (3) the vulnerability assessment and (4) the risk assessment, which brings all information together.

The magnitude of the risk may be expressed in multiple forms, which often serve complementary objectives.

- Monetary assessments are useful in planning studies, because they can be related to regional or national development budgets and can be directly used to assess the benefits of flood reduction measures.
- Number of affected entities, such as the number of classrooms affected or the number of pupils studying in flood prone areas can be easier to grasp by communities and non-specialist stakeholders. Also, this type of information is very helpful in emergency situations, when resources need to be allocated in a short time frame, and therefore a quick identification of the zones at high risk is essential.

In this study, both types of risk assessments are performed: monetary and quantitative. For the monetary assessment, a relation is needed that links the level of hazard (for example inundation depth) to the damage level of a classroom type (for example 60% of damage) combined with the estimated monetary value of a classroom. The details of this approach can be found in section 4.2.3.

For the number of affected entities, a definition is needed on the minimum level of hazard for which a classroom is considered affected. This definition is not easy to give, as it is very closely connected to the local situation. For example, for floods, we consider that for an inundation level higher than 30 cm, the pupils are no longer able to walk unaccompanied to and from school; therefore we have chosen this level as the minimum beyond which a classroom is affected. Table 4.9 gives an overview of the thresholds chosen for all hazards considered in this study, together with a motivation of our choice.

4.2 Data sources

The main required inputs for the multi-hazard risk assessment for schools in Mozambique are:

1. **Hazard maps** expressing the hazard intensity for different return periods, if available for current climate and future climate scenarios
2. **Exposure data**: Spatial information on the available school buildings, together with a description of their attributes: type of school, building material, number of pupils, etc.
3. **Vulnerability data**: Damage functions for each damage category and information on maximum damages (stock values) per object type, i.e. replacement costs as well as costs and benefits of retrofitting options.

In this assignment, hazard, exposure and vulnerability information is available to a large extent from previous studies, further listed in Table 4.1.

Table 4.1 Summary hazard input for the impact analysis

Hazard type	Current climate	Future climate (year 2050)	Data availability	Source
RF	Yes	No	Return periods: 25, 50, 100, 200, 500, 1000	CIMA and Deltares (2016)
CF	Yes	Yes	Return periods: 10, 25, 50, 100, 250, 500, 1000	Deltares (2017)
CW	Yes	No	Return periods: 10, 25, 50, 100, 250, 500, 1000	CIMA (2016)
EQ	Yes	No	Return periods: 10, 25, 50, 100, 250, 500, 1000	RED and ERN (2016)
LS (due to earthquakes)	Yes	Yes	5 susceptibility classes	ARUP (2017)
LS (due to rainfall)	Yes	Yes	5 susceptibility classes	ARUP (2017)

4.2.1 Hazards

In this multi-hazard risk assessment, the following hazards are taken into account. In parentheses, an abbreviation is suggested to be used in this report as well as for the implementation in Delft-FIAT:

- river flood (RF)
- coastal flood (CF)
- earthquake (EQ)
- cyclones wind (CW)
- landslide (LS)

4.2.1.1 Hazard river flooding (RF)

The river flood hazard has been calculated within the R5 project, using the GAR model framework. The hazard data has a resolution of 90 m, and is available starting from a return period equal to 25. Figure 4.2 illustrates the flood extent for the return period equal to 100 (RP 100).

Another option of river hazard data would have been the data from the GLOFRIS framework (Global Flood Risks with IMAGE Scenarios) (Winsemius, 2013). However, the GLOFRIS framework estimates the flood hazard at a resolution of ~ 1 km^2, which is much coarser than the flood hazard calculated using the GAR model. For that reason, the GAR model results have been used for the classroom impact assessment in Mozambique.

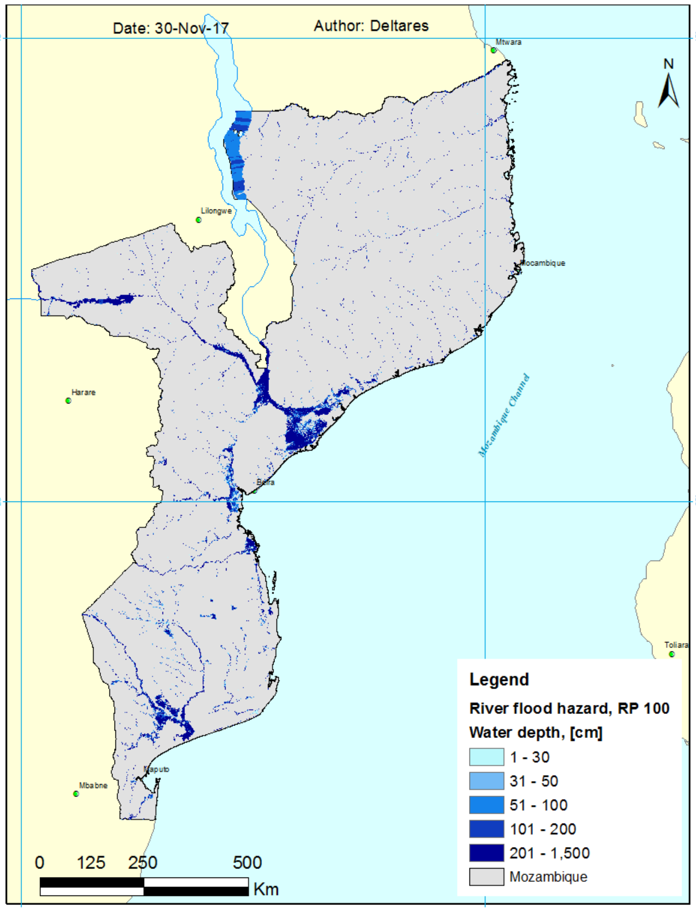


Figure 4.2 River flooding hazard for RP 100

4.2.1.2 Hazard coastal flooding (CF)

Coastal flood hazard is available with a resolution of 90 m for both the current climate (2010) and future climate scenario (2050), based on the climate projection RCP 6.0 (Representative Concentration Pathways) (Fujino, 2006). The dataset provides water depth [m] per grid cell for the return periods of 10, 25, 50, 100, 250, 500, 1000 years. Figure 4.3 illustrates the water depth for the coastal flood hazard for the 100 year return period.

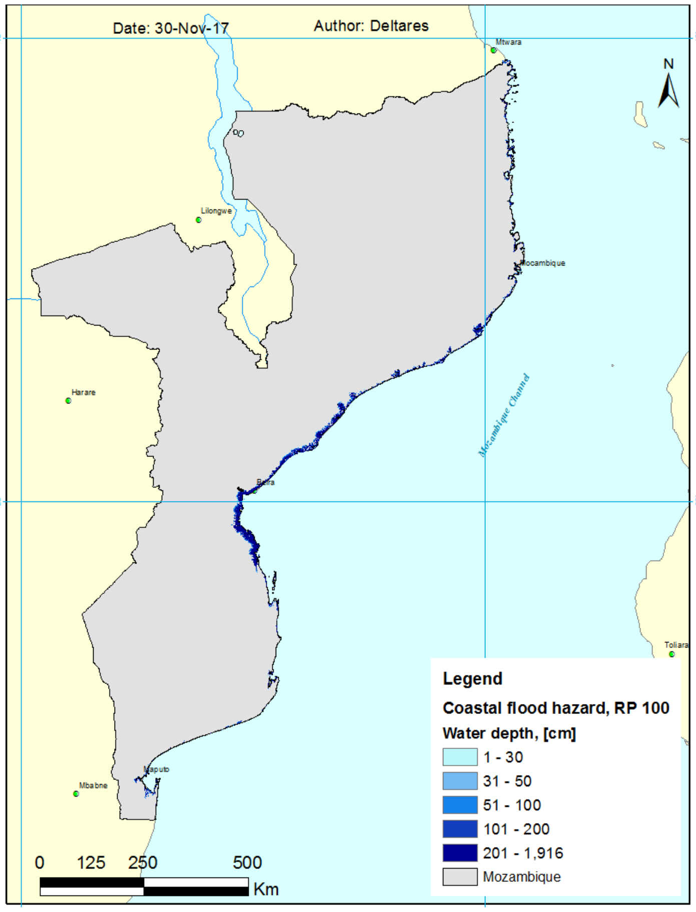


Figure 4.3 Coastal flooding hazard for RP 100

4.2.1.3 Hazard cyclones wind (CW)

The hazard maps for wind are expressed in terms of 10-minutes sustained wind speed, as described in CIMA 2016 (see section 3.7, Table 2).

The resolution of cyclone induced wind speeds is about 5 km. The wind hazard is available for seven return periods [10, 25, 50, 100, 250, 500, 1000] and provided with values ranging from 30 to 50 m/s. For illustration, Figure 4.4 shows the wind hazard for the 100 year return period. The 10-minutes wind input for this return period ranges from 26 to 38 m/s, which is equivalent to a range of 93.6 km/h to 136.8 km/h.

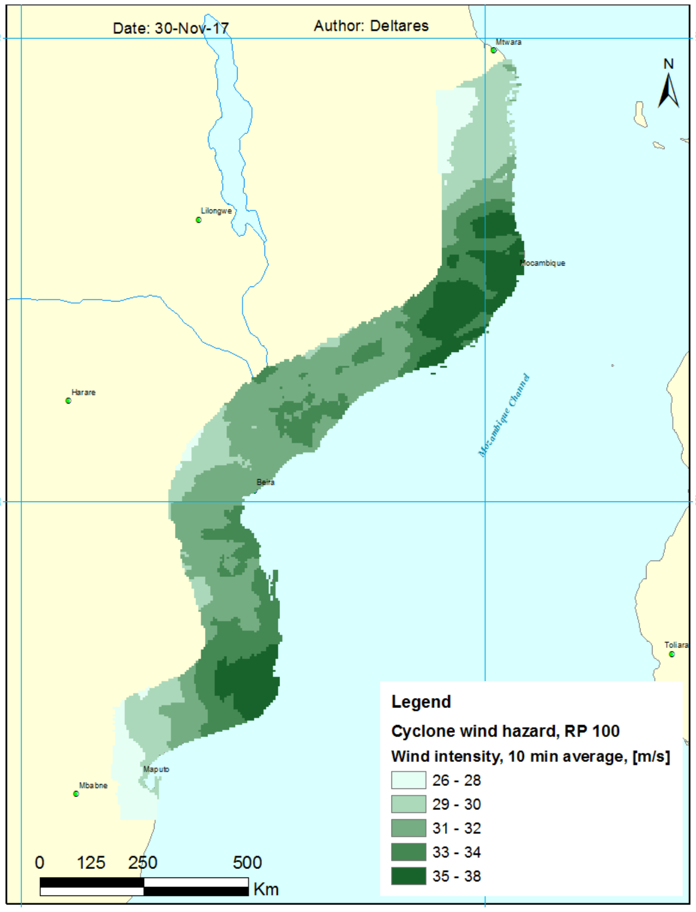


Figure 4.4 Cyclone wind hazard for RP 100

4.2.1.4 *Hazard earthquakes (EQ)*

The earthquake hazard is provided as peak ground acceleration (PGA) with and without so-called side effects, taking local variations of the soil characteristics into account. The earthquake hazard data used for the risk assessment is accounting for side effects. The hazard is provided for different exceedance probabilities, which can be translated to return periods. The abbreviation EP refers to the exceedance probability in a 50 year period, as typically expressed for EQ. The description of this quantity is given in Table 4.2.

Table 4.2 Description naming convention for the exceedance probability (EP) of the earthquake hazard

Exceedance probability (EP)	Description	Return period
0.0488	5% chance of exceedance in 50 years = 1 in 1000 years	1000
0.0952	10% chance of exceedance in 50 years = 1 in 500 years	500
0.1813	18% chance of exceedance in 50 years = 1 in 250 years	250
0.3935	39% chance of exceedance in 50 years = 1 in 100 years	100
0.6321	63% chance of exceedance in 50 years = 1 in 50 years	50
0.8647	86% chance of exceedance in 50 years = 1 in 25 years	25
0.9933	99% chance of exceedance in 50 years = 1 in 10 years	10

For each exceedance probability, eight different spectral periods are available, ranging from 0 to 2 seconds. In this risk assessment, hazard maps are considered for only one spectral period, i.e. SP = 0.2, based on match between the classroom classification of this study and the building classification of ERN (2016) (see Table 3-2 and Figure 4-11 in RED and ERN (2016)). Figure 4.5 illustrates the extent of the earthquake hazard for the 100 year return period. We can see that, for this return period, the hazard is highly localized on a restricted area.

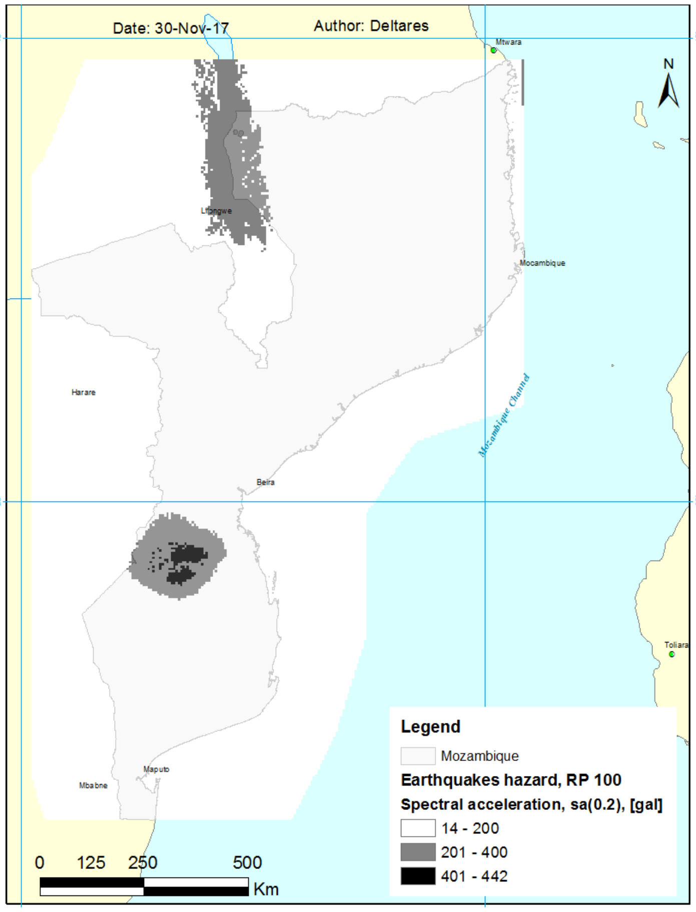


Figure 4.5 Earthquake hazard for RP 100

4.2.1.5 *Hazard landslides (LS)*

Two different types of landslide hazard are provided, 1) induced by earthquakes and 2) induced by rainfall. In comparison with the other hazards, the landslide hazard is not available for different return periods, but it is expressed in susceptibility classes (1-5), described in Table 4.3. Figure 4.6 illustrates the susceptibility classes for the landslides induced by earthquakes.

Table 4.3 Susceptibility classes LS

Hazard classification	Susceptibility class
1	very low
2	low
3	medium
4	high
5	very high

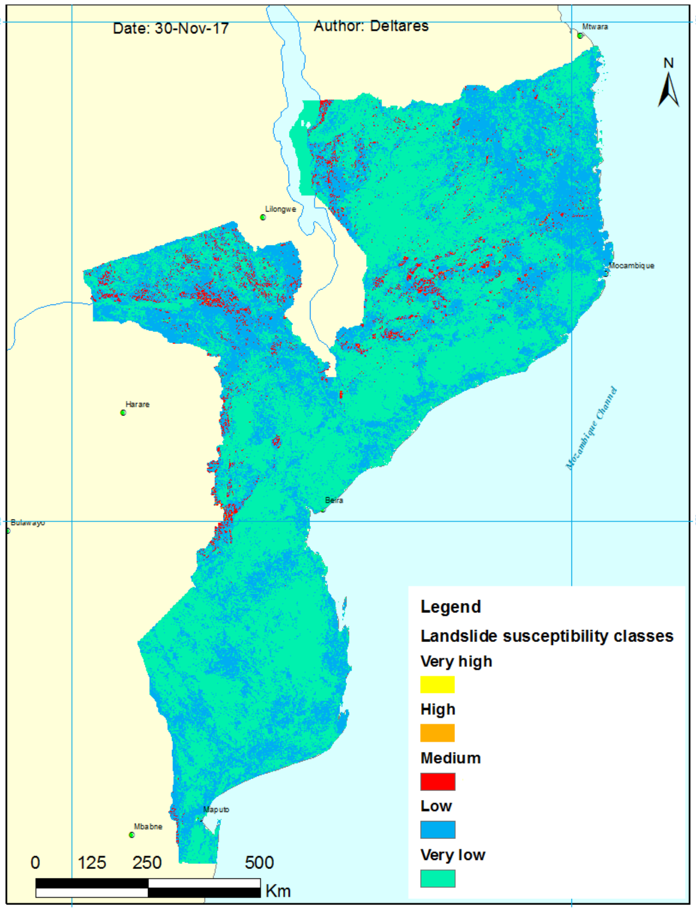


Figure 4.6 Hazard landslides induced by earthquakes

4.2.1.6 Pre-processing of the hazards maps

As a preparation step for the impact analysis, all hazard data was translated into raster files of the same resolution. This was needed in order to assure consistency between the input data for different hazards. As the RF hazard maps have the highest resolution (~ 90 m), this data set was used as reference resolution. Therefore, all the other hazards have been translated to a grid size of ~90 m (0.000833 degrees), with the coordinate system WGS84 EPSG:4326.

4.2.2 Exposure

The exposure data gives information about the location and thus spatial distribution of the classrooms over the country. Furthermore additional attributes such as the size of the footprint, the building and construction type and the number of students for each location are partly available for the risk assessment.

The number of school locations in Mozambique is estimated to be between 10,000 and 12,000. Most often, a school location consists of a multiple buildings on a campus, with different classrooms, often from different building types which respond differently to natural hazards. Because of this difference, the impact assessment within this project will be based on the about 65,000 individual classrooms in Mozambique.

The following three data sets about schools and other educational facilities within Mozambique are provided by the client for the impact analysis:

- Exposure data from the R5 Phase 2 project (Risk Profiles for African Countries, World Bank Selection # 1175393, see Rudari et al, 2017), referred as the R5 dataset
- A dataset from the Safer Schools project (GPSS, 2014); referred as the MINEDH dataset
- A spreadsheet provided by the Ministry of Education and Human Development of Mozambique (MINEDH) during the inception visit; referred as the *revised* MINEDH dataset

In addition, OpenStreetMap (OSM) data was reviewed to identify educational facilities in Mozambique, but it turns out that only 80 schools out of 12,000 are mapped in OSM. Most of these are already covered in the above mentioned datasets. Therefore, OSM is not considered as an additional exposure data source.

All of the above mentioned three datasets contain information about the location (XY coordinates in WGS84), the province (Admin1) and district (Admin2) where the schools are located and the type of school (e.g. primary school).

All three abovementioned datasets are relevant for this assignment. However, as shown in the next section, each dataset has its own limitations. Therefore, the information was merged into a combined dataset in several steps. In Section 4.2.2.4 the procedure is described.

4.2.2.1 Description of the R5 dataset

The R5 dataset maps 8,738 educational facilities (primary, secondary, technical schools) over the entire country. In addition, an average footprint area (m^2) depending on the school type is provided. The information seems to come from the Safer Schools project (presumably the MINEDH dataset as described in Section 4.2.2.2), as stated in the attribute table, as well as a number of data points from OSM. The R5 dataset has the most complete spatial representation for the whole of Mozambique (see Figure 4.7). However, information about building types, number of classrooms and the number of pupils is not available in this dataset.

It is important to emphasize that a cross-check of about 50 entries from the R5 dataset versus aerial imagery has shown that there are entries in the R5 dataset which do not match school locations. Given the limited number of entries reviewed, it is difficult to provide a robust estimate about the accuracy of the dataset. Nevertheless it is assumed that more than 90% of the entries are correct, based on the visual inspection of the data. Moreover, no statement can be made about the completeness of the dataset, but it seems that not all of the 10,000 to 12,000 schools are covered in the dataset.

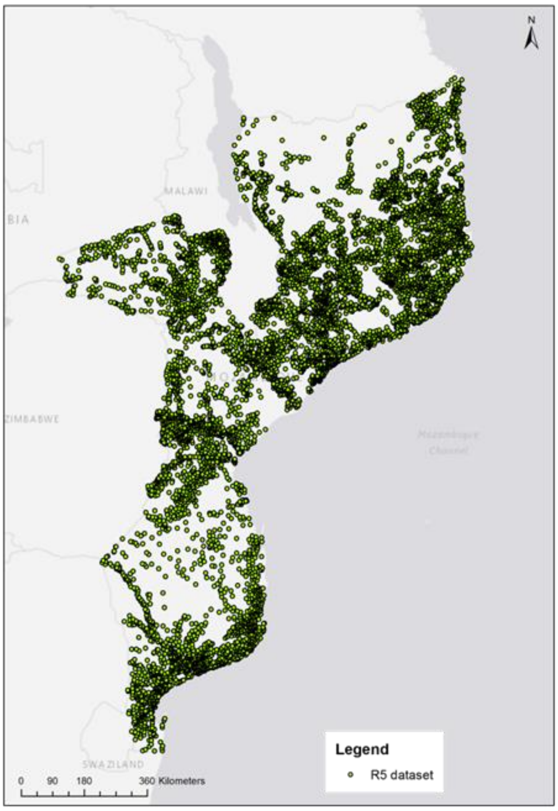


Figure 4.7 Locations of educational facilities from the R5 project

4.2.2.2 Description of the MINEDH dataset

The MINEDH dataset contains spatial information for about 9,600 schools, including XY coordinates, school-ID, number of pupils (total) and (presumably) the distribution of age.

However, for some parts of Mozambique data is missing, there is for example almost no data in the province of Nampula (Figure 4.8). Furthermore, no information on building typology and number of classrooms is available. From the direct comparison with the R5 dataset, the MINEDH dataset contains points in some regions that are not covered by the R5 dataset. From aerial imagery comparison, these points can be verified as valid entries for school complexes.

Figure 4.8 Locations of educational facilities in the MINEDH dataset

4.2.2.3 *Description of the Revised MINEDH dataset*

The revised MINEDH dataset was provided as a spreadsheet, including detailed information for approximately 12,000 schools with respect to XY coordinates (degrees North and East geographical), school-ID, the number of pupils (total), number of classrooms and construction types.

However, more than 7,000 out of the total of 12,000 entries in this dataset do not have XY coordinates, for another 1,500 entries the XY coordinates are flipped (i.e. East and North coordinates are mixed up) and another 1,500 entries do not have valid coordinates due to decimal errors. Overall, in the dataset 2,033 valid entries within the administrative boundaries of Mozambique are left, plus 3,039 where the coordinate information can be corrected.

Nevertheless, with regard to the attributes provided, this dataset it is the most relevant and most recent dataset for this assignment. Therefore, the following numbers given in the revised MINEDH dataset are used as target values for the impact assessment:

- school locations: 12,815
- pupils in Mozambique: 6,783,450
- conventional classrooms: 38,797
- unconventional classrooms: 28,747

Cement and brick buildings (columns cimento and tijolo in the revised MINEDH table) are defined as conventional, whereas unconventional buildings are made from mud, wood and other material (columns maticadas, pau-au-pique and outros).

4.2.2.4 *Merged datasets*

All three datasets are relevant for this assignment. Therefore, the information was merged into a combined dataset in several steps. The technical description in this section is written for other GIS experts to understand the assumptions made and steps taken to generate the exposure information for this assignment.

The revised MINEDH spreadsheet was used as the starting point for the merge of information. This spreadsheet contains 2,033 valid entries. For all other entries, the issues with the coordinates were solved by applying several corrections. The correction steps were carried out for the X and Y coordinates independently, as in most cases the issues affected a single coordinate.

- Correct for switched X/Y coordinates: This was done by switching between the X and Y coordinate.
- Correct for decimal errors: the coordinates need to be between 28 and 42 (decimal degrees northing), or -10 and -27 (decimal degrees easting). This was done by shifting the decimal between 10-1 and 10-10 until the range was valid.
- Correct for +/- issues: For some entries + and – are switched, meaning that the coordinate is X: -40 / Y: 13 instead of X: 40 / Y: -13. This was solved by multiplying the coordinates with -1.

After the corrections, the revised MINEDH dataset contains 5,597 valid entries with 3,060,696 pupils in 19,209 conventional and 12,008 unconventional classrooms. The remaining entries do not have XY coordinates at all and cannot be displayed on spatial basis.

However, the other MINEDH dataset covers additional school locations which were not yet part of the revised MINEDH dataset. Therefore, these locations were identified in GIS, selected and merged with the revised MINEDH dataset. In this way, another 394 valid entries with 125,552 pupils were added. Information about the number of classrooms is not available from this dataset.

It is important to highlight that in the revised MINEDH dataset no difference is made between the school levels (EP1, grades 1-5, and EP2, grades 6-7). Therefore, the amount of entries is lower than in the MINEDH dataset (5,597 compared to 9,482 locations), but the number of pupils is about the same.

The combined MINEDH dataset now covers 3,186,248 pupils in 5,990 schools. However, the combined MIDEDH dataset has the following shortcomings:

(i) For parts of Mozambique, as for example the province of Nampula, the location of classrooms is missing (c.f. Figure 4.8).

(ii) For a significant number of entries there is a structural offset between the school location on the aerial imagery and the coordinates in the combined MINEDH dataset. The comparison was done for about 100 school locations using aerial imagery (c.f. Figure 4.9).

In contrast, the spatial distribution and coverage of the R5 dataset is significantly better than the provisional result in the combined MINEDH dataset. Therefore, in the next step the information was transferred into the R5 dataset, where possible. Figure 4.9 shows for a region a structural offset between the combined MINEDH and the R5 dataset, where R5 shows a significantly better performance for entire regions, based on validation with aerial imagery.

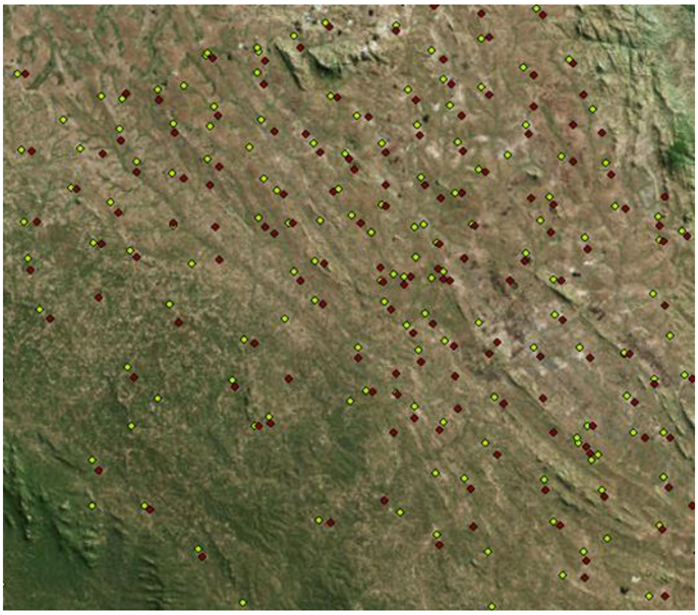


Figure 4.9 Offset between combined MINEDH (purple) and R5 dataset (green).

The transfer was done by means of a 'spatial join' with a search radius of 1,500 meters, which was based on measurements of the offset in several regions. This means that the information from the combined MINEDH dataset was transferred to the R5 dataset, if the distance is not larger than the threshold of 1,500 m. With this method, 2,232,689 pupils in 4,488 schools have been assigned to the R5 dataset.

All other 2,319 schools with a distance of more than 1,500 meters are assumed to be additional locations not yet covered in the R5 dataset. These were merged to the updated R5 dataset, leading to a total of 11,057 schools. This is roughly in line with the 12,815 locations from the revised MINEDH spreadsheet. After this step it was assumed that most school locations in Mozambique are sufficiently covered in the updated R5 dataset.

In the updated R5 dataset, a correction step was required. The spatial match assigned the attributes of the combined MINEDH dataset to several R5 entries, if they fulfil the criteria of being closer than 1,500 meters. This is often the case for larger villages, where the combined MINEDH dataset has one entry and the R5 two entries (Figure 4.10).

The reason of this behaviour can be explained by the fact that the combined MINEDH dataset does not distinguish between different school types, which is however the case in the R5 dataset. In these cases the exact number of multiple entries is identified based on the school-id, and the number of pupils is divided accordingly for each point in order to avoid double-telling.

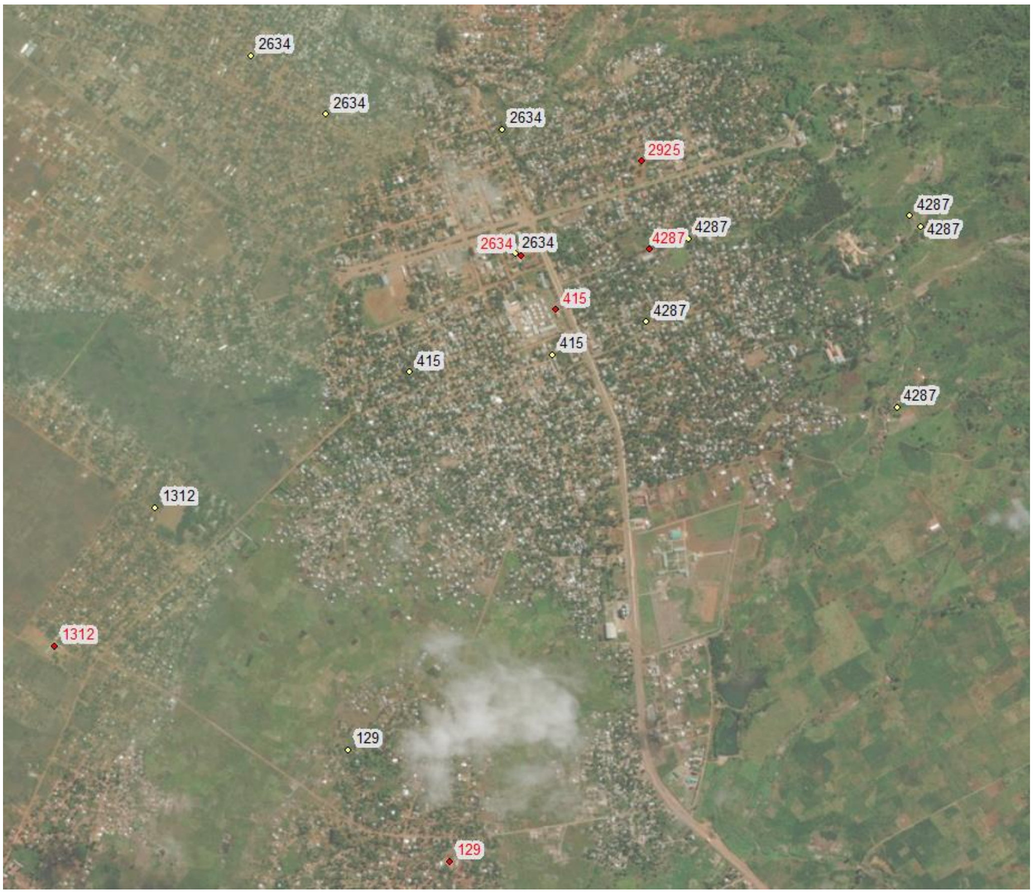


Figure 4.10 Example for both correct and multiple entries after the spatial join. The red points are from the combined MINEDH dataset, yellow points are from the R5 dataset, the label is the number of pupils. In the southern part the join was carried out correctly, while in the northern part several R5 points received the same value.

The very last step of the geoprocessing was the distribution of the remaining number of unassigned pupils and classrooms on the locations which do not yet have a value assigned, based on the target values from the *revised* MINEDH dataset. At this point, the updated R5 dataset covers 2,953,536 pupils assigned to 6,065 out of 11,057 school locations in the dataset, with 10,962 conventional classrooms and 6,872 unconventional classrooms listed.

Table 4.4 lists the calculations to distribute the remaining values to the points without information. There are more points with entries for pupils than entries for classrooms, as the former was merged from the MINEDH dataset. The rounded values are assigned to all points without a value equally.

Table 4.4 Calculation of remaining values

Indicator	Target Value	Covered in dataset	Remaining	Locations without value	Per Location	Rounded value to be assigned
Pupils	6,783,450	2,953,536	3,829,914	4,992	767.2	767
Conventional	38,797	10,962	27,835	7,345	3.79	4
Unconventional	27,747	6,872	21,875	7,345	2.97	3

Figure 4.11 Final dataset with locations of educational facilities for this assignment

Verification of the exposure data

The updated R5 exposure dataset was verified in different ways:

(i) Visual point-by-point assessment with aerial imagery for a limited number of schools,

(ii) Ensured that the total number of schools is in line with the target values from the *revised* MINEDH dataset,

(iii) Ensured that the points are assigned to the correct province, based on the Global Administrative Unit Layers provided by World Bank. This is the case for 99.9% of the points, only 16 points have not been assigned correctly. For 10 points this could be due to different definitions of the boundaries.

Based on this verification, it was concludes that the updated R5 dataset as shown in Figure 4.11 can be seen as the most complete set of information for this assignment, including the number of pupils, classrooms and construction type. Nevertheless, it is important to keep in mind that this dataset is based on a number of assumptions and geo-statistical disaggregation methods as described above, as well as the knowledge that there are still missing entries.

4.2.3 Vulnerability

The vulnerability functions are described in the previous studies listed in Table 4.1. Naturally these vary significantly due to the different damage characteristics of different hazards. In addition it was found that the classification of building typologies varies within the projects, as well as the underlying assumptions about typology distribution and ratios.

For this assignment, the UN Habitat’s classification of either *Conventional* or *Non-Conventional* building types has been followed to classify schools and to assign the best available vulnerability functions for each hazard.

According to the Safer Schools Project, the conventional classrooms are the ones built with cement and bricks, while the non-conventional Classrooms are built with local materials such as maticado, pau-a-pique (wattle and daub) and others. Figure 4.12 illustrates an example of a non-conventional classroom situated in the Manhiça district, Maputo province.

Figure 4.12 Unconventional classroom located in the Manhiça district, Maputo province

The impact assessment also requires stock values, expressed in $/m^2, of the conventional and non-conventional classroom building types and the surface area of the classrooms. Unfortunately, there is not sufficient data for a reliable estimate of this information. Two sources of information have therefore been used: 1) UN Habitat and 2) the representatives of the local education authorities MINEDH. From these two sources, an estimate of the stock values and average classroom size were provided as described in Table 4.5.

Table 4.5 Estimated stock values and average surface area per classroom building typology

	Conventional classroom		**Non-conventional classroom**	
	Stock value ($/m^2)	Average area (m^2)	Stock value ($/m^2)	Average area (m^2)
UN Habitat	500 (up to 650)	56	15	30
MINEDH	550 primary schools 650 secondary schools	56	140 (mixed)	not available

UN Habitat estimates a stock value for conventional classrooms of 500 to 650 $/m^2, while MINEDH provides a value of 550 $/m^2 for primary schools and 650 $/m^2 for secondary schools. For the impact assessment, the value of 575 $/m^2 has been used, which is the average between the values proposed by UN Habitat and sufficiently close to the value estimated by MINEDH.

For non-conventional classrooms, the estimate proposed by UN Habitat has been used, because this follows more closely our definition of fully non-conventional classrooms. Table 4.6 presents the proposed estimates for the stock values and surface area per classroom building typology.

Table 4.6 Combined stock values and average surface area per classroom building typology

	Conventional classroom	Non-conventional classroom
Stock value ($/m^2)	575	15
Average area (m^2)	56	30

4.2.3.1 *Vulnerability riverine flooding (RF)*

The damage functions for the river flood hazard have been directly used from the previous report made by CIMA and Deltares (2016), without additional adjustments. In this report, in section 5.6.3, four different building types are differentiated (based on building material):

1. Non-structured buildings
2. Wood frame buildings
3. Unreinforced masonry/concrete buildings.
4. Reinforced masonry/concrete and steel buildings.

For completion and ease of understanding of this differentiation, the following paragraphs are reproduced from section 5.6.3:

Non-structured buildings *include those constructed of mud or (non-cemented) adobe blocks, and informal buildings. These buildings are assumed to be one floor only.*

Wood frame buildings. *Theoretically, these are far more resilient to collapse as compared to mud or informal buildings. However, when wood frames become wet, they have to be replaced, or finishing needs to be removed for drying (and replaced after).*

Unreinforced masonry/concrete buildings. *These buildings are theoretically more vulnerable than reinforced masonry/concrete buildings. This is related to the fact that unreinforced walls are less able to resist pressure of water exerted on walls. However, damage is assumed to be less than that for wood frame homes as masonry and concrete will need less replacement after being flooded than wood.*

Reinforced masonry/concrete and steel buildings. *These buildings are basically the standard buildings in most western countries and large cities. Overall, they constitute the most resistant class. Many studies show that for these types of buildings vulnerability curves do not go up to 100%, as some elements need not to be replaced after a flood (e.g. foundations, or carrying walls).*

For each of the above building typology, CIMA and Deltares (2016) propose a damage curve as illustrated in Figure 4.13. For the unreinforced and reinforced building types, a second differentiation is made, based on additional building characteristics, such as size and reinforcements (detailed in Table 4.7). This leads to six different damage curves, which needed to be matched to the classrooms categories (conventional and unconventional) within this project.

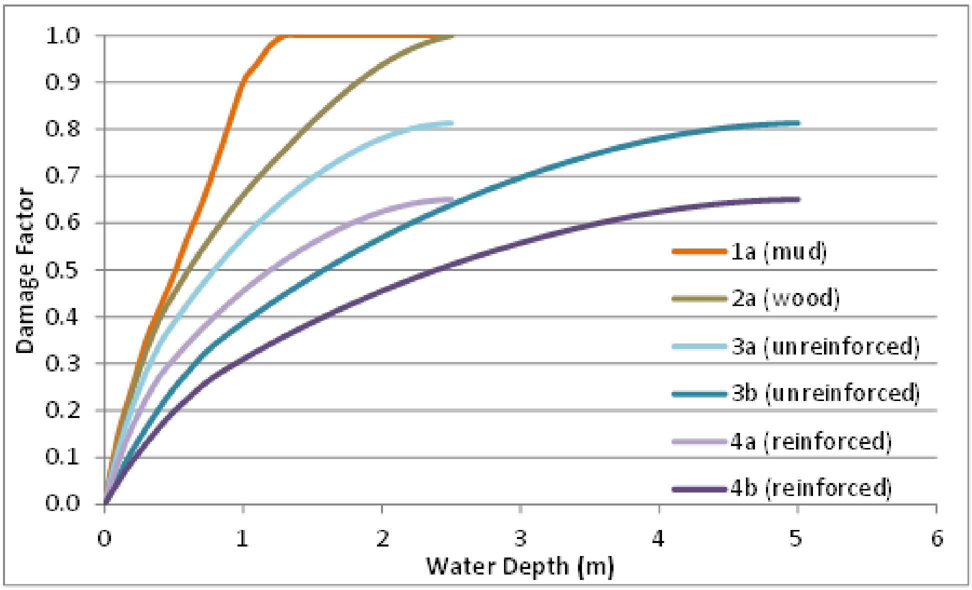


Figure 4.13 Vulnerability curves used for flood loss computation in case of buildings, identical to figure 5.43 in CIMA and Deltares (2016)

Table 4.7 Differentiation building typology identical to table 5.4 in CIMA and Deltares (2016)

Construction building type	**Code**	**Curve #**	**Comment**	**Adjustments value and curve assignment (size dependent)**
Mud Walls	M	1a		None
Adobe Block	A	1a	Non-cemented	None
Informal	INF	1a	Non-structured	None
Wood Frame	W2	2a	Only present in rural areas	None
Unreinf. Fired brick masonry	UFB	3a		None
Unreinf. Concrete block	UCB	3a / 3b	Basically	Size 50 sqm is curve 3a Size > 50 sqm is curve 3b
Reinforced Masonry	RM	4b		None
Low-rise non-ductile RC frame with masonry infill walls	C3L	4b		None
Mid-rise non-ductile RC frame with masonry infill walls	C3M	4b	Large variety in amount of floors	Size < 1000 sqm = 0.5 Size > 1000 sqm = 0.33 Size > 2000 sqm = 0.25 Size > 4000 sqm = 0.2 Size includes number of floors
Low-rise Steel	SL	4a		None
Mid-rise Steel	SM	4	Very rare	0.5

For the unconventional classrooms, which are built with local materials, the ‘2a’ damage curve (brown line in the image above) was used, which is representative of wood construction materials. According to this curve, 1 m of water results in ~65% damage of the classroom, while 2m of water results in ~95% of damage.

For the conventional classrooms, the ‘3b’ damage curve was used. This is partly based on the input received from the local authorities, stating that the average size of the classrooms is 56 m^2 (Table 4.6). Finally, the vulnerability curves for the riverine flood used in this project are illustrated in Figure 4.14, for the two building typologies: conventional and unconventional.

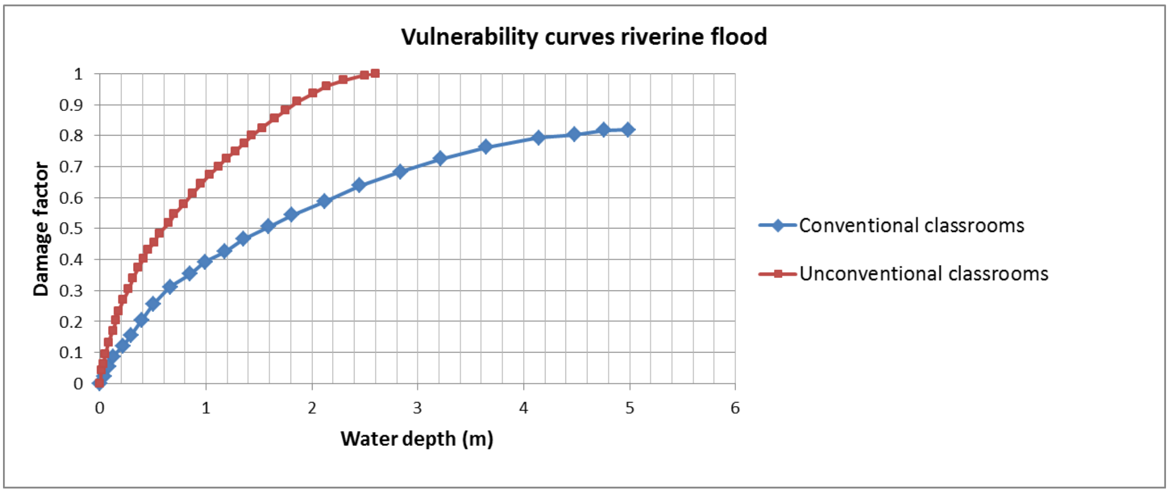


Figure 4.14 Vulnerability functions river flooding

4.2.3.2 Vulnerability coastal flooding (CF)

As reported in section 4.3.1 Storm surge vulnerability in CIMA (2016), there is usually not a strong distinction between vulnerability functions for riverine flooding and vulnerability functions for coastal flooding (caused by cyclone surge). For the coastal flooding, the wave and salinity components may increase the impacts; however, this would mainly affect the constructions very close to the coast line. According to the above mentioned report, such constructions are rare in Mozambique. The same vulnerability functions for coastal flooding will be used as for the river flooding. Damage due to waves is therefore explicitly not taken into account.

4.2.3.3 Vulnerability cyclone wind (CW)

The vulnerability functions for the cyclone wind hazard have been directly used from the report CIMA (2016). In this report, two cyclone wind vulnerability curves are available, for structured and mud/informal buildings, they are reproduced in Figure 4.15. In this study, we make the assumption that the structured buildings are a good proxy for conventional classrooms and that mud/informal buildings are a good proxy for unconventional classrooms.

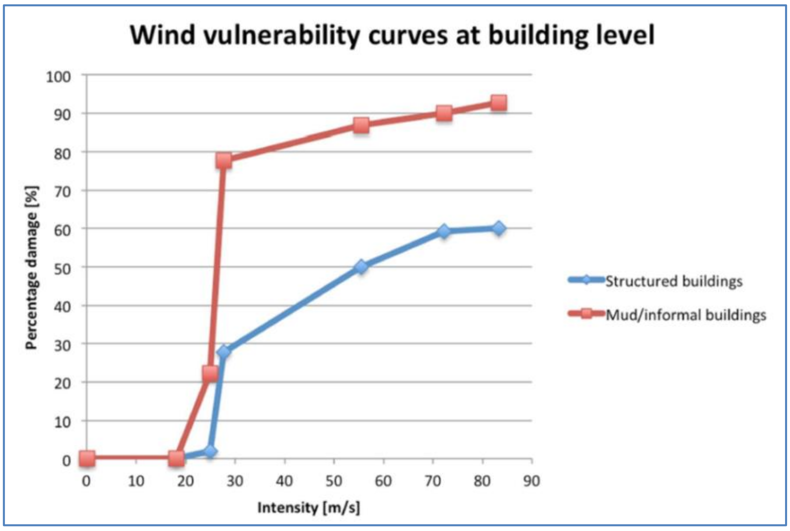


*Figure 4.15 Wind vulnerability curve (asset level) for informal buildings and structured buildings. The independent variable here is the **max gust win 3-sec sustained**. (Figure identical to Figure 7 in CIMA, 2016).*

However, the vulnerability curves depicted in Figure 4.15 are not directly suitable for the impact assessment of cyclone wind.

First, the data from the hazard maps is expressed in 10 minutes average wind, while the vulnerability curve at building level is related to the 3 second gust wind. In order to be able to couple the hazard wind data to the vulnerability functions described in Figure 4.15 , a conversion is required to translate the 10 minutes average wind to 3 second gust wind. For this translation, a conversion factor (“Gust Factor”) of 1.38 that decreases the wind value as suggested in the WMO “Guidelines for Converting between Various Wind Averaging Periods in Tropical Cyclone Conditions” (Harper et al., 2010) was used. Therefore, the vulnerability curve from Figure 4.15 was adjusted by dividing the wind intensity by 1.38, resulting in the vulnerability curve on building level illustrated in Figure 4.16.

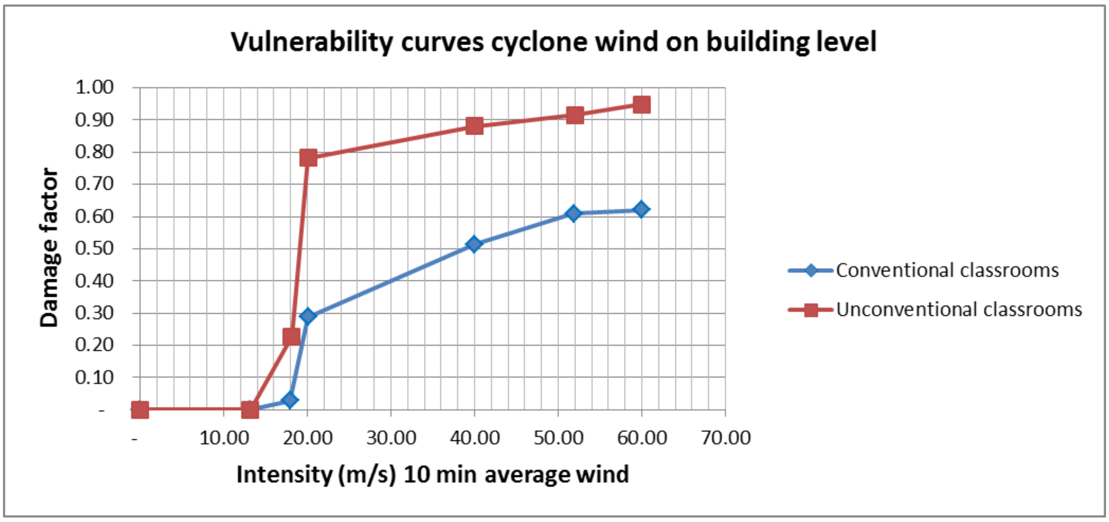


*Figure 4.16 Vulnerability functions related to the **10 min average wind on building level***

Second, in CIMA (2016), it is mentioned that the hazard input has a coarse hazard definition (10 by 10 km) and therefore a reduction factor needs to be applied in order to take into account the gustiness variability inside the hazard pixels. The report states:

> *"In fact, it is characteristic to the damage patterns of severe storm that not all potentially affected buildings suffer significant damages. Historic events show a stochastic nature as to whether buildings are affected or not, which is mainly subjected to the event characteristic in a high level of detail and the interaction with the immobile elements at risk and their specific structures. To estimate observable ratios of affected elements, simple statistical relations (ratios of affected buildings or loss frequency) based on historic event analyses have to be integrated into consequence analyses. "*

In order to transform the building level vulnerability curves to areal level vulnerability curves, CIMA (2016) proposes the use of a reduction ratio, as follows:

> *"Assuming that main effects on affected people is linked to damage to houses caused by wind, and assuming that a similar proportion between affected people/total people and between affected buildings / total buildings exists, we computed a ratio of affected buildings to total buildings is about 3% to 10%.*

With this additional step, this results in the vulnerability function for cyclone wind on areal level depicted in Figure 4.17.

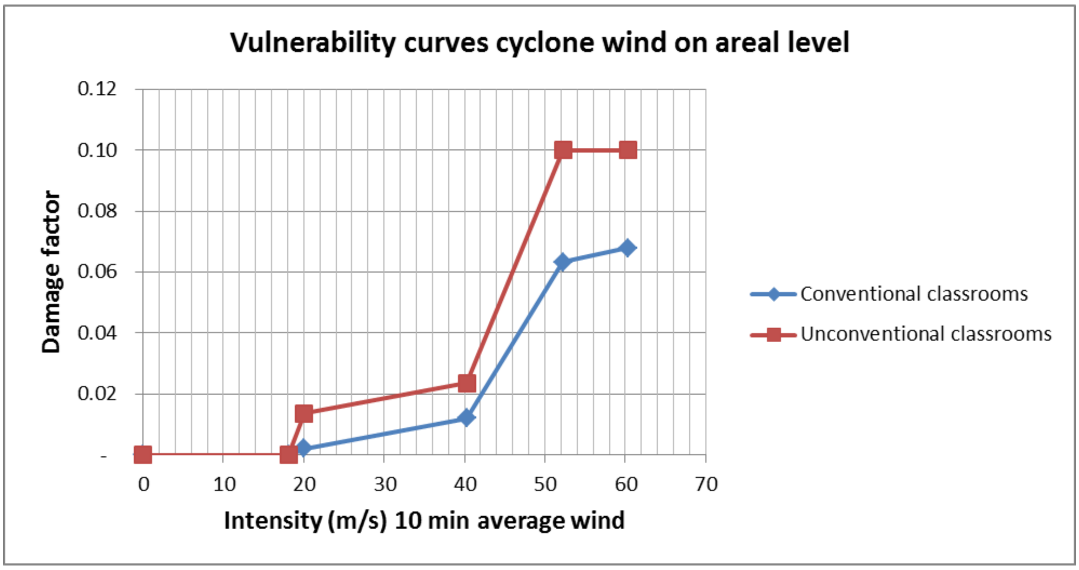


Figure 4.17 Vulnerability functions related to ***the 10 min average wind on areal level***

4.2.3.4 *Vulnerability earthquakes (EQ)*

The vulnerability functions for impacts related to earthquakes are employed from RED and ERN (2016). The report takes into consideration several building typologies (Table 4.8).

Table 4.8 Description of building typologies for the earthquake hazard. Table corresponding to Table 3-2 from RED and ERN (2016).

Table 3-2 – Average number of dwellings and replacement costs by building class [Amo-Oduro *et al.*, 2015]

Class ID	Description	Average dwellings per building	Average area per dwelling (sqm)	Replacement cost per unit area (USD/sqm)
RC_L	Reinforced concrete frame with URM infill low-rise building	1.25	50	340
RC_M	Reinforced concrete frame with URM infill mid-rise building	3.25	50	340
RCW_L	Reinforced concrete shear wall low-rise building	1.25	50	340
ST_L	Steel low-rise building	1.25	50	340
ST_M	Steel mid-rise building	3.25	50	340
ADB	URM adobe building	1.25	50	200
MUD	Mud walls	1	35	140
BRK	URM brick building	1.25	50	200
STN	URM stone building	1.25	50	200
CB	URM concrete block building	1.25	50	200
ERTH	Earthen building	1	35	140
WLI	Light wood building	1	35	140
INF	Informal building	1	35	140
RM_L	Reinforced masonry brick low-rise building	1.25	50	340

The vulnerability functions for ADB-MUD-ERTH and BRK-CB building types are covered in the spectral period T=0.2s, as shown in Figure 4.18. For this project, it is therefore proposed to match the building type ADB-MUD-ERTH to conventional classrooms and BRK-CB to unconventional classrooms. This leads to the vulnerability curves illustrated in Figure 4.19.

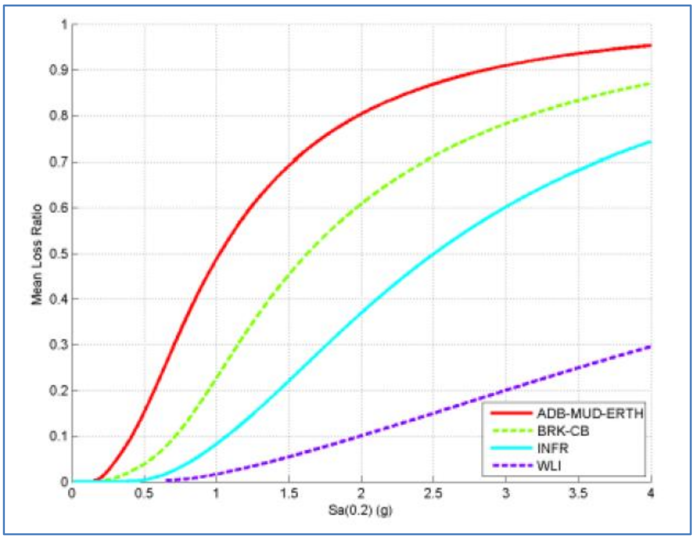


Figure 4.18 Vulnerability function for Mozambique for economic losses for the spectral period Sa (T=0.2s). Figure identical to Figure 4-11 in RED and ERN (2016).

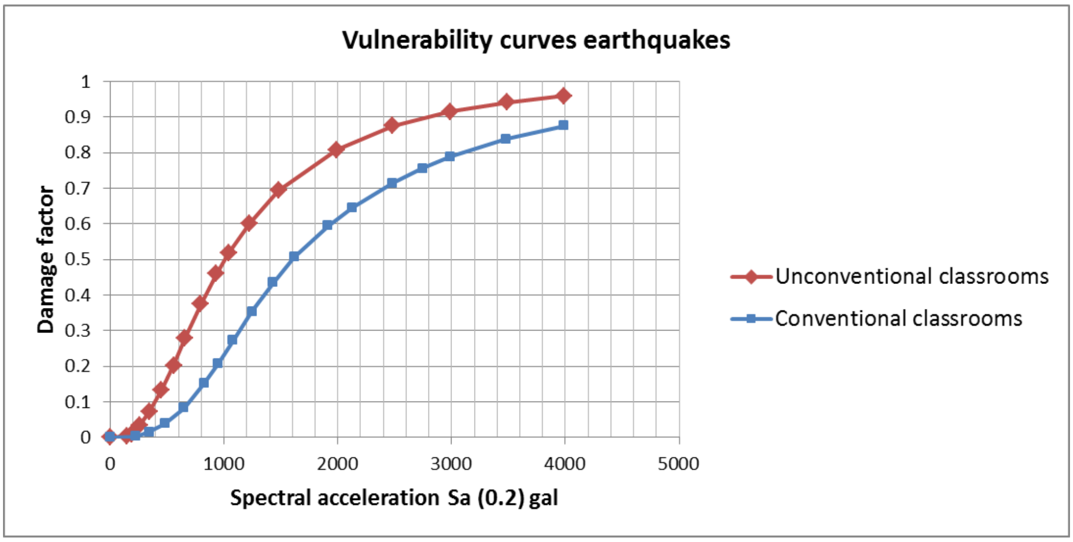


Figure 4.19 Vulnerability curves for EQ

4.2.3.5 Vulnerability landslides (LS)

In section 4.2.1.5, the landslide hazard has been described as expressed in susceptibility classes, ranging from 1-very low susceptibility to 5-very high susceptibility. Because of this classification, it is not possible to use vulnerability functions to estimate the impacts of landslides to classrooms. The calculation will therefore provide a number of unconventional and unconventional classrooms, and of pupils, exposed to different classes of landslide susceptibility.

4.3 Impact modelling with Delft-FIAT

The Delft-FIAT (Delft Flood Impact assessment tool) damage model calculates the potential monetary losses, based on damage functions for different damage categories. This approach to estimate losses based on damage functions is a widely applied and commonly accepted approach to calculate the impacts of floods The damage modelling concept is depicted in Figure 4.20. Delft-FIAT has been applied in various flood risk studies around the world and can handle various types of input data and formats and is compliant to geotiff, QGIS and other open (spatial) standards.

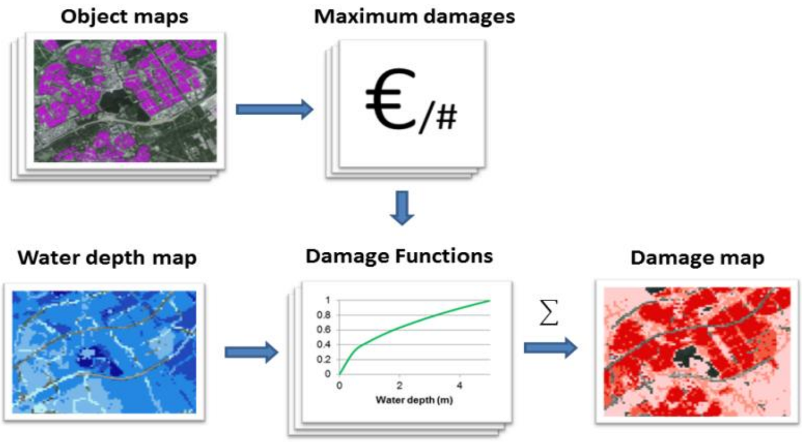


Figure 4.20 Conceptual approach for calculating monetary flood damages using Delft-FIAT

Delft-FIAT requires an identical resolution and extent of both hazard and exposure datasets. Therefore, all datasets have been resampled to a resolution of 90 meters, which is the highest resolution of the coastal flood hazard as reviewed above. The hazard data was not interpolated when resampling to ensure the validity of the hazard. Likewise, the exposure data has been converted from point information into raster datasets.

4.3.1 Overview of indicators

The following outputs of the multi-hazard risk assessment are used:

- Monetary damages: Monetary damages express the economic impacts of natural hazards. When damages are substantial, they can support the justification of protection of schools against the negative impacts of natural hazards. Monetary damages have been calculated for both conventional and unconventional building typologies and are expressed per return period, and where possible as annual expected damage (AED).
- Number of affected classrooms per building type.
- Number of affected pupils: The number of the affected pupils per hazard is indicative of the social impacts of the hazards, indicating the number pupils that would no longer have access to education.

While for the monetary damages the vulnerability functions described in sections 4.2.3.1 to 4.2.3.4 are employed, threshold values are needed to estimate the number of affected classrooms per building type and the number of affected pupils. Such thresholds are not easy to define and are highly dependent on local contexts. For the impact assessment to schools in Mozambique, the chosen thresholds are presented in Table 4.9. Generally, the hazard level is taken for when 10-15% of damage is attained.

For floods (both coastal and riverine), a threshold equal to 0.3 m is chosen. We consider that for an inundation level higher than 0.3 m, the pupils are no longer able to walk unaccompanied to and from schools; therefore this level was chosen as the minimum beyond which a classroom is affected. This choice disregards the possibility that the classrooms may be situated on the second floor, as no information was available to be able to identify multiple floor classrooms.

For cyclone winds, we have chosen a hazard threshold that leads to approximately 10% of the damage, according to the vulnerability function described in Figure 4.16. This corresponds to approximately 15 m/s for unconventional classrooms and 19 m/s for conventional classrooms. The threshold for conventional classrooms is comparable to the lower limit on the Beaufort wind scale (20.8 m/s) to which slight structural damage to buildings starts to occur (chimney pots and slates removed).

For earthquakes, in lack of information that would suggest otherwise, we have chosen a threshold that corresponds to approximately 10% of the damage, in order to maintain consistency with the approach for cyclone wind. This results in a spectral acceleration equal to 400 gal for unconventional classrooms and 700 gal for conventional classrooms.

Table 4.9 Proposed thresholds to estimate the number of affected classrooms and pupils

Hazard	Damage category	Threshold	Unit	Percentage of damage
RF	unconventional	0.3	m	35%
	pupils	0.3	m	15%
	unconventional	0.3	m	15%
CF	unconventional	0.3	m	35%
	pupils	0.3	m	15%
	unconventional	0.3	m	15%
CW	unconventional	15	m/s 10 min	~10%
	pupils	15	m/s 10 min	~10%
	conventional	19	m/s 10 min	~10%
EQ	unconventional	400	gal	~10%
	pupils	400	gal	~10%
	conventional	700	gal	~10%

4.4 Risk assessment results

The direct outputs of the Delft-FIAT are geotiffs, which are used for map making as well as further post-processing into tables and graphs. The results are aggregated to three administrative levels: national (Admin0), province (Admin1) and district (Admin2).

The conversion of the damage data in Excel tables is done as a pre-processing step outside of Delft-FIAT. Delft-FIAT calculates the impact per grid cell and provides one impact layer per damage category. These damage categories are preserved in the creation of the Excel tables, such that one Excel table is available for each damage category. Also, the impacts are prepared for the same administration levels: national, province and district.

Table 4.10 shows an example of a risk profile table result for the number of affected conventional classrooms.

Table 4.10 Example risk profile table for the number of affected conventional classrooms for the riverine floods

	A	B	C	D	E	F	G	H	I	J	K	L	M
1		REFERENCE	ISO	Admin_NAME	Admin_LEVEL	ZONE_CODE	25	50	100	200	500	1000	AED
2	0	Mozambique	MOZ	Mozambique	0	1	920	1056	1190	1367	1542	1665	45.01
3	1												
4	2	Mozambique	MOZ	Cabo Delgado	1	1	0	4	4	8	8	8	0.15
5	3	Mozambique	MOZ	Gaza	1	2	145	191	242	286	357	395	8.58
6	4	Mozambique	MOZ	Inhambane	1	3	45	64	76	90	123	159	2.82
7	5	Mozambique	MOZ	Manica	1	4	28	32	40	48	54	57	1.45
8	6	Mozambique	MOZ	Nampula	1	5	28	28	28	32	32	32	1.15
9	7	Mozambique	MOZ	Niassa	1	6	36	39	39	39	39	39	1.53
10	8	Mozambique	MOZ	Sofala	1	7	195	227	246	293	314	334	9.5
11	9	Mozambique	MOZ	Tete	1	8	212	223	240	254	263	263	9.2
12	10	Mozambique	MOZ	Zambezia	1	9	197	212	229	256	270	274	8.84
13	11	Mozambique	MOZ	Maputo	1	10	34	36	46	61	82	104	1.79
14	12	Mozambique	MOZ	Area under National Administration	1	11	0	0	0	0	0	0	0
15	13												
16	14	Mozambique	MOZ	Ancuabe	2	1	0	0	0	0	0	0	0
17	15	Mozambique	MOZ	Balama	2	2	0	0	0	0	0	0	0

The names of the regions are listed in the column “Admin_NAME”, while the administration levels are listed in the column “Admin_LEVEL”. The damage numbers per return period are given on the right side. The average expected damage (risk) is provided in the last column, and has been calculated using the formula:

$$\mathrm{AED} = \sum_{i=1}^{len(RP)-1} \frac{Damage\ at\ RP[i] + Damage\ at\ RP[i+1]}{2} * \left(\frac{1}{RP[i]} - \frac{1}{RP[i+1]}\right) + Damage\ at\ RP[end] * \frac{1}{RP[end]}$$

$where\ RP\ represent\ the\ return\ periods$

When a flood has a 10-year return period, it means the probability of occurrence of a flood of that magnitude or greater is 10 percent per year. A 100-year flood has a probability of occurrence of 1 percent per year. This means that over a long period of, a flood of that magnitude will, on average, occur once every 100 years. It does not mean a 100-yearflood will occur exactly once every 100 years. In fact, it is possible for a flood of any return period to occur more than once in the same year, or to appear in consecutive years, or not to happen at all over a long period of time.
The results are presented as the impacts of the hazard scenarios are presented on the exposed classrooms and pupils. The resulting risk analysis indicates which regions in Mozambique are prone to the highest impacts. Also, the estimates for damages for different return periods, together with the AED can be used to support decisions on risk reduction measures.

The analysis focuses on three outputs:

1. Quantify the number of classrooms affected, for both conventional and unconventional typologies
2. Quantify the number of affected pupils
3. Quantify the monetary damages for both conventional and unconventional classrooms

For the risk analysis, the hazard, exposure and vulnerability data as described in section 4.2 have been used. Section 4.4.1 presents a general overview of the impact assessment at national level, while the following sections give more detailed results and analysis per hazard. The analysis has focused on the monetary assessments of the hazard impacts to conventional and unconventional classrooms. The number of affected classrooms and pupils has been as well determined, however these amounts are very sensitive to the choice of thresholds for which a classroom is considered affected. Because of this, the results are first presented from the perspective of monetary damages and afterwards from the perspective of number of classrooms and pupils affected. Also, we have obtained results for multiple return periods and multiple hazards, which can be compared in multiple ways. In order to preserve a good reading of the report, we have chosen to present annual expected damages, and per hazard, also the damages for the 100-year return period. The choice for the 100 year return period is motivated by the fact that it gives an impression of what are the possible consequences of a relatively extreme event. The results for all return periods will be delivered in Excel files, such that the information for lower or higher return periods than RP 100 are available.

4.4.1 General results

Mozambique is vulnerable to multiple hazards: river and coastal flooding, cyclones wind, earthquakes and landslides. In order to facilitate the further use of this study, the results are first presented by grouping them per different hazard type, for both conventional and unconventional classrooms. In the following sections, more detailed information is given for each hazard type, together with a comparison, when possible, with the UN Habitat study (UN-Habitat, 2015).

4.4.1.1 Estimation of annual expected monetary damages

Table 4.11 illustrates the annual expected damage for conventional and unconventional classrooms, at national level. The total annual expected damage for Mozambique is 2,125,000 $/year for conventional classrooms and 39,000 $/year for unconventional classrooms. For the multi-hazard risk results including all return periods we refer to Appendix B.

Table 4.11 Annual expected monetary damages of affected classrooms at national level

	Annual expected monetary damages for Mozambique				
	RF **[$/year]**	**CF** **[$/year]**	**CW** **[$/year]**	**EQ** **[$/year]**	**Total** **[$/year]**
Conventional classrooms	800,000	900,000	350,000	75,000	2,125,000
Unconventional classrooms	11,000	15,000	11,000	2,000	39,000

Figure 4.21 and Figure 4.22 illustrate how each hazard contributes to the total annual expected damage. For conventional classrooms, the highest contribution is from coastal flooding (43%), followed by river flooding (37%), cyclone wind (16%) and earthquakes (3%). For unconventional classrooms, the contribution of cyclone wind is more significant and increases to 29%. Further, it is estimated that the coastal flood is responsible for 36% of the annual damages, the riverine flood for 29% and the earthquakes for 6%.

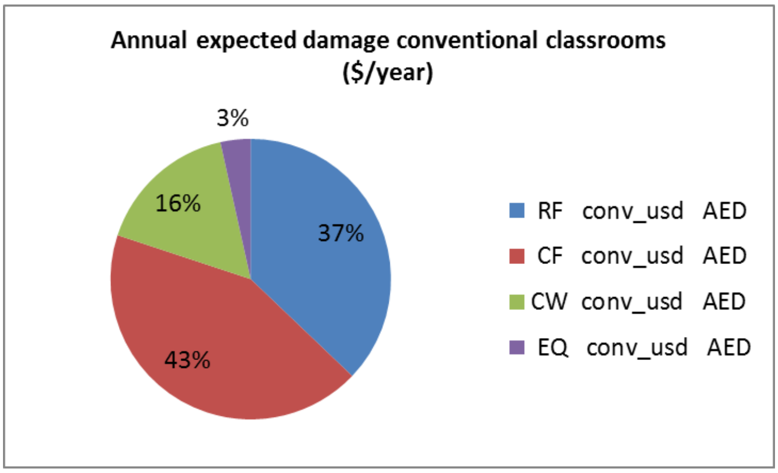


Figure 4.21 Annual expected damage for conventional classrooms, hazard distribution

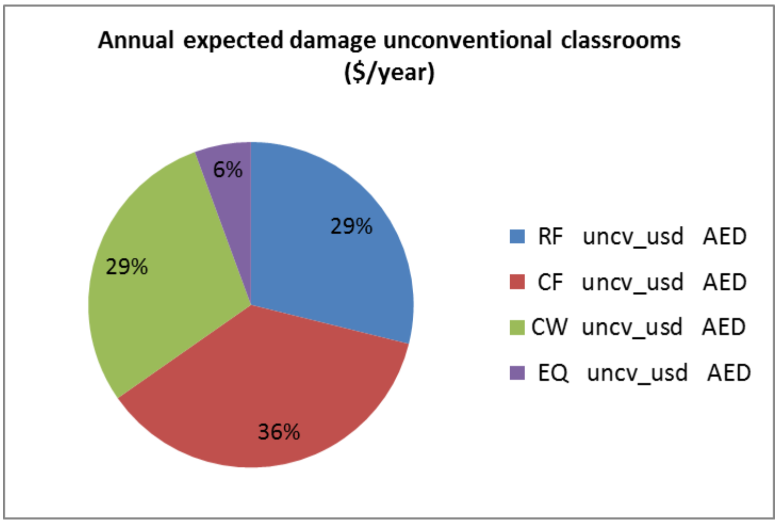


Figure 4.22 Annual expected damage for unconventional classrooms, hazard distribution

Table 4.12 Hazard contribution to annual expected damage to classrooms in Mozambique

	Conventional classrooms - contribution to annual expected damage-	**Unconventional classrooms - contribution to annual expected damage-**
Coastal flooding (CF)	43%	36%
River flooding (RF)	37%	29%
Cyclone wind (CW)	16%	29%
Earthquakes (EQ)	3%	6%

From Figure 4.21 and Figure 4.22, we may conclude that coastal flooding is the hazard most responsible for the classroom damages in Mozambique (43% for the conventional classrooms and 36% for the unconventional classrooms), followed by river flooding, cyclones and earthquakes (Table 4.12). However, we note that this might be an underestimation of the contribution of the other hazards. We describe below few discussion points that should be taken into consideration when further making use of the results:

- With respect to river flooding, the hazard data is available starting from the 25 year return period, while for the coastal flooding, cyclone wind and earthquakes, the hazard data is available starting with the 10 year return period. This has a direct impact on the calculation of the annual expected damage. In the formula described in section 0, the monetary damage corresponding to low return periods has a very high contribution to the annual expected damage. If hazard data would have been available for the 10year return period, the annual expected damage may be up to 50% higher.
- With respect to cyclone wind, the study of CIMA (2016), proposes the use of a reduction factors for the vulnerability curves to overcome the misbalance between coarse hazard information (10km X 10km) and the gustiness behaviour of cyclones. The proposed reduction factors, between 3% and 10%, result in relatively low economic damages to classrooms in Mozambique. It is therefore advisable that a rigorous review of the vulnerability functions for cyclone wind is performed. We also suggest making a comparison with other studies on cyclone damage, to have a better estimate of the most suitable vulnerability function for cyclone wind.

Figure 4.23 illustrates the annual average number of affected classrooms, per hazard type, while Table 4.13 presents the same information, together with the calculation of the contribution of each hazard to the annual expected number of affected classrooms and a few notes on the ‘definition’ of an affected classroom.

- For river and coastal flooding, a threshold of 30 cm water depth has been chosen.
- For cyclones, we have chosen a threshold of 19 m/s 10 min average wind for conventional classrooms and 15 m/s for unconventional classrooms. These numbers represent approximately the level for which 10% of the total damage is attained for cyclone wind at building level (Figure 4.16). As explained in section 4.2.3.3, a reduction factor was needed to cope with the mismatch between the coarse wind resolution (10km X 10 km) affecting almost all buildings and the gustiness character of the wind (with strong local effects). We have followed the methodology proposed by CIMA (2016) and applied reduction factor to deal with the mismatch. We have chosen a reduction factor of 10% for both conventional and unconventional classrooms. This means, for example, that out of the total number of conventional classrooms subject to a wind speed higher than 19 m/s 10 min average, only 10% are truly affected and thus arriving to the estimate given in Table 4.13.
- For earthquakes, thresholds of 700 gal peak ground acceleration for conventional classrooms and 400 gal peak ground acceleration for unconventional classrooms have been chosen. These thresholds correspond to the level for which 10% of the total damage is attained for earthquakes at building level (Figure 4.19).

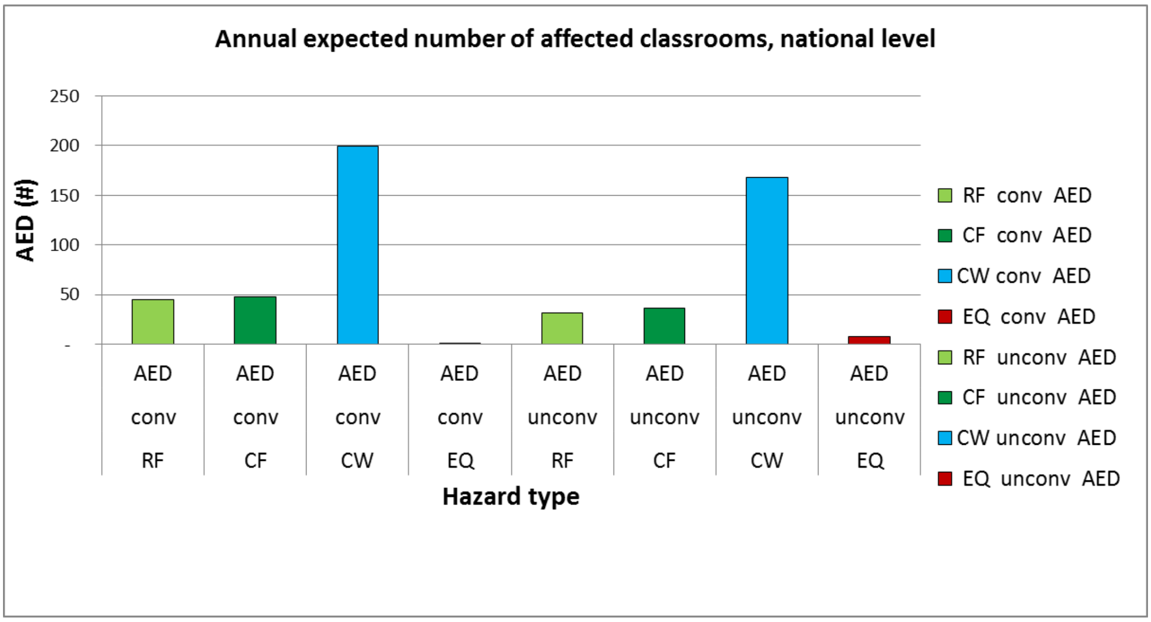


Figure 4.23 Annual expected number of affected classrooms

Table 4.13 Hazard contribution to the annual expected number of affected classrooms in Mozambique

Hazard	Classroom type	Annual expected number of classrooms affected [#/year]	Percentage with respect to the total number of annual affected classrooms	Notes
RF	conventional	45	15%	Threshold equal to 30 cm
CF	conventional	48	16%	Threshold equal to 30 cm
CW	conventional	199	68%	Threshold equal to 19 m/s 10-min average wind, together with a reduction factor of 10%
EQ	conventional	1	0.2%	Threshold equal to 700 gal
	SUM	**292**	**100%**	
RF	unconventional	32	13%	Threshold equal to 30 cm
CF	unconventional	37	15%	Threshold equal to 30 cm
CW	unconventional	168	69%	Threshold equal to 15 m/s 10-min average wind, together with a reduction factor of 10%
EQ	unconventional	8	3%	Threshold equal to 400 gal
	SUM	**245**	**100%**	

With the above notes as background, the impact assessment results in an average number of 292 annually affected conventional classrooms and 245 annually affected unconventional classrooms. For both conventional and unconventional classrooms, the cyclone wind has the highest contribution (~70%), followed by coastal flooding (~15%), river flooding (~13%) and earthquakes (~2%).

Further on, Figure 4.24 and Table 4.14 show the annually expected number of affected pupils, under the chosen thresholds described in Table 4.14. With these assumptions, the annually expected number of affected pupils is in the order of 50,000. Cyclone winds contribute the most to the annual expected number of affected pupils (70%), followed by coastal flooding (14%), river flooding (12%) and earthquakes (3%).

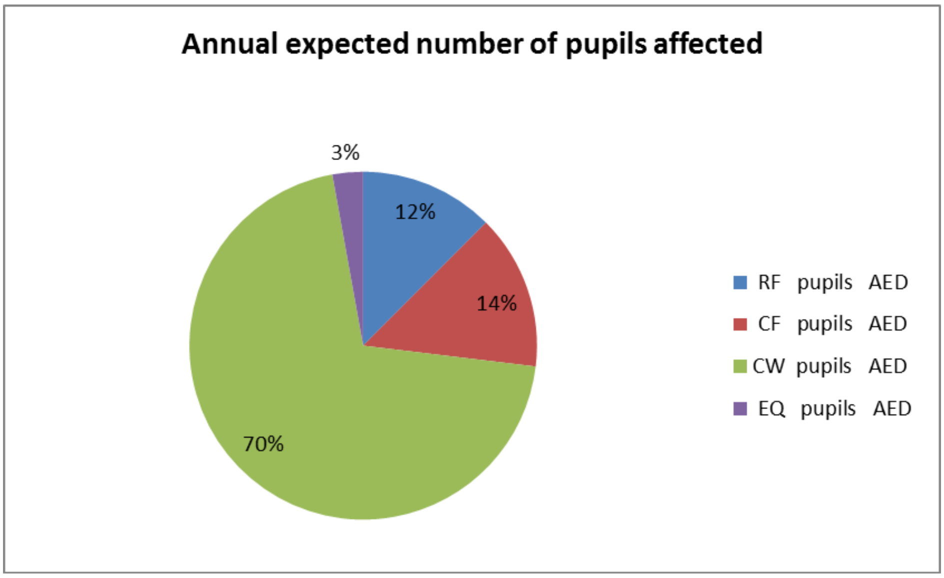


Figure 4.24 Annual expected number of affected pupils

Table 4.14 Hazard contribution to the annual expected number of affected pupils in Mozambique

Hazard	**Pupils**	**Annual expected number of affected pupils [#/year]**	**Percentage with respect to the total number of annual affected pupils**	**Notes**
RF	pupils	7,093	12%	Threshold equal to 30 cm
CF	pupils	8,190	14%	Threshold equal to 30 cm
CW	pupils	39,888	70%	Threshold equal to 15 m/s 10-min average wind, together with a reduction factor of 10%
EQ	pupils	1,615	3%	Threshold equal to 400 gal
	SUM	**56,786**	**100%**	

4.4.2 Riverine flooding

4.4.2.1 Estimated riverine flood damages at national level

The flood damage estimates for the riverine flood, at national level, are indicated in Table 4.15. For the conventional and unconventional classrooms, the expected monetary damages are calculated and expressed in USD. Table 4.15 gives an overview of the annual expected damages for these two categories. At national level, the annual expected damage for conventional classrooms is ~ 788,000 $, while for the unconventional classrooms the expected damage is ~11,500 $. This sums up to ~ 800,000 $ annual expected damage for classrooms in Mozambique, due to riverine flooding. A 100-year flood will result in much higher damages, estimated at approximately 21,000,000 $.

Table 4.15 RF: Estimated monetary damages of affected classrooms at national level

	Conventional classrooms monetary	Unconventional classrooms monetary	Sum
AED [USD/year]	788,027	11,436	799,463
RP100 [USD]	20,830,000	302,470	21,132,470

At national level, the annual average number of affected classrooms has been also calculated, using a threshold of 30 cm of water depth. This means that a classroom is considered as affected if it is subject to a flood depth higher or equal than 30 cm. Using this threshold, the annual average number of affected conventional classrooms is equal to 45, while the annual average number of affected unconventional classrooms is 32 (Table 4.16). The number of annually average affected pupils is in the order of 7000 pupils, also using a threshold of 30 cm water depth. However, a 100-year flood would results in a much higher number of affected pupils, in the order of 190,000.

Table 4.16 RF: Estimated number of affected classrooms and pupils at national level

	Conventional classrooms count	Unconventional classrooms count	Pupils count
AED [#/year]	45	32	7,092
RP100 [#]	1190	830	187,510

4.4.2.2 *Estimated riverine flood damages at district level*

At district level, Figure 4.25 shows the annual expected damage for conventional classrooms in Mozambique, expressed in $/year. This figure is then visually compared with the UN Habitat study, to assess whether the most impacted districts are comparable within the two studies (Figure 4.26). In the UN Habitat study, the districts are classified as prone to *High*, *Moderate* or *Low* risk, however the thresholds for this classification are not reported. For some regions, the two maps are in good agreement. Still, the comparison between the two maps also identifies regions with different risk levels. Most likely this difference lies in the definition of *High*, *Moderate* and *Low* risk in the UN habitat approach. Also, in the present study, the riverine flood and coastal flood are presented in two different sections, as they originate from two sources of flooding. This explains why the coastal zones do not have high damages due to riverine flooding.

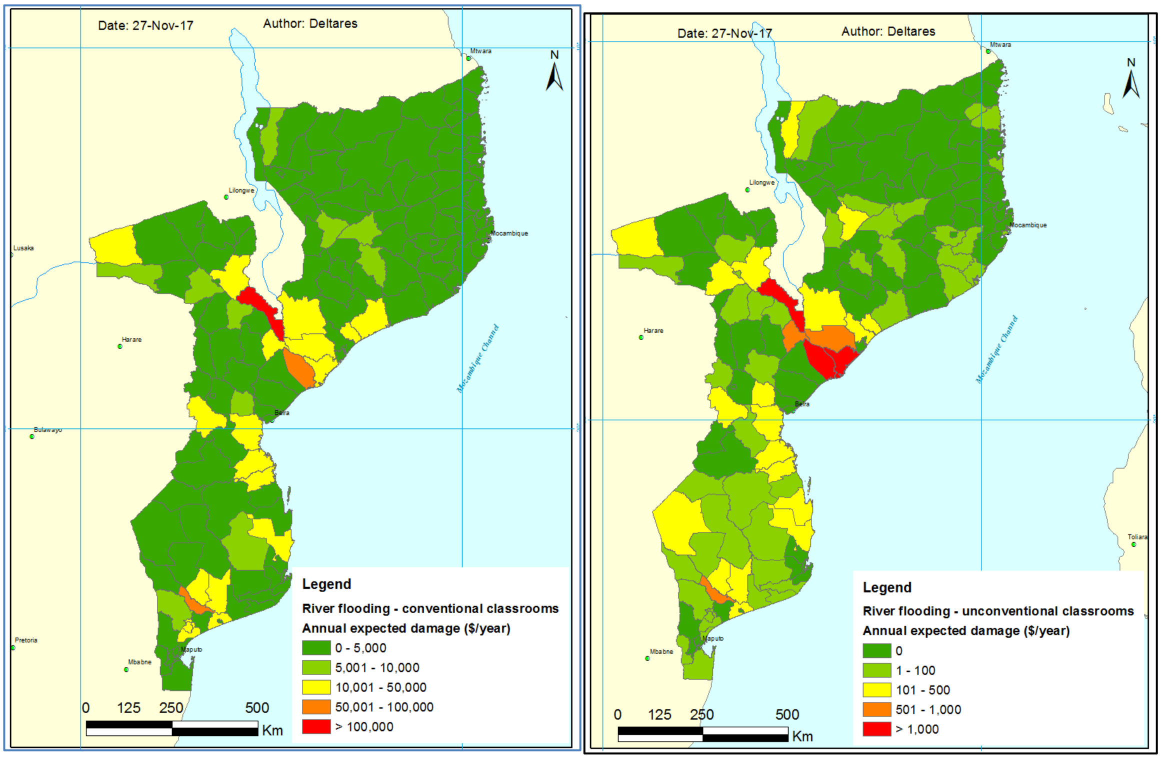


Figure 4.25 Left: Annual expected damage for ***conventional classrooms*** *affected by RF*
Right: Annual expected damage for ***unconventional classrooms*** *affected by RF*

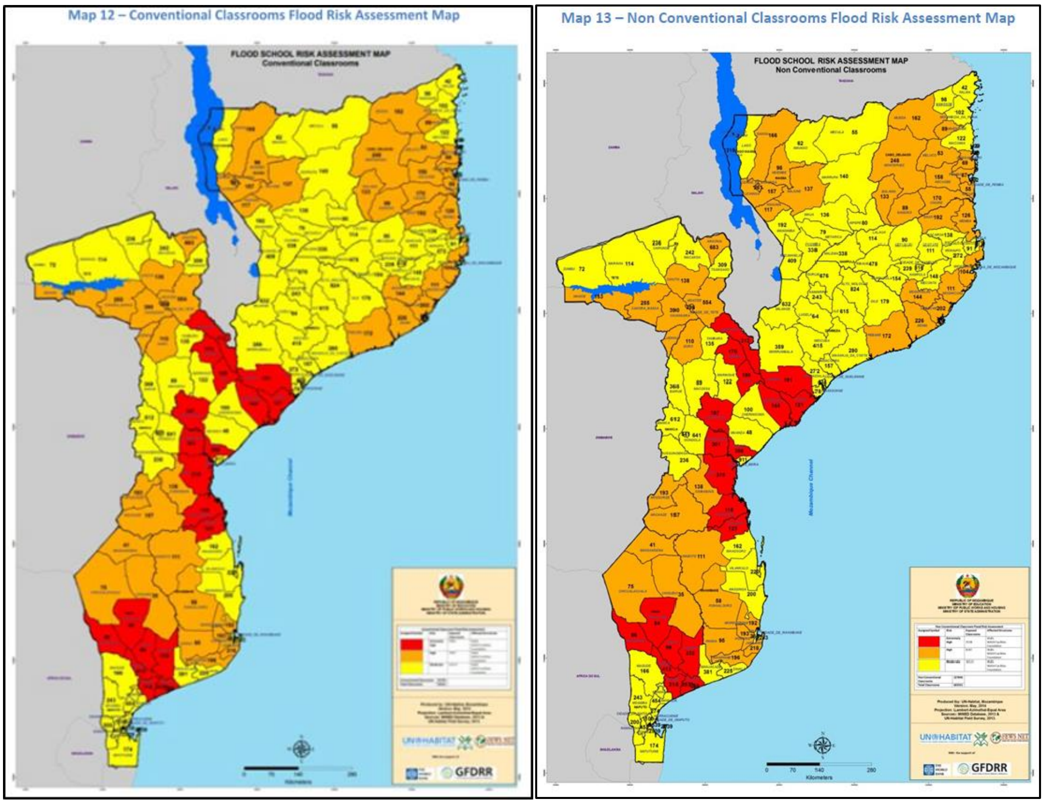


Figure 4.26 Left: UN Habitat risk classification for ***conventional classrooms***
Right: UN Habitat risk classification for ***unconventional classrooms***

The top 10 districts, ranked on the annual expected damage of affected conventional classrooms, are listed in Table 4.17 and Table 4.18. The top most impacted districts are Mutarara, Marromeu and Chokwe and Chinde.

Table 4.17 RF: Top 10 affected districts based on the expected damage of conventional classrooms

Admin NAME	Conventional classrooms AED [$/year]	Conventional classrooms RP100 [$]
Mutarara	135,644	3,510,080
Marromeu	65,390	1,674,120
Chokwe	56,394	1,549,380
Chinde	49,445	1,289,890
Mopeia	45,497	1,205,850
Caia	37,395	1,001,200
Xai-xai	35,652	1,011,100
Moatize	29,694	761,805
Morrumbala	26,927	723,683
Chibuto	17,212	488,532

Table 4.18 RF: Top 10 affected districts in terms of expected damage of unconventional classrooms

Admin NAME	Unconventional classrooms AED [$/year]	Unconventional classrooms RP100 [$]
Mutarara	1,267	32,639
Chinde	1,112	29,038
Marromeu	1,084	27,660
Mopeia	866	23,234
Chokwe	817	22,852
Caia	593	15,646
Xai-xai	483	13,657
Chibuto	298	8,558
Buzi	250	8,305
Nhamatanda	301	7,913

At district level, Figure 4.27 shows the annual average number of affected pupils by riverine flooding at district level. A comparable figure for UN Habitat study is not available. The top 20 districts are given in Table 4.19. Mutarara is by far the most impacted district, for which ~839 pupils are expected to be affected yearly by a riverine flood. For this district, a 100-year flood would result in ~21 000 pupils affected, which is approximately 39% of the total number of pupils in this district. Similar information for other districts is available. For example, the district of Cidade de Tete has an annual average number of pupils affected equal to 137, however, a 100-year flood would result in 32% of the pupils within this district being affected by the riverine flood.

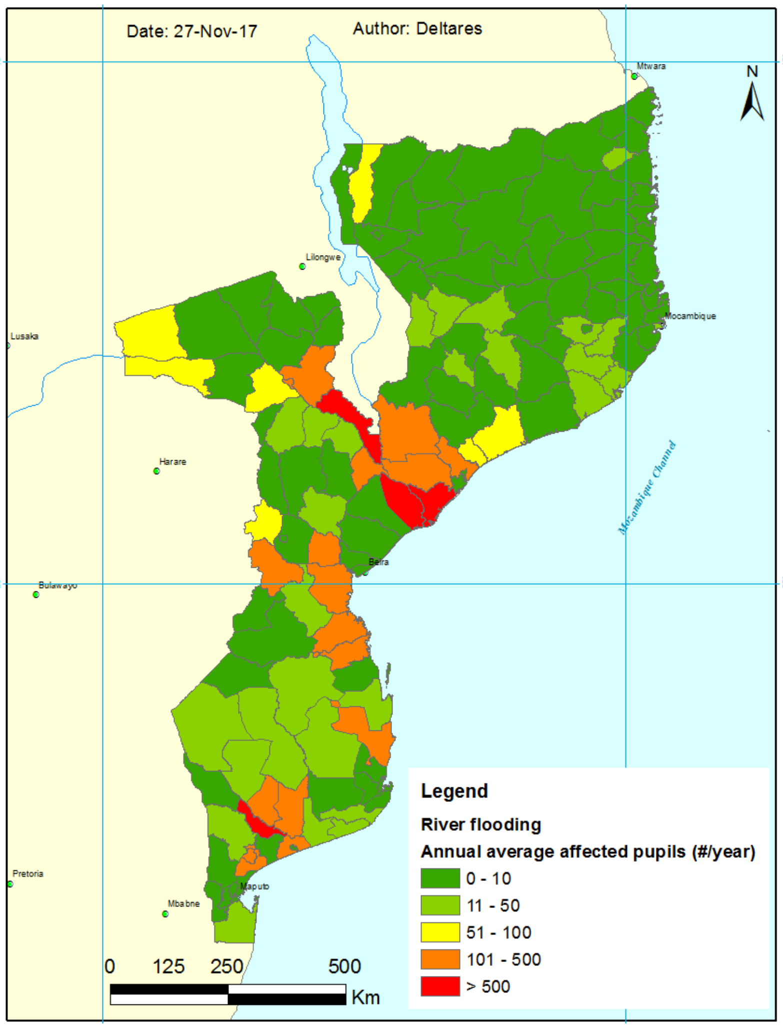


Figure 4.27 RF: Annual expected number of pupils affected

Table 4.19 RF: Estimated number of affected pupils at district level

	Admin NAME	Annual expected number of pupils affected AED [#/year]	RP100 [#]	Percentage exposed AED	Percentage exposed RP100
1	**Mutarara**	839	21,553	2%	39%
2	**Marromeu**	790	19,942	2%	58%
3	**Chinde**	586	15,262	1%	39%
4	**Chokwe**	570	15,773	1%	33%
5	**Mopeia**	424	11,291	1%	22%
6	**Caia**	397	9,971	1%	25%
7	Xai-xai	259	7,084	0%	10%
8	Chibuto	238	6,903	0%	11%
9	Morrumbala	175	4,965	0%	4%
10	Manhica	175	4452	0%	8%
11	**Machanga**	170	4102	1%	23%

12	Nhamatanda	163	4504	0%	5%
13	Buzi	162	5231	0%	8%
14	Guija	148	4766	0%	13%
15	Moatize	147	4298	0%	5%
16	**Cidade de Tete**	137	3404	1%	32%
17	**Govuro**	110	3012	1%	21%
18	Nicoadala	105	2634	0%	3%
19	Sussundenga	103	2835	0%	3%
20	Massinga	103	2599	0%	3%

4.4.3 Coastal flooding

4.4.3.1 Estimated coastal flood damages at national level

Table 4.20 presents the estimated monetary damages caused by coastal flooding at national level, for both conventional and unconventional classrooms. The annual expected damage for conventional classrooms is approximately 910,000 $/year, while for conventional classrooms, build up with traditional materials, this sums up to ~ 15,000 $/year, leading up to a total annual expected monetary damages of 925,000 $/year. However, this amount is much lower than, for example, the damages produced by a 100-year coastal flood, which may result in cumulated monetary damages of up to 12,000,000 $.

Table 4.20 CF: Estimated monetary damages of affected classrooms at national level

	Conventional classrooms monetary	Unconventional classrooms monetary	Sum
AED [USD/year]	911,384	14,439	925,822
RP100 [USD]	11,921,400	176,434	12,097,834

At national level, the annual average number of affected classrooms is also calculated, using a threshold of 30 cm of water depth. This means that a classroom is considered as affected if it is subject to a flood depth higher or equal than 30 cm. Using this threshold, the annual average number of affected conventional classrooms by coastal flooding is equal to 48, while for unconventional classrooms, the annual average is equal to 37 (see Table 4.21). However, a 100-year coastal flood would result in a much higher number of affected classrooms, up to 576 and 435 for conventional and respectively unconventional classrooms.

The annual average of affected pupils affected by coastal flooding is in the order of 8000 pupils, while the estimated number of affected pupils by a 100-year coastal flood would result in approximately 100 000 pupils affected (Table 4.21)

Table 4.21 CF: Estimated number of affected classrooms and pupils at national level

	Conventional classrooms count	Unconventional classrooms count	Pupils count
AED [#/year]	48	37	8,190
RP100 [#]	576	435	97,151

4.4.3.2 Estimated coastal flood damages at district level

At district level, Figure 4.28 shows the annual expected damage for conventional and unconventional classrooms in Mozambique due to coastal flooding, expressed in $/year. These figures give a visual impression of the location of the most impacted districts. As seen from Table 4.24 and Table 4.27, the districts with the highest damage are Cidade da Beira and Machanga, for both conventional and unconventional classrooms.

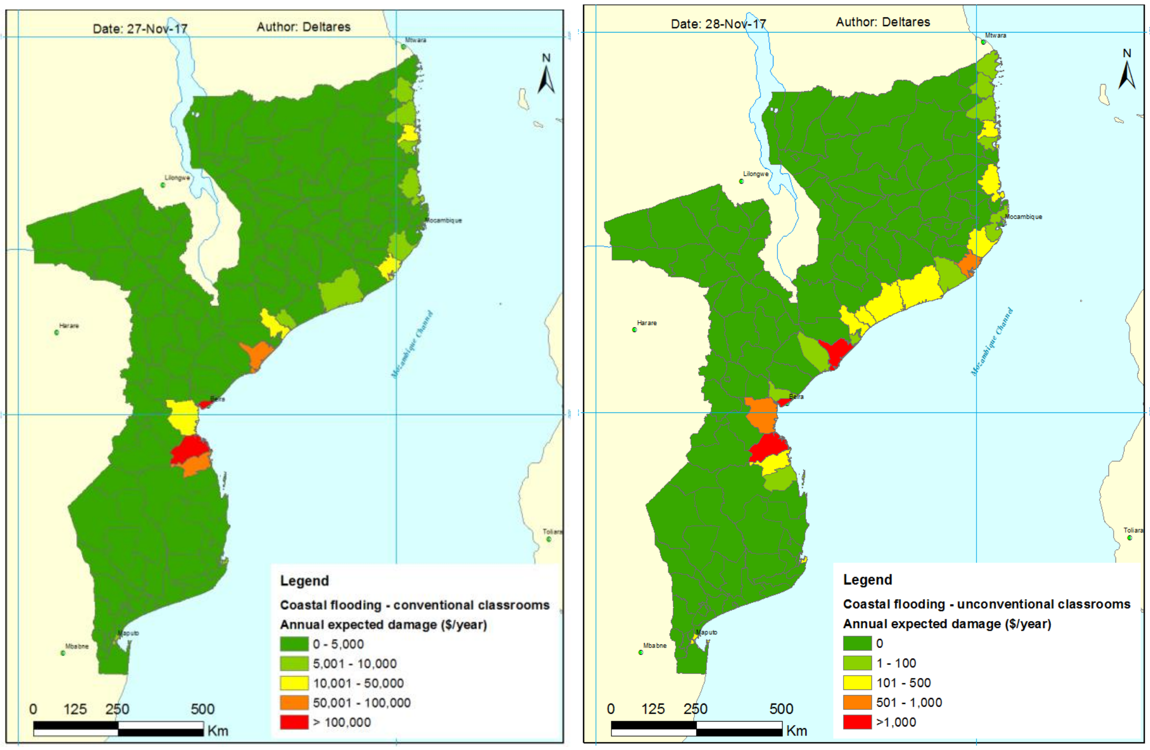


*Figure 4.28 Left: Annual expected damage for **conventional classrooms** affected by CF*
*Right: Annual expected damage for **unconventional classrooms** affected by CF*

Table 4.22 CF: Top 10 affected districts in terms of expected damage of conventional classrooms

Admin NAME	Conventional classrooms AED [$/year]	Conventional classrooms RP100 [$]
Cidade da Beira	496,073	6,347,270
Machanga	102,394	1,340,780
Govuro	52,321	828,787
Chinde	51,101	759,250
Buzi	48,240	638,591
Angoche	46,725	570,198
Quissanga	13,146	135,495
Nicoadala	13,052	190,139
Macomia	9,118	100,815
Mogincual	9,032	91,529

Table 4.23 CF: Top 10 affected districts in terms of expected damage of unconventional classrooms

Admin NAME	Unconventional classrooms AED [$/year]	Unconventional classrooms RP100 [$]
Cidade da Beira	7,345	86,720
Machanga	1,833	21,810
Chinde	1,032	15,668
Angoche	995	11,457
Buzi	751	9,052
Govuro	379	5,344
Nicoadala	323	4,408
Quissanga	220	2,234
Cidade de Maputo	148	1,933
Pebane	143	1,849

At district level, Figure 4.29 shows the estimated number of affected pupils at district level.

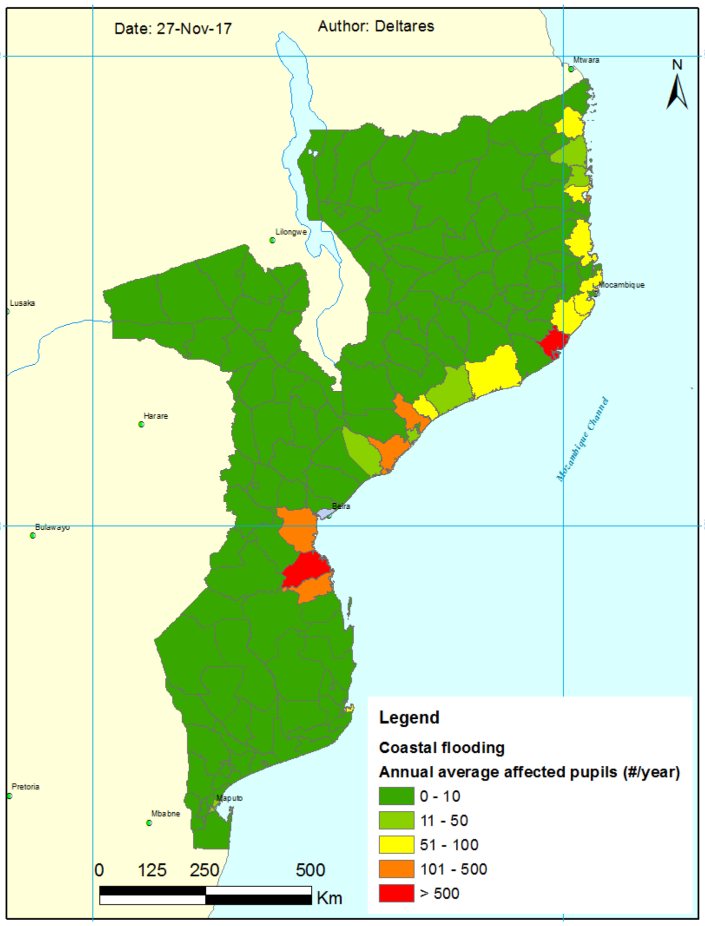


Figure 4.29 CF: Annual expected number of pupils affected

The top 20 districts are given in Table 4.24. The districts are ranked based on the annual expected number of affected pupils. The Cidade de Beira district is by far the most impacted district, for which ~4,500 pupils are expected to be affected yearly by a coastal flood. For this district, a 100-year flood would result in ~50,000 pupils affected, which is approximately 65%

of the total number of pupils in this district. Similar information for other districts is available in Table 4.24. For example, the district of Govuro has an annual average of pupils affected equal to 300, however, a 100-year flood would result in more than 30% of the pupils within this district being affected by the flood.

Table 4.24 CF: Expected number of affected pupils at district level

	Admin NAME	Annual expected number of pupils affected [#/year]	RP100 [#]	Percentage exposed	Percentage exposed RP100
1	Cidade da Beira	4,554	51,389	6%	66%
2	Machanga	678	8,119	4%	45%
3	Angoche	567	6,112	1%	9%
4	Buzi	420	4,650	1%	7%
5	Chinde	348	5,426	1%	14%
6	Cidade de Pemba	306	3,058	1%	12%
7	Govuro	300	4,506	2%	32%
8	Nicoadala	170	2,081	0%	3%
9	Cidade de Inhambane	90	1,447	1%	10%
10	Pebane	80	999	0%	1%
11	Mogincual	79	767	0%	1%
12	Mocimboa da Praia	77	767	0%	2%
13	Pemba	77	767	0%	5%
14	Memba	77	767	0%	1%
15	Mossuril	77	767	0%	2%
16	Namacurra	58	566	0%	1%
17	Maganja da Costa	47	1,049	0%	1%
18	Quissanga	46	445	1%	5%
19	Inhassunge	42	1,534	0%	5%
20	Cidade de Maputo	34	872	0%	1%

4.4.3.3 Identified issues with coastal flood hazard

After the finalization of the multi-hazard risk assessment a processing error of the coastal flood hazard was found. More specific, the underlying digital elevation model was not correct, which led to an overestimation of the coastal flood hazard.

The results as presented above are therefore overestimated, too. To get a qualitative estimation of the significance of this error, we compared the results with the revised dataset based on the number of schools affected.

Table 4.25 shows a comparison of old and revised hazard dataset based on the number of schools affected. It can be seen that the reduction is as much as 96% for the RP0100. For higher return periods the reduction may reach 100%. This means that the AED values should not be used further.

Table 4.25 Comparison of number of schools affected (water depth >30cm) between old and revised dataset

	old	revised	Reduction
RP0100	154	5	96%
RP0500	193	31	83%
RP1000	208	45	78%

4.4.4 Earthquakes

4.4.4.1 Estimated earthquake damages at national level

Table 4.26 presents the estimated monetary damages caused by earthquakes at national level, for both conventional and unconventional classrooms. The annual expected damage for conventional classrooms is approximately 74,000 $/year, while for conventional classrooms, build up with traditional materials, this sums up to ~ 2,200 $/year, leading up to a total annual expected monetary damages of 76,000 $/year. However, this amount is much lower than, for example, the damages produced by a 100-year earthquake. Such an earthquake may result in cumulated monetary damages of up to 1,100,000 $.

Table 4.26 EQ: Estimated monetary damages of affected classrooms at national level

	Conventional classrooms monetary	Unconventional classrooms monetary	Sum
AED [USD/year]	73,889	2,223	76,111
RP100 [USD]	1,092,120	35,883	1,128,003
RP500 [USD]	4,773,370	189,558	4,962,928

The annual average number of affected classrooms is also calculated, using a threshold of 700 gal for conventional classrooms, and 400 gal for unconventional classrooms. These thresholds have been chosen as corresponding to approximately 10% of the damages described in the vulnerability curves (see section 4.2.3.4). However, this is a very subjective choice and more in depth analysis is needed to propose better suited values.

With these thresholds, the results indicate that the annual average number of conventional classroom affected by earthquakes is less than 1, a relatively small number, while for unconventional classrooms, the annual average is equal to 8, also low (Table 4.27). For conventional classrooms, possible damage is estimated only starting with the 500-year earthquake, when 39 classrooms are estimated as affected. For the unconventional classrooms, damage is present starting at the 100-year earthquake, when the estimated number of affected buildings is equal to 135. Based on these results, further analysis of most suitable thresholds for the earthquake hazard is recommended.

The annual average of affected pupils affected by earthquakes is in the order of 1600 pupils, while the estimated number of affected pupils by a 100-year earthquake would result in approximately 18000 pupils affected (Table 4.3). For completion, note that, in order to estimate the number of affected pupils, the lowest threshold between conventional and unconventional classrooms has been used, corresponding to a hazard higher or equal than 400 gal.

Table 4.27 EQ: Estimated number of affected classrooms and pupils at national level

	Conventional classrooms count	Unconventional classrooms count	Pupils count
AED [#/year]	0.67	8	1,615
RP100 [#]	0	135	17,871
RP500 [#]	39	870	165,067

4.4.4.2 Estimated earthquake damages at district level

At district level, Figure 4.30 shows the annual expected damage for conventional and unconventional classrooms in Mozambique due to earthquakes, expressed in $/year. These figures give a visual impression of the location of the most impacted districts. As seen from Table 4.28 and Table 4.29 the districts with the highest damage are Machaze for conventional classrooms and Machaze and Mossurize for unconventional classrooms.

These figures are quite different from the figures published by UN Habitat (Figure 4.31). This might be due to the thresholds used by UN Habitat to differentiate between *High*, *Moderate* and *Low* risk. These thresholds are unknown to us. Also, the input hazard data has low values, leading to a maximum of 40% of damage for the highest available return period. This might explain the limited amount of affected districts by earthquakes.

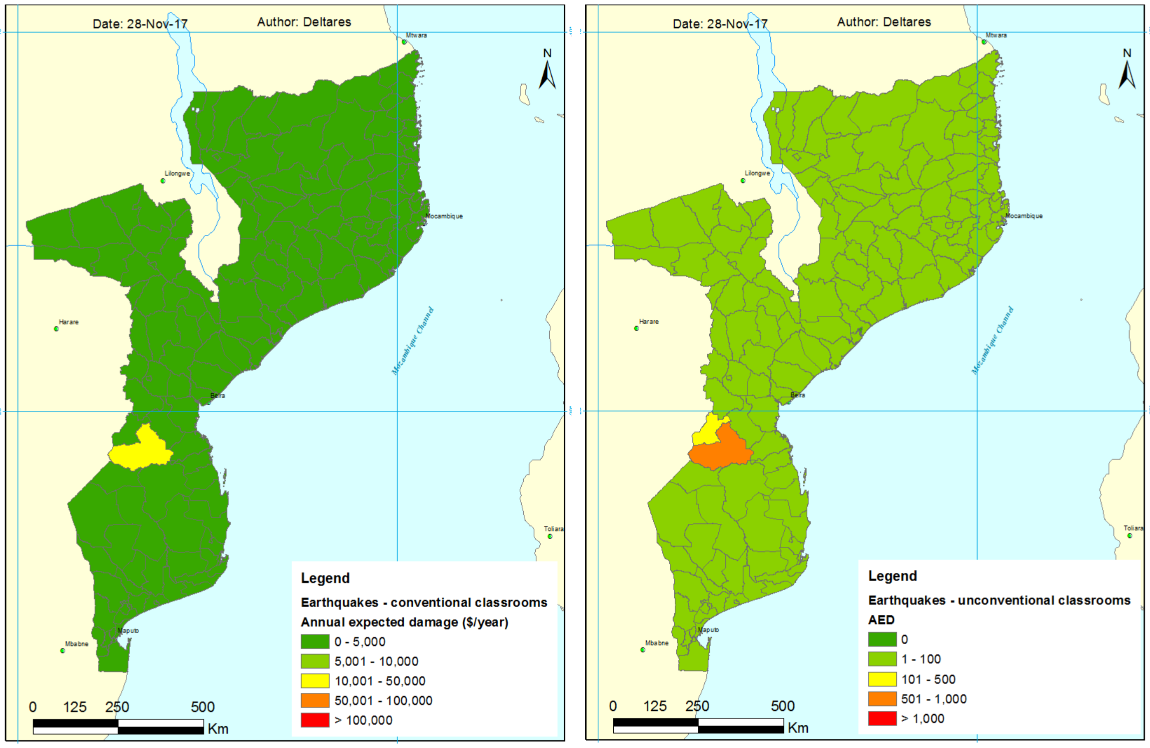
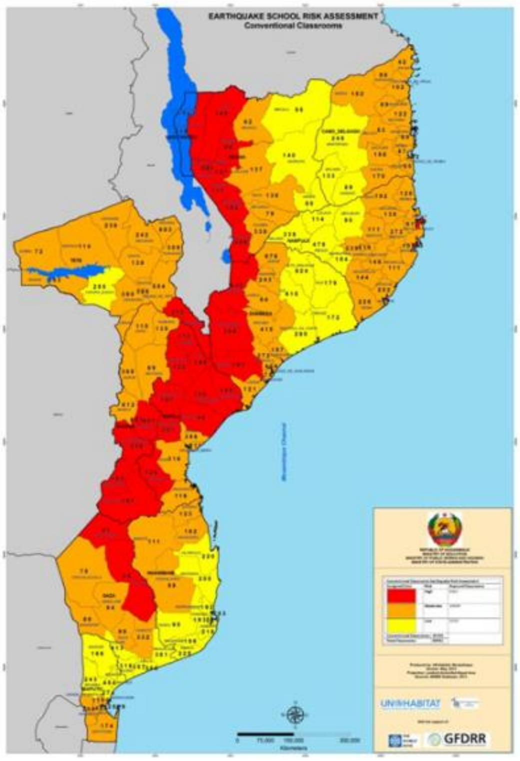


*Figure 4.30 Left: Annual expected damage for **conventional classrooms** affected by EQ*
*Right: Annual expected damage for **unconventional classrooms** affected by EQ*

Map 10 – Conventional Classrooms Earthquake Risk Assessment Map



Map 11 – Non Conventional Classrooms Earthquake Risk Assessment Map

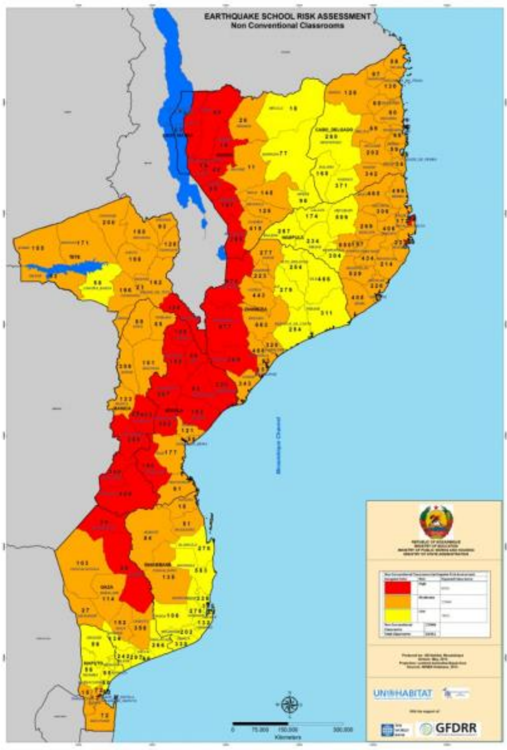


Figure 4.31 Left: UN Habitat map for ***conventional classrooms*** *affected by EQ*
Right: UN Habitat map for ***unconventional classrooms*** *affected by EQ*

Table 4.28 EQ: Top 10 affected districts in terms of expected damage of conventional classrooms

Admin NAME	Conventional classrooms AED [$/year]	Conventional classrooms RP100 [$]
Machaze	10,080	210,037
Lago	3,103	42,327
Mossurize	2,748	40,173
Angonia	2,645	28,814
Cidade da Beira	1,840	18,269
Mutarara	1,590	16,470
Dondo	1,521	15,192
Massangena	1,518	31,288
Lichinga	1,476	14,820
Buzi	1,379	15,288

Table 4.29 EQ: Top 10 affected districts in terms of expected damage of unconventional classrooms

Admin NAME	Unconventional classrooms AED [$/year]	Unconventional classrooms RP100 [$]
Machaze	587	13,550
Mossurize	122	2,599
Lago	96	2,155
Cidade da Beira	69	548

Massangena	57	1,353
Mabote	55	1,182
Lichinga	48	865
Buzi	46	408
Chibabava	45	687
Ngauma	42	616

At district level, Figure 4.32 shows the annual average number of affected pupils by earthquakes at district level. The top 20 districts are given in Figure 4.32. The most affected district is Machaze, with 487 average affected pupils per year. The ranking is followed by the districts of Mossurize and Cidade da Beira, with 120 and correspondingly 117 pupils affected yearly by earthquakes.

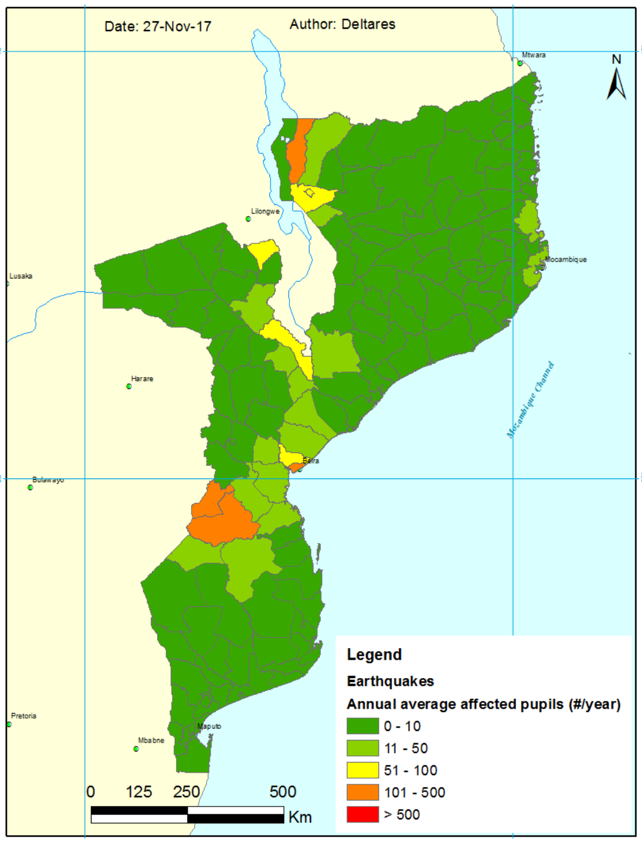


Figure 4.32 Annual expected number of pupils affected by EQ

For these districts, the estimated number of pupils for the 100 and 500-year earthquakes are also indicated, together with an indication of the relation between the estimated number of affected pupils and the total number of exposed pupils. This can be used to have a better grasp of the true impact of the earthquakes: we see that for the Machaze district, a 100-year earthquake would impact ~30% of the pupils within this district, while a 500-year year earthquake would impact almost all pupils within this district.

Table 4.30 EQ: Expected number of affected pupils at district level

	Admin NAME	Annual expected number of pupils affected AED [#/year]	RP100 [#]	RP500 [#]	Percentage exposed AED	Percentage exposed RP100	Percentage exposed AED RP500
1	Machaze	487	16,048	53,954	0.9%	29.3%	98.6%
2	Mossurize	120	-	18,683	0.2%	0.0%	36.1%
3	Cidade da Beira	117	-	-	0.1%	0.0%	0.0%
4	Lago	109	-	24,959	0.4%	0.0%	92.9%
5	Dondo	84	-	-	0.1%	0.0%	0.0%
6	Cidade de Lichinga	73	-	24,425	0.3%	0.0%	100.0%
7	Mutarara	57	-	-	0.1%	0.0%	0.0%
8	Lichinga	55	-	12,733	0.3%	0.0%	58.5%
9	Angonia	51	-	-	0.1%	0.0%	0.0%
10	Caia	49	-	-	0.1%	0.0%	0.0%
11	Massangena	41	-	6,003	0.6%	0.0%	80.8%
12	Ngauma	39	-	9,481	0.2%	0.0%	43.2%
13	Muanza	39	-	-	0.1%	0.0%	0.0%
14	Mabote	33	1,823	3,338	0.2%	9.4%	17.3%
15	Buzi	27	-	-	0.0%	0.0%	0.0%
16	Sanga	26	-	7,884	0.1%	0.0%	41.4%
17	Nhamatanda	25	-	-	0.0%	0.0%	0.0%
18	Chibabava	23	-	1,407	0.1%	0.0%	3.6%
19	Mossuril	21	-	-	0.1%	0.0%	0.0%
20	Chemba	17	-	-	0.0%	0.0%	0.0%

4.4.5 Cyclone wind

4.4.5.1 Estimated cyclone wind damages at national level

Table 4.31 presents the estimated monetary damages caused by cyclone wind at national level, for both conventional and unconventional classrooms.

The annual expected damage for conventional classrooms is approximately 350,000 $/year, while for conventional classrooms, build up with traditional materials, this sums up to ~ 11000 $/year, leading up to a total annual expected monetary damages of 360,000 $/year. However, this amount is much lower than, for example, the damages produced by a 100-year cyclone wind. Such a flood may result in cumulated monetary damages of up to 6,200,000 $.

Table 4.31 CW: Estimated monetary damages of affected classrooms at national level

	Conventional classrooms monetary	**Unconventional classrooms monetary**	**Sum**
AED [USD/year]	349,040	11,534	360,573
RP100 [USD]	6,053,320	155,024	6,208,344

In order to estimate the number of affected classrooms and pupils, the building level vulnerability curves have been used, to which a reduction factor was applied. This approach gives the most reliable results, on a comparable scale to the UN Habitat conclusions. A 10% reduction factor was used for conventional classrooms and a 10% reduction factor for unconventional classrooms and pupils. These numbers are based on the maximum wind speed values in the hazard files, related to the areal level vulnerability curves.

Using this approach, the annual average conventional classroom affected by coastal flooding is equal to 199, while for unconventional classrooms, the annual average is equal to 168. However, a 100-year coastal flood would result in a much higher number of affected classrooms, up to 2316 and 1729 for conventional and respectively unconventional classrooms.
The annual average of affected pupils affected by coastal flooding is in the order of 40000 pupils, while the estimated number of affected pupils by a 100-year coastal flood would result in approximately 416,000 pupils affected (Table 4.32)

Table 4.32 CW: Estimated number of affected classrooms and pupils at national level

	Conventional classrooms count	**Unconventional classrooms count**	**Pupils count**
AED [#/year]	199	168	39,888
RP100 [#]	2316	1729	416,104

4.4.5.2 *Estimated cyclone wind damages at district level*

At district level, Figure 4.33 shows the annual expected damage for conventional and unconventional classrooms in Mozambique due to coastal flooding, expressed in $/year. These figures give a visual impression of the location of the most impacted districts. As seen from Table 4.33 and Table 4.34 the districts with the highest damage are Massinga, Mocuba and Mogovolas for both conventional and unconventional classrooms.

These figures are quite different from the figures published by UN Habitat (Figure 4.34). This might be due to the thresholds used by UN Habitat to differentiate between *High*, *Moderate* and *Low* risk. These thresholds are unknown to us. Also, it is not known whether the cyclone hazard in UN-Habitat only refers to wind, or whether it includes flooding as well.

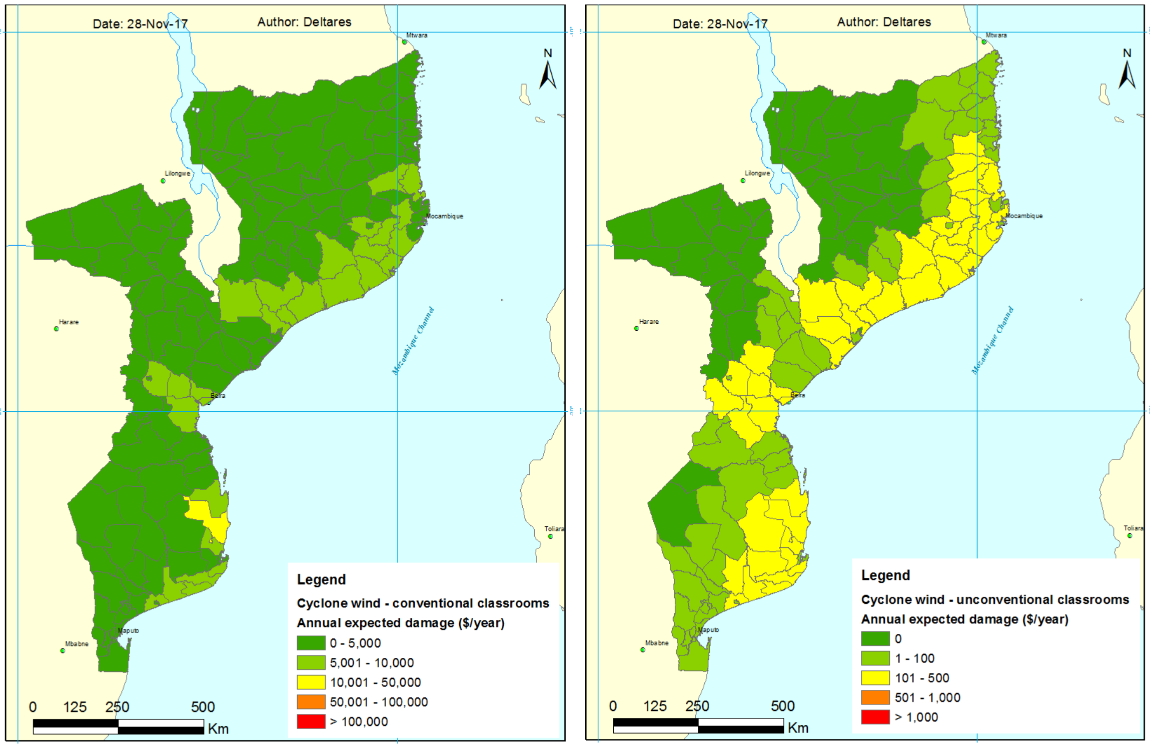


*Figure 4.33 Left: Annual expected damage for **conventional classrooms** affected by CW*
*Right: Annual expected damage for **unconventional classrooms** affected by CW*

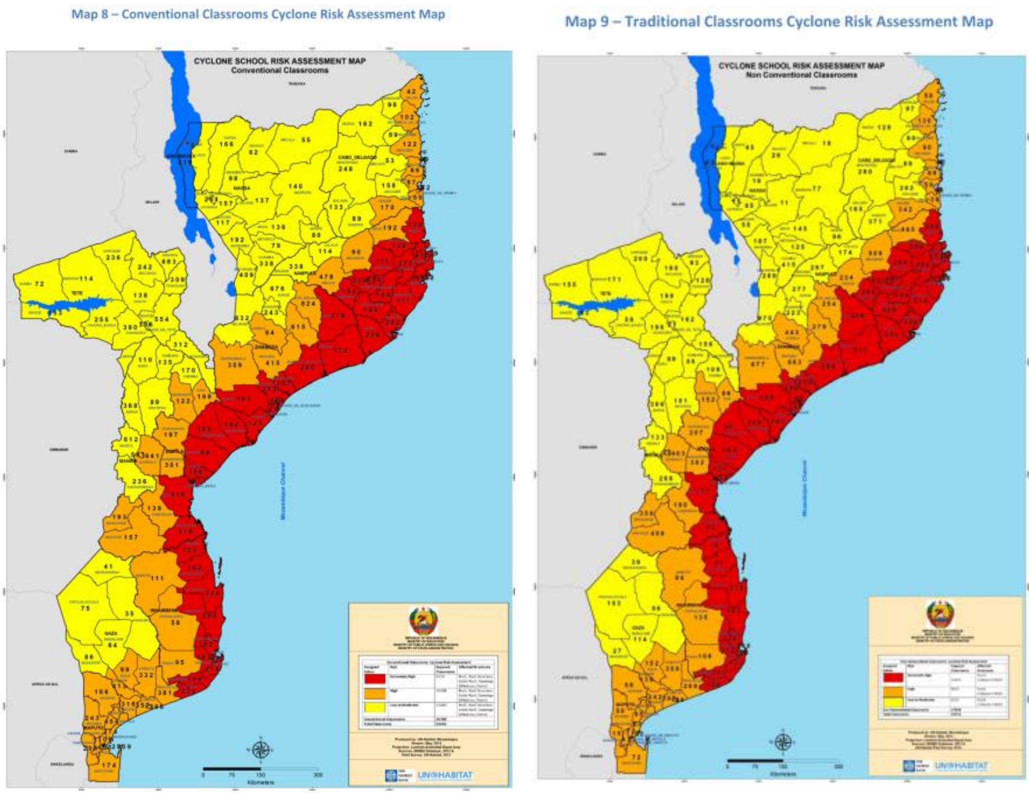


*Figure 4.34 Left: UN Habitat map for **conventional classrooms** affected by CW*
*Right: UN Habitat map for **unconventional classrooms** affected by CW*

Table 4.33 CW: Top 10 affected districts in terms of expected damage of conventional classrooms

Admin NAME	Conventional classrooms AED [$/year]	Conventional classrooms RP100 [$]
Massinga	10,364	150,053
Mogovolas	9,740	155,997
Mocuba	9,042	182,636
Maganja da Costa	8,844	134,224
Moma	8,654	130,085
Angoche	7,662	103,816
Erati	7,490	157,705
Morrumbala	7,322	158,953
Mandlakaze	7,239	116,069
Gondola	7,146	143,563

Table 4.34 CW: Top 10 affected districts in terms of expected damage of unconventional classrooms

Admin NAME	Unconventional classrooms AED [$/year]	Unconventional classrooms RP100 [$]
Massinga	384	4,441
Mocuba	340	5,442
Mogovolas	301	3,551
Maganja da Costa	298	3,533
Pebane	295	3,404
Nicoadala	283	3,556
Moma	262	3,015
Morrumbala	248	4,096
Mandlakaze	238	3,006
Erati	237	3,803

At district level, Figure 4.35 shows the annual average number of affected pupils by cyclone wind at district level. The top 20 districts are given in Table 4.35. The most affected districts are Mocuba, Morrumbala and Erati.

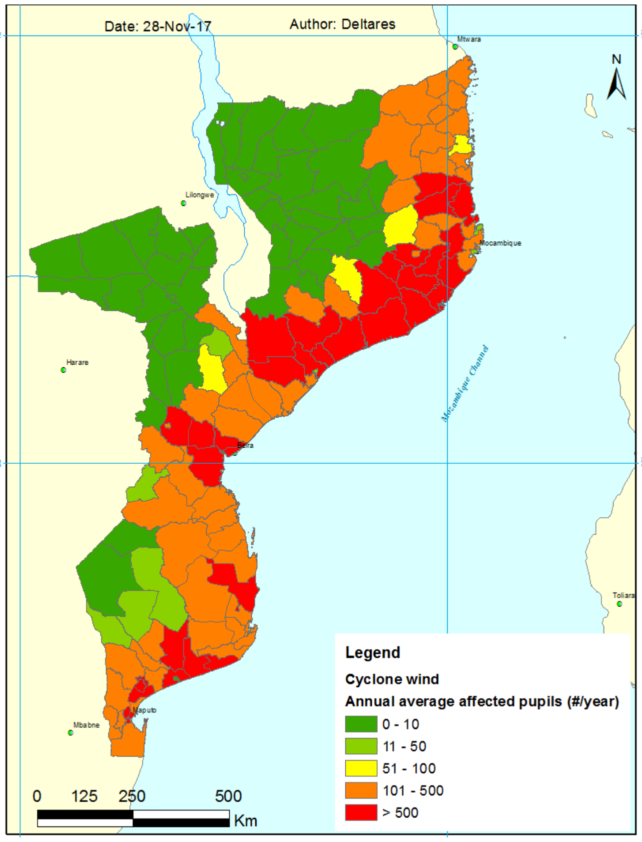


Figure 4.35 Annual expected number of pupils affected by CW

Table 4.35 CW: Estimated number of affected pupils by cyclone wind at district level

	Admin NAME	Annual expected number of pupils affected [#/year]	RP100 [#]	Percentage exposed	Percentage exposed RP100
1	Mocuba	1,454	14,536	1%	10%
2	Morrumbala	1,161	11,623	1%	8%
3	Erati	1,058	10,585	1%	10%
4	Gondola	990	10,431	1%	9%
5	Mogovolas	932	9,318	1%	10%
6	Maganja da Costa	907	9,066	1%	10%
7	Nhamatanda	842	8,417	1%	10%
8	Mandlakaze	840	8,404	1%	10%
9	Nicoadala	826	8,264	1%	10%
10	Moma	813	8,130	1%	10%
11	Cidade da Beira	782	7,823	1%	10%
12	Nampula	779	7,787	1%	9%
13	Namacurra	764	7,644	1%	10%

14	Massinga	764	7,636	1%	10%
15	Memba	752	7,517	1%	10%
16	Pebane	717	7,175	1%	10%
17	Xai-xai	706	7,057	1%	10%
18	Chiure	674	6,742	1%	10%
19	Angoche	670	6,703	1%	10%
20	Cidade da Matola	659	9,418	1%	10%

4.4.6 Landslides

The impact of the landslides on the classrooms and pupils in Mozambique has been done for two types of landslides: earthquakes induced and rainfall induced. For both types of landslides, the hazard input consists of five classes, which describes the susceptibility of the slopes to landslides. The classes are within the [1, 5] interval, with 1 representing very low susceptibility and 5 representing very high susceptibility (see Table 4.3).

Table 4.36 shows the number of conventional classrooms affected by both earthquake and rainfall induced landslides, at national scale. For each susceptibility class, the number of affected classrooms is indicated, as well as the relative percentage with respect to the total number of exposed conventional classrooms (in red). It can be noted that, for both sources of landslides, the majority of the conventional classrooms have a very low (1) and low (2) landslide susceptibility index. Rainfall induced landslides result in a higher number of conventional classrooms within the low susceptibility category (75%) compared to earthquake induced landslides (62%).

Table 4.36 LS: Estimated number of conventional classrooms affected at national level

	Conventional classrooms (#)				
	1 **Very low**	**2** **Low**	**3** **Medium**	**4** **High**	**5** **Very high**
Landslides induced by earthquakes	14,666 (37%)	24,470 (62%)	149 (0.4%)	4	-
Landslides induced by rainfall	7,952 (20%)	29,606 (75%)	1,707 (4%)	20	4

Table 4.37 shows the number of unconventional classrooms affected by both earthquake and rainfall induced landslides. Similar to conventional classrooms, most unconventional classrooms have a very low and low landslide susceptibility index.

For earthquake induced landslides, 40% of the unconventional classrooms have a susceptibility index equal to 1 (very low) and 59% have a susceptibility index equal to 2 (low).

For rainfall induced landslides, 23% of the unconventional classrooms have a susceptibility index equal to 1 (very low) and 73% have a susceptibility index equal to 2 (low).

Rainfall induced landslides seem to result in higher susceptibility (73% of unconventional classrooms in susceptibility class 2) compared to earthquake induced landslides (59% of unconventional classrooms in susceptibility class 2).

Table 4.37 LS: Estimated number of unconventional classrooms affected at national level

	Unconventional classrooms (#)				
	1 Very low	**2 Low**	**3 Medium**	**4 High**	**5 Very high**
Landslides induced by earthquakes	11,394 (40%)	16,635 (59%)	111 (0.4%)	3	-
Landslides induced by rainfall	6,486 (23%)	20,486 (73%)	1,153 (4%)	15	3

Table 4.38 presents the number of pupils that may be affected by landslides. The impact analysis results indicate that the majority of the pupils are subject to a very-low and low landslide susceptibility. However, 4.3% of the pupils may be prone to a medium landslides susceptibility index, when the landslides are induced by rainfall.

Table 4.38 LS: Estimated number of pupils affected at national level

	Pupils (#)				
	1 Very low	**2 Low**	**3 Medium**	**4 High**	**5 Very high**
Landslides induced by earthquakes	2,469,140 (37%)	4,146,120 (62%)	22,701 (0.34%)	403	-
Landslides induced by rainfall	1,298,420 (20%)	5,050,550 (76%)	286,217 (4.3%)	2,778 (0.01%)	403

4.5 Limitations

It is important to highlight that damage and risk assessment carried out in this project have several limitations. First, the assessment is based on average depth-damage functions, which do not necessarily represent the correct vulnerability of individual buildings. It is justified to assume that these variations cancel out over a large number of sample points.

Secondly, the available information on vulnerable classrooms might show discrepancies with the real world, with respect to their location, amount and vulnerability. In consequence, it might be that a number of schools have not been correctly taken into account in the damage and risk assessment.

With respect to the abovementioned limitations, it is important to interpret and analyse the results of the assessment carefully and to further investigate the feasibility of risk management strategies and retrofitting options on a smaller scale.

4.6 Summary

In this chapter, the results of the impact assessment of five natural hazards to the classrooms and pupils in Mozambique have been presented. Five types of natural hazards are considered: riverine flooding (RF), coastal flooding (CF), cyclone wind (CW), earthquakes (EQ) and landslides (LS). The focus of the study is on two types of classrooms, conventional and unconventional, following the classification of the UN-Habitat previous study. The conventional classrooms are the ones built with cement and bricks, and the non-conventional classrooms are built with local materials such as maticado, pau-a-pique (wattle and daub) and others.

Risk assessment is a product of hazard, exposure and vulnerability; therefore all these elements have been brought together in this chapter. The hazard data has been directly used from previous projects, as explained in section 4.2.1. The exposure data, comprising the amounts of classrooms exposed to different hazards, originates from three data sources, which have been combined to form a complete exposure dataset (4.2.2). The vulnerability functions, which connect the hazard intensity to the exposure in terms of monetary damage, have been also directly used from previous studies and are described in section 4.2.3.

The impact assessment has been done using the Delft-FIAT (Flood Impact Assessment Tool). This tool allows the calculation of the economic impacts of natural hazards and also the amounts of classrooms affected, using predefined thresholds of when a classroom is affected by a given hazard. When damages are substantial, they can support the justification of protection of schools against the negative impacts of hazards.

The risk assessment results are presented in two main parts: a general section, at national level (4.4.1) and per hazard dedicated sections (4.4.2 to 4.4.6). Overall, the results focus on the monetary assessments of the hazard impacts to conventional and unconventional classrooms. The number of affected classrooms and pupils has been as well determined, however these amounts are very sensitive to the choice of thresholds for which a classroom is considered affected. Because of this, the results are first presented from the perspective of monetary damages first and afterwards from the perspective of number of classrooms and pupils affected.

The total annual expected damage for Mozambique is 2,125,000 $/year for conventional classrooms and 39,000 $/year for unconventional classrooms. For conventional classrooms, the highest contribution is from coastal flooding (43%), followed by river flooding (37%), cyclone wind (16%) and earthquakes (3%). For unconventional classrooms, the contribution of cyclone wind is more significant and increases to 29%, followed by coastal flooding (36%), riverine flooding (29%) and earthquakes (6%). The coastal flooding seems to be the driving hazard for the monetary damages to classrooms; however there are reasons for which the other hazards might be underestimated. They mainly refer to the missing low return period for the riverine flood and the choice of vulnerability function for the cyclone wind.

With respect to the average number of affected classrooms, this is estimated at 292 annually affected conventional classrooms and 245 annually affected unconventional classrooms. For both conventional and unconventional classrooms, the cyclone wind has the highest contribution (~70%), followed by coastal flooding (~15%), river flooding (~13%) and earthquakes (~2%). These estimates correspond to an areal reduction factor of 10%, which aims to account for the gustiness variability of the wind hazard.

Further on, the annually expected number of affected pupils is in the order of 50,000. Cyclone winds contribute the most to the annual expected number of affected pupils (70%), followed by coastal flooding (14%), river flooding (12%) and earthquakes (3%).

5 Cost-benefit analysis of retrofitting options

5.1 Definition of retrofitting options

The intervention for school buildings is aimed at correcting possible structural defects and at providing the structure with an appropriate combination of rigidity, resistance and ductility which may ensure its increased resilience for future hazard events. Four main intervention alternatives can be defined:

- Conventional reinforcement or retrofitting: The reinforcement intervention is made in a single phase and in such a way that the school building reaches an acceptable level of resilience/reinforcement/structural strength.
- Substitution of school buildings for new buildings: It is applied when there is no technical and/or economic feasibility for structural reinforcement. It involves the demolition of the existing building, the installation of temporary classrooms, and the design and construction of a new building with increased resilience.
- Contingent intervention to prevent collapse: It is a type of reinforcement of highly vulnerable building typologies with the sole purpose of preventing collapse. It is a temporary intervention that would be carried out when the above alternatives are technically, financially or logistically impossible.

For this assignment, the focus is put on conventional reinforcement or retrofitting in order to evaluate the possible benefits of such an approach and its feasibility with respect to the associated costs.

Retrofitting consists of upgrading the existing building for increasing the resistance against natural hazards. This is done through technical interventions in the structural system of a building for optimization of the strength, ductility and load capacity. Strength of the building is generated from the structural dimensions, materials, shape, and a number of structural elements, etc. Ductility of the building is generated from good detailing, materials used, degree of resistance. Load capacity is generated from the site characteristics, mass of the structures, importance of buildings, degree of resistance, etc.

The main advantages of retrofitting are:
- It can be done in phased manner.
- There is no need for temporary structure(s)
- There is no cost associated to the total demolition of the building

The approach to define retrofitting options is based on two types of data/information. The first type of information/data consists of the technical manuals as developed by UN-Habitat for the Ministry of Education and Human Development. The second type consists of field data collection and data validation of the options from the technical manual. To that end, during a field mission, the condition of 22 schools has been assessed.

The technical manuals have been screened to define retrofitting options relevant for schools in Mozambique. Retrofitting for both riverine and coastal floods consists of the flood proofing of the structure. For cyclones, the retrofitting options include additional fixations for the roof cover and for the roof frame. Another option consists of the retrofitting of windows and doors by introducing protective beams and covers. A retrofitting option for earthquakes consists of reinforcing elements of the structure (more especially of the roof frame and the roof cover). For the hazard of landslides there is no technical manual available. In addition, no retrofitting options exist for landslides, whereas new construction should be considered following guidelines for not building in a landslide-prone area.

Due to the variety of the structural condition of a building, it is hard to develop typical rules for retrofitting. Each building will have different approaches depending on the structural deficiencies. In the design of retrofitting options, the engineer must comply with the building codes. The results generated by the adopted retrofitting techniques must fulfil the minimum requirements on the buildings codes, such as deformation, detailing, strength, etc.

The retrofitting options are therefore presented below at a conceptual level for the defined hazards, being (riverine and coastal) flooding, cyclones and earthquakes.

5.1.1 Retrofitting of non-conventional buildings

For non-conventional buildings, substitution of school buildings is recommended. It is supported by the fact that there is no technical and/or financial feasibility for structural reinforcement. In this case, substitution involves the demolition of the existing building, the installation of temporary classrooms, and the design and construction of a new building, possibly in a different location if the old building is located in a disaster prone area

5.1.2 Retrofitting of conventional buildings for flooding

Dry flood proofing (Figure 5.1) is proposed as the retrofitting option RF1 for conventional buildings in case of flooding. Dry flood proofing consists of:

- Strengthening (when possible) of the existing foundation, floors and walls, by sealing the portion of structure below flood level, using sealants, wall coating, and water proofing for sealing components, to reduce seepage of floodwaters through walls.
- Closing of the doors and windows, sewers and water lines and vents, with permanent or removable vales. Some examples of dry flood proofing include the installation of watertight shields for windows and doors. Alternatively, in Mozambique, this can be done by building steps at the entrances (doors) to prevent water to flow in for flood levels typically lower than 50 cm (see example in Figure 5.1-b).

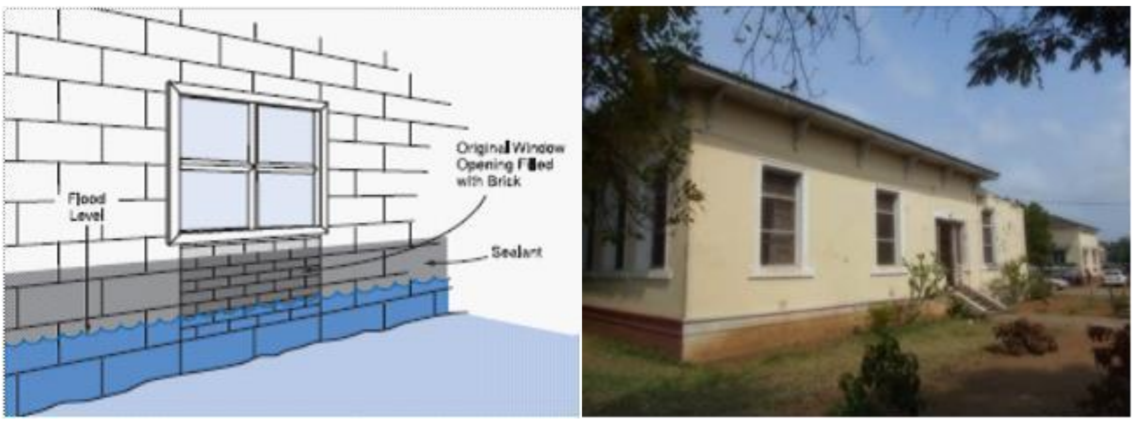


Figure 5.1 Sketch for dry flood proofing and local example of Xai Xai

For the conventional classrooms, the ‘3b’ damage curve, as defined in Figure 4.14, is adjusted by considering that no damage will occur for flood levels up to 50 cm. Above this threshold, the damage to the building will be identical to the damage occurring to the non-retrofitted building.

This has resulted in the vulnerability curves for the coastal and riverine floods illustrated in Figure 5.2, for the two non-retrofitted building with typologies conventional and unconventional, and for the dry flood proofed building.

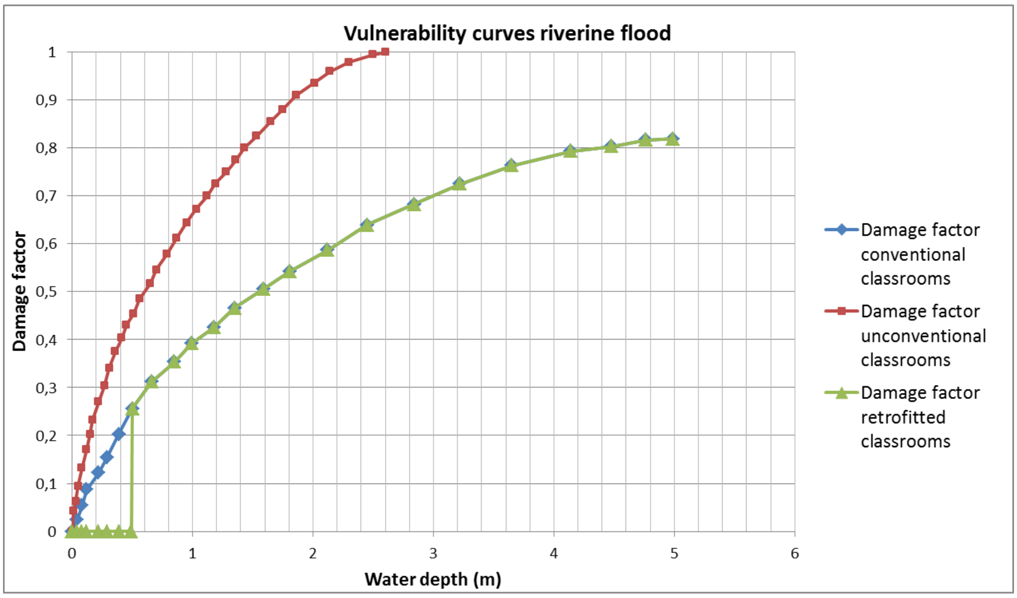


Figure 5.2 Adjusted vulnerability function for coastal and riverine floods

5.1.3 Retrofitting of conventional buildings for cyclones

Retrofitting of conventional buildings for cyclones is proposed in 3 different levels:

RF2: Improving connection between wall, frame and roof, with
- Placement of additional fixations of the roof cover to the roof frame (with connection of metal sheets to roof through ‘J’ or ‘U’ bolts, see Figure 5.3-a)
- Placement of additional framing to the roof (Figure 5.3-b)
- Installation of load wall/parapet on roof to hold the roof firmly

RF3 In addition to RF2, placing pillars to support roof extension (Figure 5.4)

RF4 In addition to RF2 and RF3, strengthening and protecting doors and windows (Figure 5.5)
- Provision of vertical bands at corners of building and door-window openings to provide them tensile strength against vertical bending
- Additional anchorage of door-window frames with holdfasts
- Use of (temporary) covers for closing the openings during the extreme events

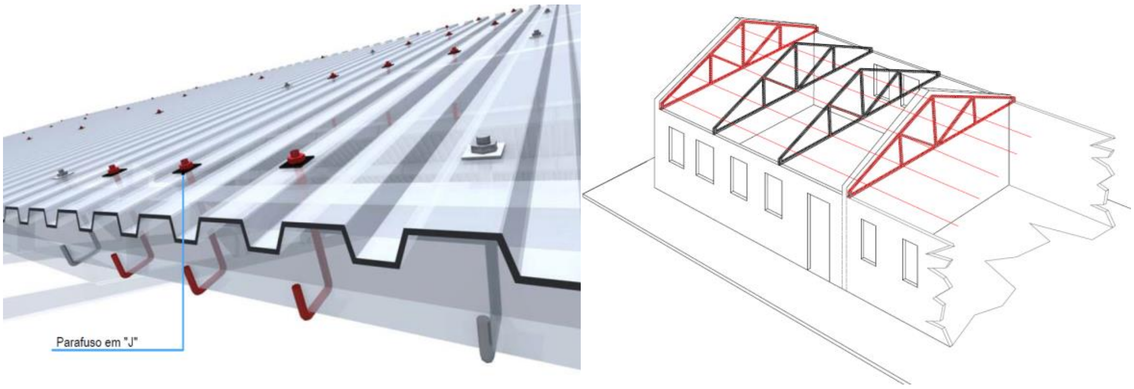


Figure 5.3   Sketch for improving connection between wall, frame and roof (from UN-Habitat, 2015)

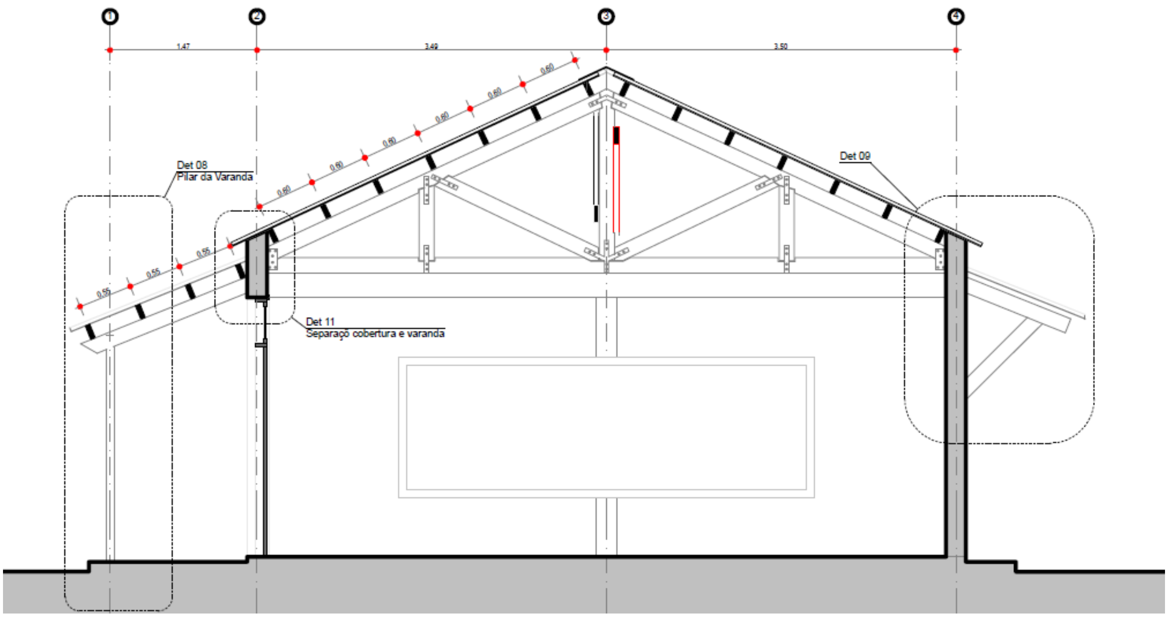


Figure 5.4   Sketch for placing pillars to support roof extension (from UN-Habitat, 2015)

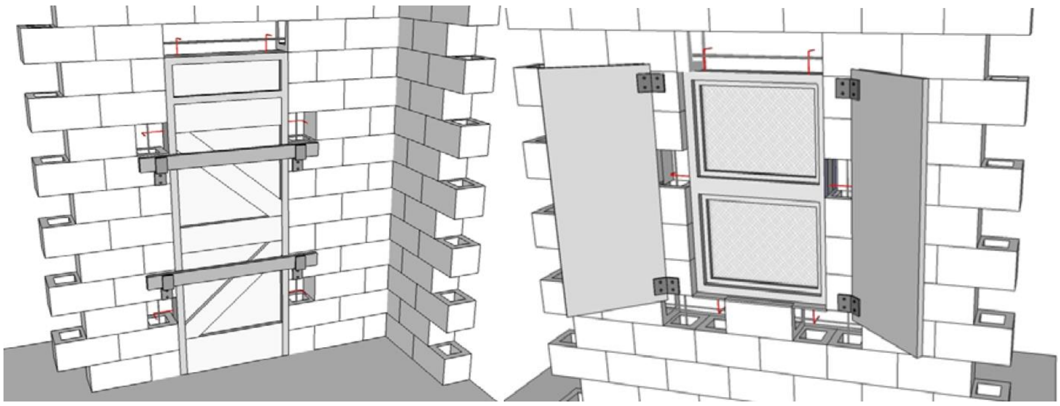


Figure 5.5   Sketch for strengthening and protecting doors and windows (from UN-Habitat, 2015)

The three above-defined options are hereinafter referred to RF2 retrofitted roof, RF3 fully retrofitted roof and RF5 fully retrofitted buildings, respectively.

The vulnerability function related to the 10 min average wind for conventional classrooms, as given in Figure 4.17, is adjusted on the basis of expert judgement to account for the three different levels, as follows:

- Retrofitted roof (RF2): Because of the improved fixing of roof sheeting to constructional framework there will be a shift of the threshold when first damages occur from 18 m/s to 23 m/s, and resulting in ~10% lowering of damage factor for 10min average wind speeds from 23 m/s to 50 m/s, maximum damage similar than to the original curve;
- Fully retrofitted roof (RF3): Because of major structural reinforcements on the roof construction, there will be a further shift of the threshold when damages occur, from 18 m/s to 30 m/s, furthermore a reduction of ~20% of damage factor for 10min average wind speeds from 30 m/s to 60 m/s, as the improvements in roof constructions will increase resilience of the room to higher wind speeds. Maximum damage similar to the original curve;
- Fully retrofitted buildings (RF4): Next to the structural reinforcements of the roof, there will be structural reinforcements to the whole building, further adding to the resilience of the classroom to wind. Because of these reinforcements no further shift of the threshold when damages occur will result, and threshold and vulnerability function will remain the same for wind speeds from 18 m/s to 30 m/s, Because of the structural reinforcements damages will be reduced with ~40% consequently lowering the damage factor for 10min average wind speeds from 30 m/s to 70 m/s. Maximum damages will also be lower due to improved constructional integrity.

The adjusted vulnerability functions are given in Figure 5.6.

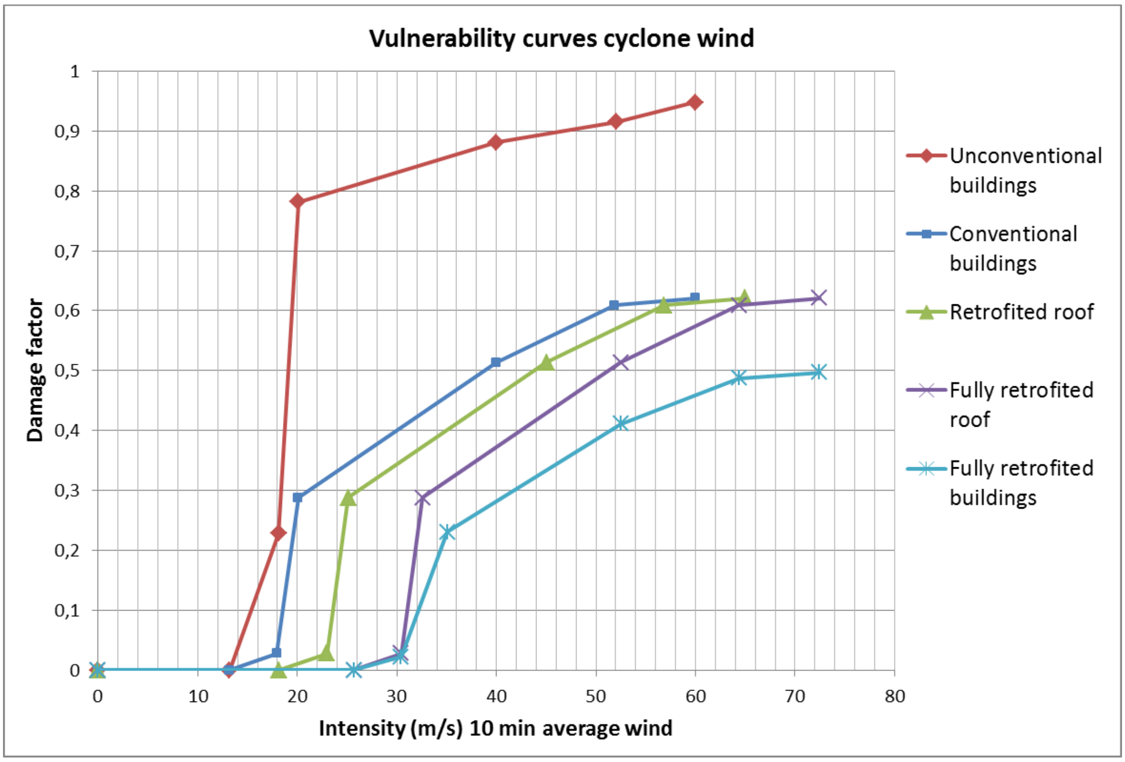


Figure 5.6 Adjusted vulnerability functions for cyclones

5.1.4 Retrofitting of conventional buildings for earthquakes

Earthquake-proof reinforcement of the building (roof and wall structure) is proposed as the retrofitting option RF5 for conventional buildings in case of earthquakes. Reinforcement can be done by:

- Placing additional fixations of the roof cover to the roof frame, and of additional framing to the roof (Figure 5.7-a);
- Placing additional pillars to support roof extension (Figure 5.7-b);
- Reinforcing the supporting walls or building corners and masonry, by providing horizontal seismic belts at plinth, lintel and gable level of building (Figure 5.8).

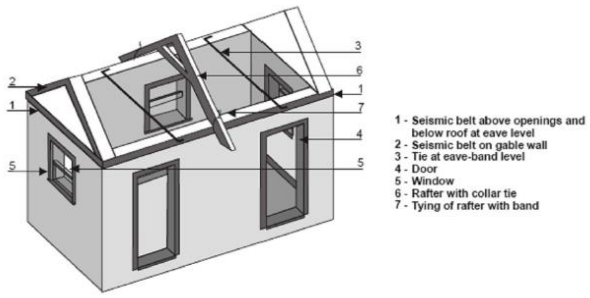


Figure 5.7 Sketch for reinforcement of the roof frame and of the roof cover (courtesy from Centre for Integrated Development, UNISDR), and local example of De Outubro

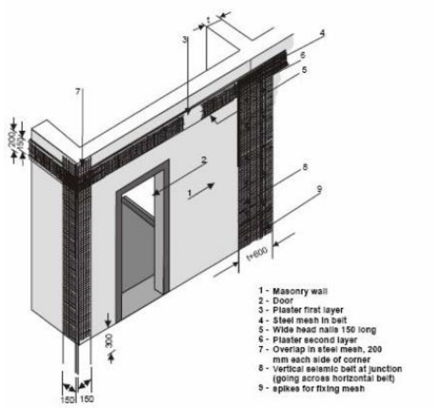


Figure 5.8 Sketch for reinforcement of supporting walls or building corners (courtesy from Centre for Integrated Development, UNISDR), and local example of De Outubro

The vulnerability curve for earthquake hazard as given in Figure 4.19 is adjusted on the basis of expert judgement, in which resistance to earthquakes of the retrofitted buildings is increased with 20% in comparison to conventional buildings resulting in a lowering of the damage factor as a function of the spectral acceleration. The adjusted vulnerability function is given in Figure 5.9.

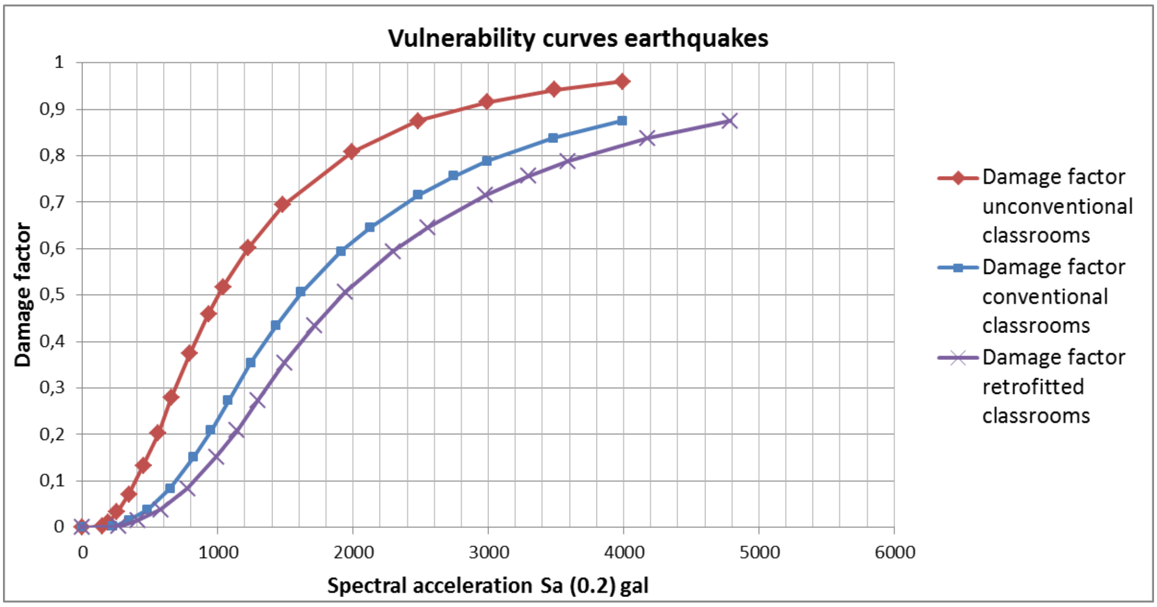


Figure 5.9 Adjusted vulnerability function for earthquakes

5.2 Cost-benefit analysis

In order to determine the economic rationale of the retrofitting options a cost-benefit analysis (CBA) of the retrofitting options has been conducted. For the CBA the differences in risks between the original and retrofitted classrooms are calculated based on the adjusted vulnerability curves. For the CBA the costs for retrofitting of a classroom is compared to the reduction in damages that is the effect of the retrofitting.

5.2.1 Costs of the retrofitting options

The costs for the retrofitting options as described in paragraph 5.1 are presented in Table 5.1 (see Appendix C details of the costing of the different options).

Table 5.1 Costs for the different retrofitting options

Retrofitting options	**Costs per classroom (USD)**
1. *Dry flood proofing (RF1)*	443
2. *Retrofitted roof (RF2)*	677
3. *Fully retrofitted roof (RF3)*	2.375
4. *Fully retrofitted buildings (RF4)*	2.760
5. *Earthquake-proof reinforcement of building (RF5)*	3.584

5.2.2 Benefits of the retrofitting options

As discussed in Paragraph 5.1 based on the effect of the retrofitting options, an adjusted vulnerability function is given for each of the five retrofitting options.

The estimated stock values as given in Table 4.5 are used. UN Habitat estimates a stock value for conventional classrooms of 500 to 650 $/m2, while MINEDH provides a value of 550 $/m2 for primary schools and 650 $/m2 for secondary schools. For the CBA, the value of

575 $/m2 is used, which is the average between the values proposed by UN Habitat and sufficiently close to the value estimated by MINEDH.

Based on the adjusted vulnerability function for the different hazards and hazard levels, adjusted damages for the different hazards and hazard level can be calculated as illustrated in Table 5.3, Table 5.3 and Table 5.4 for floods, wind and earthquakes.

Table 5.2 Damages for retrofitting for Floods in USD per classroom

Avg. Flood (cm)	Org	RF1
10	2.826	-
30	6.459	-
50	10.335	-
100	16.148	16.148

Table 5.3 Damages for the different retrofitting options[15] for wind in USD per classroom

Avg. Wind (m/s)	Org	RF2	RF3	RF4
18	1.130	-	-	-
20	11.627	404	-	-
30	16.148	13.726	1.211	1.211
40	20.589	18.167	14.937	11.304
50	24.020	22.405	19.579	15.542
60	24.626	24.424	23.213	18.167
70	24.626	24.626	24.626	20.185

Table 5.4 Damages for retrofitting for earthquakes in USD per classroom

Avg. EQ (gal)	Org	RF5
700	4.037	3.230

5.2.3 Economic evaluation

An important aspect in the economic evaluation is the ability to target the retrofitting options adequately on the schools that are actually exposed to a specific hazard, in order to avoid protecting “non-affected” classrooms. For the calculation of the risk of individual classrooms it is assumed that only classrooms will be subject to retrofitting when they are located in a hazard prone area.

For floods this can be easily derived from the flood maps. However, for wind this is more problematic, due to the nature of the exposure and the way it affects individual classrooms. Therefore for wind it is assumed that all classrooms in the whole of Mozambique are affected, with the exception of Niassa and Tete provinces, rendering the number of potentially affected classrooms to be 31.956. For earthquakes targeting of retrofitting options will be quite difficult,

[15] Note: RF2, RF3 and RF4 refer to retrofitted roof, fully retrofitted roof and fully retrofitted buildings, respectively.

as very few classrooms are affected in a number of provinces. For the purpose of calculations it is assumed that targeting can be done towards the number of classrooms mentioned in the risk profile.

In Table 5.5 the number of affected classrooms and stock value is presented per hazard. The total stock value is based on a stock value per classroom of USD 40,369, received from the local administration. This is consequently the number of classrooms that is subject to the retrofitting option in order to achieve the calculated benefits.

Table 5.5 Number of affected classrooms and stock value per hazard

Hazard	**# classrooms exposed to the hazard**	**Total stock Value (M USD)**
Floods (riverine and coastal floods)	2,379	96
Wind	31,956	1,290
Earthquakes	408	16
Total		1,403

In order to calculate the Annual Expected Damages (AED) for each of the hazards per classroom, the risk profiles as explained in Paragraph 4.4 are used to determine the AED for each of the implemented retrofitting options. For each hazard, the damages for each hazard level and return period are calculated form the adjusted vulnerability curves and the risk profiles.

The calculated damages are combined to determine the AED by including the actual hazard exposure for each individual classroom. In this way the calculated AED per classroom will be used to determine the economic feasibility for the different retrofitting options. The changes in damages as shown in Table 5.3, Table 5.3 and Table 5.4 are combined with the risk profiles from paragraph 4.4 in order to calculate the AED for a single classroom for a specific retrofitting option. The results of this calculation are presented in the Table 5.6, Table 5.7 and Table 5.8 for floods, wind and earthquakes.

Table 5.6 AED for floods for retrofitting in USD per classroom

Avg. Flood (cm)	**AED1 (USD)**
10	76
30	175
50	276
100	
Total	527

Table 5.7 AED for wind per hazard intensity and retrofitting option in USD per classroom

Avg. Wind (m/s)	AED2 (USD)	AED3 (USD)	AED4 (USD)
10			
18	7	7	7
20	70	72	72
30	3	19	19
40	0	1	2
50	0	0	0
60	-	-	-
70			-
Total	**80**	**99**	**100**

Table 5.8 AED for earthquakes for retrofitting in USD per classroom

Avg. EQ (gal)	AED5 (USD)
700	1,3
Total	1,3

Based on the AED the present value (PV) is determined for a period of 12,5 years, an old classrooms with 12,5 years remaining before replacement and for a period of 25 years for relatively new classrooms that still can be used for a minimum of 25 years. For the calculation of the PV a net interest rate of 4.5 % (discount rate of 12 % with economic growth 7.5 %, the economic growth rate over the past 10 years in Mozambique) is used.

Based on these assumptions the costs and benefits for individual classrooms can be calculated as presented in Table 5.9. From the table, it can be concluded that retrofitting with dry proofing of classrooms for floods is economically feasible for all classrooms, as both the low (12.5 years) and high (25 years) benefits are higher than the costs for retrofitting of the classroom. Also the option with retrofitted roof for wind is always feasible for all exposed classrooms. However, none of the other retrofitting options are economically feasible, as for all of the other retrofitting options the costs for retrofitting are higher than the obtained benefits. Only for Inhambane province retrofitting option RF3 (fully retrofitted roof) is economically feasible for newer classrooms, as hazard exposure for wind in Inhambane province has a higher probability than in the rest of Mozambique. More details on the CBA calculations are provided in Appendix D.

Table 5.9 Costs and Benefits for the different retrofitting options

	Costs per classroom	Avoided damages per classroom		Avoided damages (Inhambane)	
		12,5 years	25 years	12,5 years	25 years
1. *Dry flood proofing (RF1)*	443	5.106	8.236		
2. *Retrofitted roof (RF2)*	677	756	1.193		
3. *Fully retrofitted roof (RF3)*	2.375	933	1.471	1.580	2.493
4. *Fully retrofitted buildings (RF4)*	2.760	939	1.481	1.590	2.509
5. *Earthquake-proof reinforcement of building (RF5)*	3.584	13	21		

5.3 Recommendations

Based on the calculation from paragraph 5.2 it is now possible to make an estimate for the required budget for retrofitting for the exposed classrooms in Mozambique. If targeted retrofitting with dry proofing is done for coastal and fluvial floods a total of 2.379 classrooms need retrofitting (see Table 5.9). For wind, because of the difficulty in targeting the retrofitting, 31.956 classrooms would need to be provided with a retrofitted roof. This would require a total budget of USD 22.677.275 for retrofitting the classrooms with dry proofing for floods and the targeted classrooms for wind with retrofitted roof. When the option with fully retrofitted roof (RF3) is implemented for Inhambane province, the total required budget would change from USD 22.677.275 to USD 28.184.402 for including the option RF3 (fully retrofitted roof) in Inhambane province. These are fairly small amounts as compared to the total stock value of the affected classrooms which is close to USD 1.4 billion. No retrofitting for earthquakes is recommended. Details for implementing budgets and retrofitting options are presented in Table 5.10 and Table 5.11.

Table 5.10 Required budget for implementing the retrofitting option 1 (Dry flood proofing) and option 2 (Retrofitted roof) in Mozambique

Hazard	# classrooms affected	Total stock value of affected classrooms (M USD)	Retrofitting Cost/classroom (USD)	Total Budget for retrofitting (USD)
Floods	2.379	96	443	1.053.289
Wind	31.956	1,290	677	21.623.986
Total (USD)		1,386		**22.677.275**

Table 5.11 Required budget for implementing the RF1 and RF2 in Mozambique and RF3 in Inhambane province

Hazard	# classrooms affected	Total stock value of affected classrooms (M USD)	Retrofitting Cost/classroom (USD)	Total Budget for retrofitting (USD)
Floods	2.379	96	443	1.053.289
Wind	28.714	1,159	677	19.430.190
Inhambane	3.242	131	2.375	7.700.923
Total (USD)		1,386		**28.184.402**

6 Review of Representative Events

6.1 Introduction

In this chapter, reported damages to school facilities are compared with the results of the Safer Schools multi-hazard risk assessment for Mozambique. For this, the hazard information, from satellite imagery taken from major flood events, and the exposure information, as developed for the multi-hazard risk assessment, are used. The task serves two goals: (i) relating annual expected damages or the number of damaged school facilities with historical damages to school facilities to (ii) underline the credibility of the risk assessment carried out.

The chapter is structured in three main parts. In the first part, a review of recent events and the reported losses is provided. Also, available hazard information from these events are reviewed (section 6.3). In the second part (sections 6.4 and 6.5), two major flood events are compared regarding the reported losses with respect to the results of the Safer Schools risk assessment. The third part (section 6.6) provides a short discussion about the possibilities and limitations of the approach.

6.2 Review of Reported Losses

Damages to school facilities are reported repeatedly after major hazard events. The fact that school buildings are emphasised as part of the reported losses shows their high importance for the society, as they lead to significant interruptions of the education.

Flood and Cyclone Emergency (Year: 2000)

A World Bank Damage Assessment Report[16] (Post Disaster Needs Assessment, PDNA) after the flood and cyclone event in February and March 2000. It is reported that 500 primary schools (corresponding to 8 percent of all schools in the country) have been damaged due to the event. The number is broken down to 1,300 classrooms for 208,000 children within five provinces and 35 districts as well as in Maputo city, with estimated losses of USD 10.750.000.

Cyclone Funso and Tropical Storm Dando (Year: 2012)

In a 2014 press release published by World Bank[17] it is reported that the storm has damaged 1,000 classrooms along the eastern coastline.

Major Flooding in the Limpopo Basin (Year: 2013)

The same press release also mentions damages due to the 2013 flood event in the Limpopo basin, affecting 250 classrooms.

Hydro-Meteorological Events in the Central and Northern Regions (Year: 2015)

In 2015, a major hydro-meteorological flood and storm event in the Central and Northern Regions reportedly[18] affected 2,362 classroom units, mostly classrooms in Zambezia (total of 1,457 units). The total damage of the education sector estimated with US$6 million. The report mentions that "while conventional school structures (built with bricks and concrete) were able to resist the intensity of rainfall and winds,

[16] Source: http://siteresources.worldbank.org/INTDISMGMT/Resources/WB_flood_damages_Moz.pdf

[17] Source: https://www.gfdrr.org/sites/default/files/Mozambique%20SOI.pdf

[18] Source: https://www.gfdrr.org/sites/default/files/publication/Mozambique%20Report-RapidAssessment-EN.pdf

some roof covers were destroyed or heavily damaged by strong winds for a total damage of US$1.7 million." Furthermore it is stated that, "in spite of flooding in many schools, the Ministry of Education reported that those conventional structures would be fully recovered once the water dries out."
Already in January 2015, flooding along the Zambezi River, Mozambique's largest river, caused 21 schools to be flooded in the Machanga district of Sofala province. More than 7,000 pupils weren't able to go back to school[19].

<u>Cyclone Dineo (Year: 2017)</u>

In February 2017, cyclone Dineo affected the southern province of Inhambane. According to reports[20], in the more severely affected districts, the cyclone had blown the roofs off 70 per cent of the schools. The total damages in the region are estimated with 8 million Dollars.

<u>Storm and Flood Damages due to Tropical Depression (Year: 2018)</u>

More than 5 million Dollars are needed to repair storm and flood damages caused by a tropical depression in January 2018, which brought torrential rains and high winds to the northern provinces of Nampula, Niassa and Cabo Delgado[21]. Besides other infrastructure, 378 classrooms were damaged, particularly in Nampula, according to the source.

This summary of recent hazard events shows that schools are damaged by floods and cyclones on a regular basis. For the majority of event, losses cannot be attributed to either flooding or cyclones.

6.3 Review of hazard information from previous events

Hazard information from previous events is mainly available for flooding. No datasets could be found for cyclone wind records. Therefore, the analysis focuses on available data from previous flood events obtained by satellite imagery.

It is important to note that from satellite imagery only flood footprint can be generated. The flood footprint (flood extent) does not contain information about the flood depths.

Furthermore, for each event there are multiply datasets taken by different satellites (hereafter referred as sensors), at different moments with different coverages. This is due to the fact that each sensor has very specific characteristics (e.g. sensor-type, band-width, resolution, scene size, revisit interval, track, or latitude). Therefore, the imagery does not necessarily cover the entire flood event, and does not necessarily show the peak of the flood extent.

Imagery for Mozambique was found from two sources:

- http://www.unitar.org/unosat/maps/MOZ with data for events
  - 2007 Lower Zambezi Floods
  - 2008 flooding of several provinces
  - 2011 Zambezi Floods
  - 2013 Limpopo River floods
  - 2015 flooding of several provinces
  - 2017 Save River and Maputo

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[19] *Source: https://www.news24.com/Africa/News/mozambique-floods-death-toll-hits-44-schools-closed-railway-line-damaged-20170125*

[20] *Source: http://allafrica.com/stories/201702190212.html*

[21] *Source: http://allafrica.com/stories/201801230154.html*

- http://floods.unosat.org/geoportal/catalog/search/search.page
    - 2013 (5 datasets from 4 satellites)
    - 2017 (6 datasets from 2 satellites)

6.4 Comparison based on the Limpopo River flood 2013 event

Satellite imagery is available for the 2013 Limpopo River floods, published by UNOSAT[22]. The imagery is from three different sensors, namely Radarsat-2, TerraSAR-X, and SPOT-5, taken between January 24 and 29, 2013.

The comparison is carried out on two aspects: (i) review of the number of schools / classrooms affected to validate the exposure layer, and (ii) comparison of the flood extent to possibly derive an estimate of the return period of the event.

When looking at the footprints from all sensors, it is found that the 2015 Limpopo River floods are clearly a riverine event. We do not see flooding of coastal areas as represented in the coastal flood hazard datasets calculated by Deltares for the Safer Schools risk assessment.

6.4.1 Analysis of the number of affected classrooms

As mentioned above, the footprints vary significantly by sensor. The Radarsat-2 sensor has the biggest area covered. However, only 8 schools with 31 conventional and 21 non-conventional classrooms (total of 52) are within the flood footprint. Note that an additional search radius of 30 m is used in order to account for the uncertainty introduced by the sensor resolution, here 28 meters[23], as well as the fact that the point coordinates do not represent the dimensions of the entire school location, which is typically larger than 30 by 30 meters[24] (Figure 6.1).

Figure 6.1 Example of a school location close to the outlines of the flood footprint.

[22] *Source: http://www.unitar.org/unosat/node/44/1729?utm_source=unosat-unitar&utm_medium=rss&utm_campaign=maps*

[23] *The detection of the outlines of the flood footprint is less reliable than for example for large, continuous flood plains. The uncertainty is treated by using an additional search radius in the spatial analysis.*

[24] *The reports about losses repeatedly highlight that damages are not limited to the classrooms but also side buildings such as cafeteria, medical points, lavatories, etc. Therefore the entire campus should be taken into account instead of only the location of the classrooms.*

One possible reason of the relatively small number of class rooms identified, despite the large coverage of the sensor, is that the imagery is taken after the peak of the flood in the Limpopo basin. Footprints from other sensors 1 week earlier show an entirely different situation in the basin (Figure 6.2).

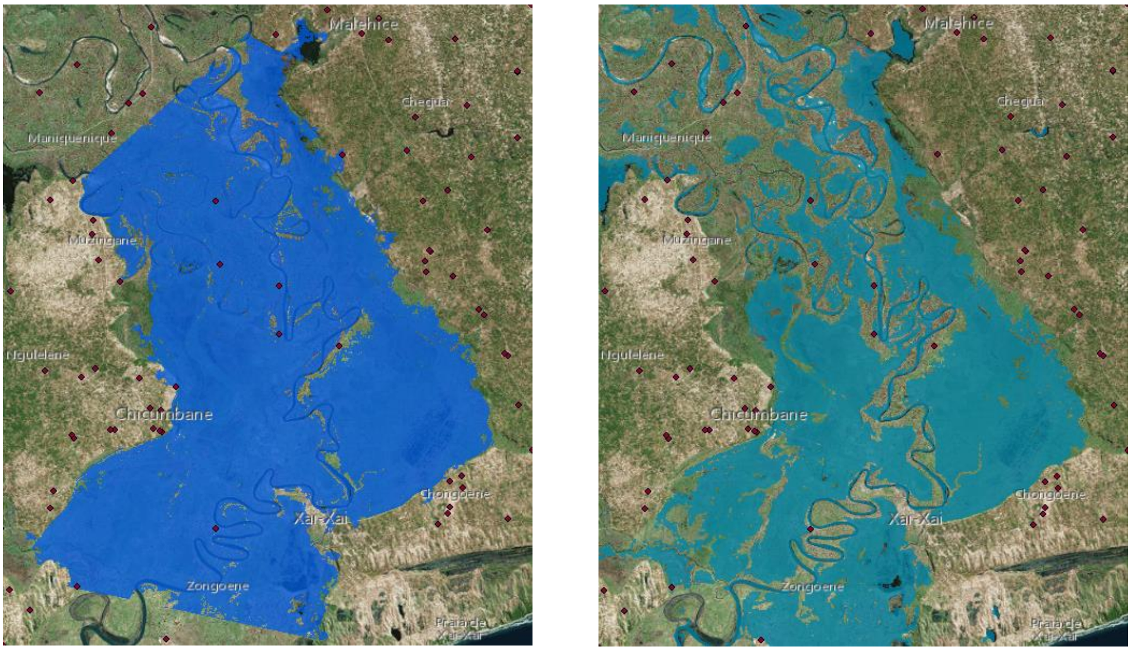

Figure 6.2 SPOT5 Imagery taken January 29 (left) compared to Radarsat-2 Imagery, taken February 2, 2013. The flood extent in the upper Limpopo River is much smaller in the second image.

The Figure 6.3 shows the footprints from both sensors combined.

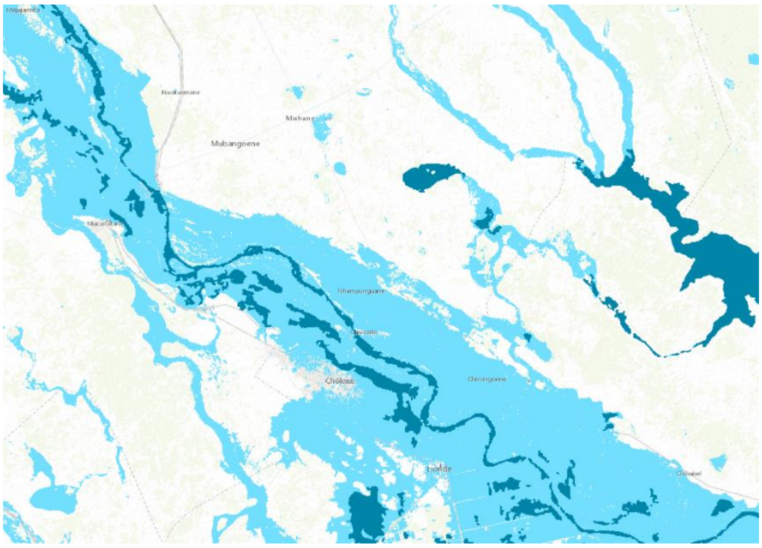

Figure 6.3 Comparison of the Spot-5 footprint taken January 29 (light blue) with Radarsat-2, taken February 2 (dark blue)

However, there is also a big difference between the sensors when looking at the same date (Figure 6.4).

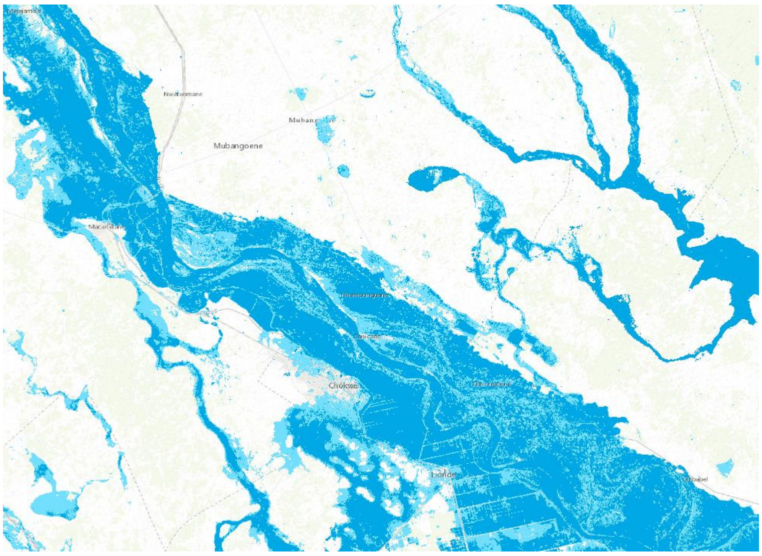

Figure 6.4 Comparison of TerraSAR-X (dark blue) versus SPOT-5 (light blue). SPOT-5 identifies a significantly larger flood extent (both images taken on January 24)

The flood footprints were therefore combined from all sensors (using the ArcGIS operation MERGE), in order to get a more complete representation of the event in the entire Limpopo basin. Note that still there may be areas which are not covered by satellite imagery.

When using an additional search radius of 30m, the MERGED dataset identifies 53 locations with 202 conventional and 132 unconventional classrooms, leading to a total of 335 affected classrooms. However, we note that some schools located to permanent water bodies have been identified too (Figure 6.5).

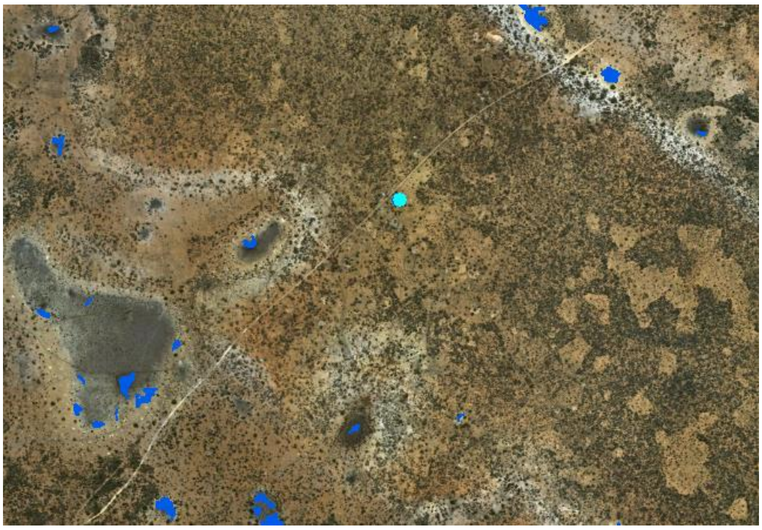

Figure 6.5 School location identified to be affected by flooding, which is located close to permanent water bodies.

When using the search radius, but remove locations close to permanent water bodies as illustrated above, the spatial query retrieves 37 locations with 132 conventional and 87 non-conventional classrooms, a total of 219 (Figure 6.6). This number is roughly in line with the 250 affected classrooms as reported in the 2014 World Bank press release.

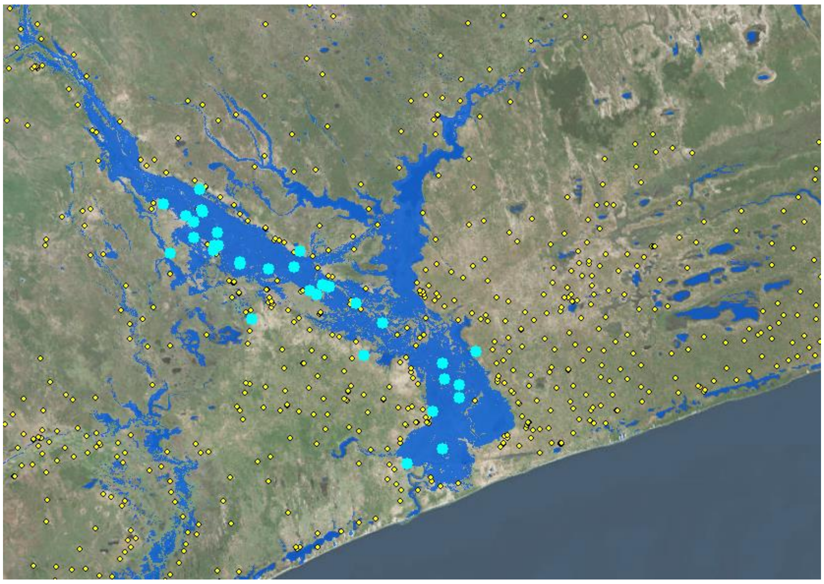

Figure 6.6 Map with 37 identified school locations within the flood footprint

6.4.2 Analysis of the flood extent

For the estimation of an approximate return period, the extent of the flood footprints from satellite imagery is compared with the riverine flood scenarios as calculated by CIMA for the Safer Schools risk assessment. It is important to note that the CIMA datasets show national maps for the same return period, say 1 in 100 years. In contrast, the 2013 Limpopo River floods are limited to the Limpopo basin, or parts hereof. Secondly, it is important to note that the CIMA datasets have a resolution of 90 meters, while the resolution of the data from satellite imagery ranges from 8.25 meters to 28 meters.

When comparing different return periods of the CIMA dataset, it is seen that there are areas with negligible differences in the extent between return periods, for within example steep valleys. The Figure 6.7shows an example of the flood extent for the 1/25 and 1/1000 flood scenario. For these areas, no statement can be made about based on the flood extent.

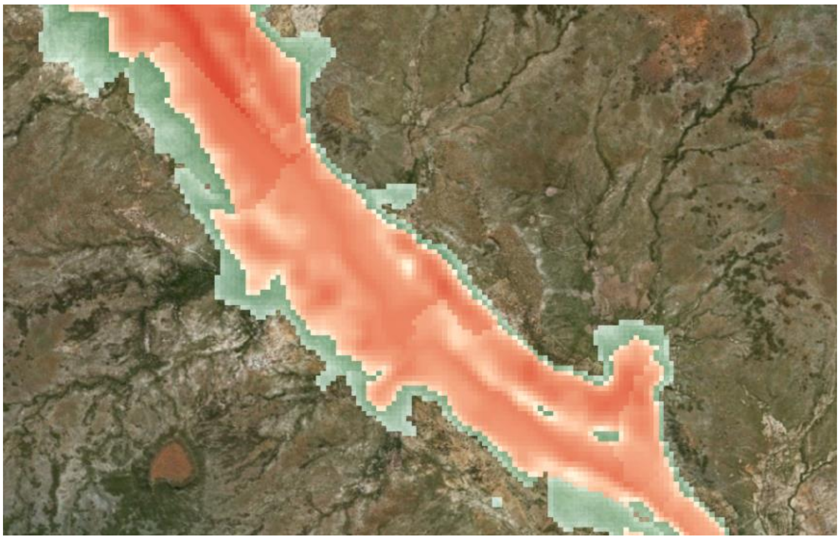

Figure 6.7 Relatively small differences in flood extent between 1/25 (red) and 1/1000 (green) dataset for parts of the Limpopo River.

Therefore, first it is required to find an area where differences are clearly visible. This is mainly expected where the river can meander naturally and different parts of the river banks are flooded sequentially.

For suitable upstream sections of the Limpopo River, the 1/25 shows a much bigger footprint than the MERGED imagery. This may be attributed to the fact that the imagery from the Radarsat-2 sensor is captured a week after the flood peak (Figure 6.8).

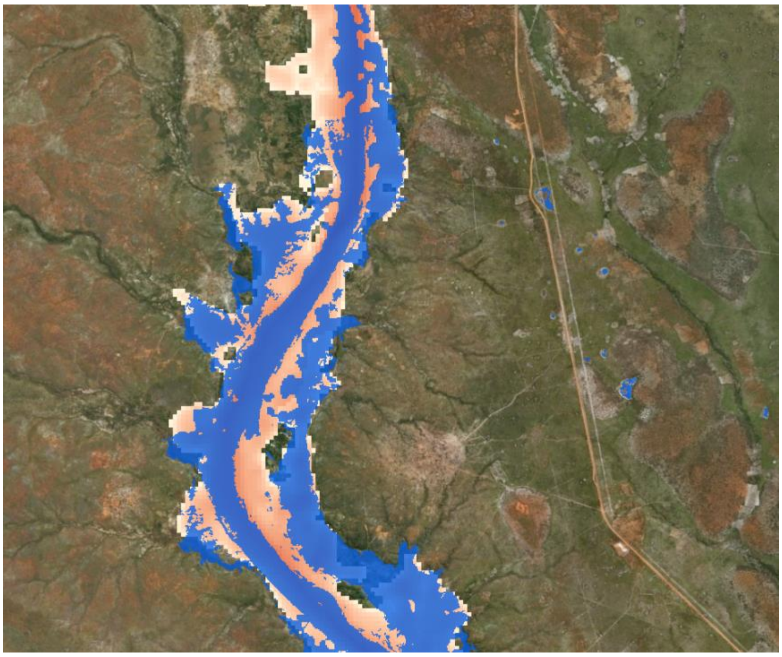

Figure 6.8 Upstream sections of the Limpopo River show a smaller footprint than in the 1/25 CIMA dataset

Close to Chokwe town, there is good agreement between the 1/25 dataset and the flood extent from imagery. Also, there are clearly visible differences between the 1/25 flood and lower return periods (the latter not shown in Figure 6.9).

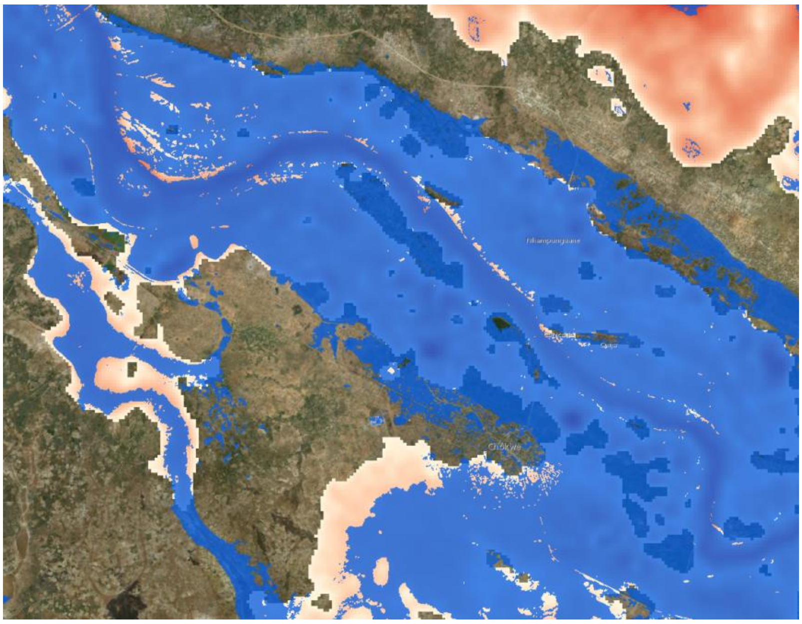

Figure 6.9 Comparison of the flood extent between the 1/25 CIMA dataset (red) and imagery (blue)

From the comparison, also performed at other parts of the river, it is concluded that the event can be roughly compared with the 1/25 return period, presumably even slightly higher. However, it should be emphasised that the assessment of the return period should be carried out based on extreme value statistics of the discharge or water levels from long-term gauge records. The comparison of the flood extent is not sufficiently reliable.

6.4.3 Comparison with the CIMA flood scenario

As a last step, the number of classrooms affected when using the 1/25 CIMA flood dataset is compared. For the calculation, the flood scenario for the lower Limpopo River only is exported, where the flood is most significant in the dataset from the satellites (Figure 6.10).

The spatial query identifies 39 school locations in the flood extent, with 139 conventional and 98 non-conventional classrooms affected, a total of 237. The analysis is again roughly in-line with the 250 classrooms reported in the 2014 World Bank press release.

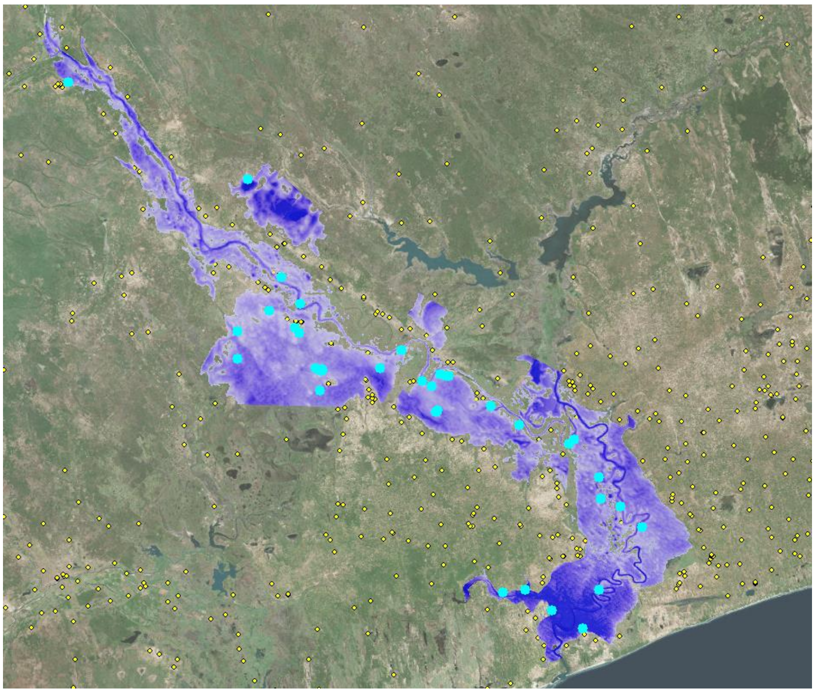

Figure 6.10 Locations identified to be affected in a 1/25 flood scenario, based on the CIMA dataset

6.5 Comparison based on the 2015 hydro-meteorological event

In the 2015 hydro-meteorological event, 2362 classroom units were affected. Mostly classrooms in Zambezia province were affected with 1457 units. This event is the biggest event recorded from the events listed above.

Satellite imagery[25] is captured between January 18, 2015 and February 13, 2015 by different sensors: LandSat, MODIS, Radarsat-2, COSMO SkyMed, Sentinel-1 (Pre-Flood).

From the description of the event, and the fact that the rainfall was cyclone-induced, the event can be characterised as a combination of riverine and coastal flooding.

[25] *available from http://www.unitar.org/unosat/maps/MOZ*

6.5.1 Analysis of the number of affected classrooms

The flood footprints from all sensors are merged in order to get the most complete picture of the overall flood extent.

Under consideration of a 30 m search radius, 46 school locations are identified with 154 conventional and 113 non-conventional classrooms, a total of 167. However, from imagery it is also noticed that a number of school locations is completely enclosed by flood waters, which would be considered as being affected.

Therefore, the search radius was slightly increased to 100 m, also to cover situations as shown in Figure 6.11, where the point location is just outside the flooded area (light blue spot), but large parts of the campus are within the flood extent (upper half of the campus)

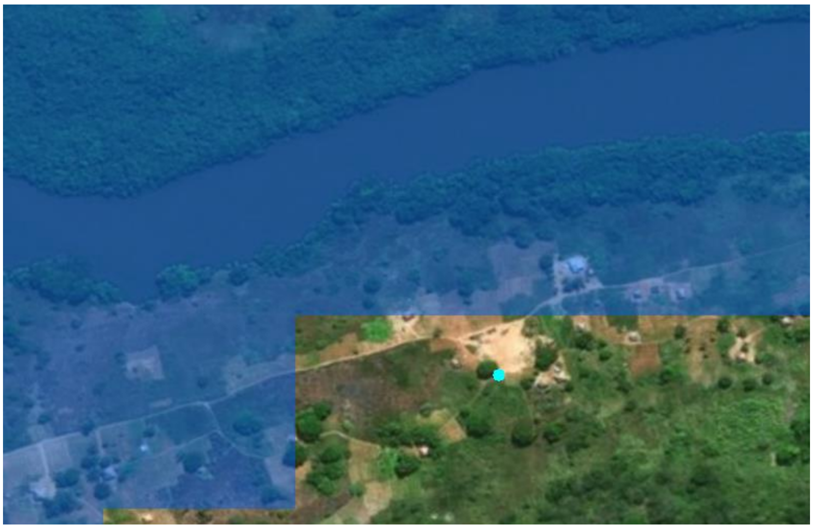

Figure 6.11 Example of a school location close to the outlines of the flood footprint.

With a 100 m search radius, 125 locations are identified with 376 conventional and 279 non-conventional classrooms, a total of 655 (Figure 6.12).

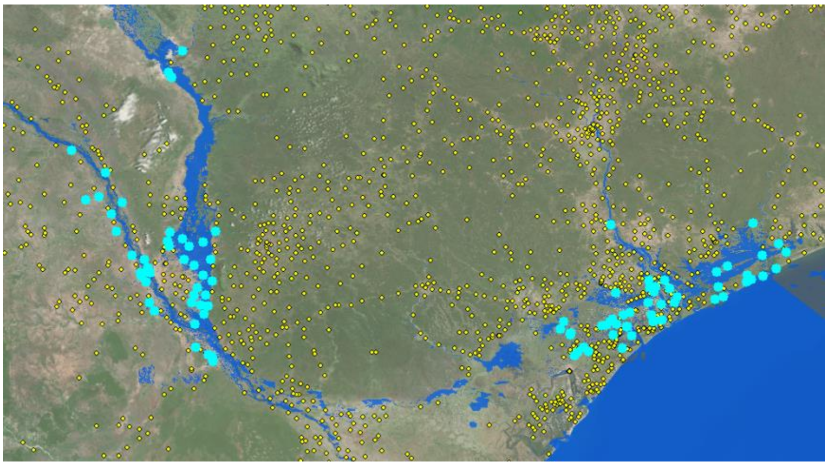

Figure 6.12 School locations identified to be affected by the 2015 hydro-meteorological event.

From the 2015 PDNA, it is understood that a majority of the damages is attributed to the Cyclone, including walls and roofs destroyed. For example, Table 6 on page 11 of the PDNA lists recovery and retrofitting measures on 2925 class rooms.

It is therefore assumed that only a smaller number of schools were affected by flooding, the exact number is however not stated in the PDNA. Therefore, our current findings cannot be compared with the reported numbers.

6.6 Discussion

The overall goal of this task was to compare the outcomes of the Safer Schools risk assessment with reported loss numbers for school buildings, in order to underline the credibility of the risk assessment carried out.

A number of recent events has been review, as well as the number of school buildings reported to be affected or damaged. The review shows that schools are damaged by floods and cyclones on a regular basis.

In the Safer Schools risk assessment it is reported that 45 conventional and 32 non-conventional classrooms are affected annually by floods. From the review of a limited number of recent flood events, it may be concluded that the reported number of classrooms affected on annual average is for larger than 10, but not higher than 100 classrooms. However, particularly smaller flood events are not covered in such reports, which might also affect a significant number of classrooms each year.

When comparing the reported losses with the flood footprints from remote sensing, uncertainties are noticed, including:

(i) The extent of the satellite imagery: the entire flood footprint is not seen, but only sections, derived from different passes of the sensors at different moments in time.
(ii) The sensor characteristics: Depending on the sensor characteristics, different impressions of the flood event can be obtained. For example, the resolution of the sensor and the wavelength particularly influence how flooded areas are identified. For a number of sensors, the flood footprint cannot be identified for areas where clouds are present.
(iii) Reporting of the damages: For most events, it is no well-documented in which areas the classrooms have been counted. Particularly during the flood event, only the accessible part of the flooded area can be surveyed.
(iv) Definition of affected: It remains unclear when a classroom is classified as being affected. For example, if a school cannot be reached anymore because it is completely surrounded by flooding, it may be seen as being affected. However, in the Safer Schools risk assessment affected is defined as being flooded for at least 30 cm.
(v) Cause of the damage: For the combined hydro-meteorological events, it is not reported which hazard caused the damages. Therefore, the comparison with remote sensing data is limited.

Therefore, the results of the validation of the Safer Schools risk assessment based on reported losses should be interpreted with care. However, even with the existing limitations it was possible to show that the results are in the right order of magnitude, which underlines the credibility of the risk assessment carried out.

7 Outreach

7.1 Communication strategy

The aim of this project is to further understand and assess the risk to the school sector in Mozambique through a multi-hazard disaster risk assessment of school infrastructure. This has been addressed in this project by (i) assessing the impact of floods, cyclones, earthquakes and landslides on schools and (ii) quantifying the cost and benefits of retrofitting schools for the purpose of enhancing the resilience of these schools to natural hazards.

The results from this study and earlier research such as the UN-Habitat report as well as experiences from recent historical events show that a large number of schools in Mozambique have been built in disaster prone areas. Therefore, it is of great importance that the school sector of Mozambique will make better use of available hazard and risk information to inform their decisions on building new schools or retrofitting existing schools to increase the resilience of the school sector in Mozambique.

To support this, the outreach strategy focus on (i) raising awareness on the importance of enhancing the resilience of schools through risk-informed decision making and (ii) building technical capacity within the school sector in Mozambique on enhancing the resilience of schools. This has been achieved through two events, held in 2018 in Maputo, Mozambique. During a high-level meeting and a technical workshop, the findings of the risk assessment and cost-benefit analysis for retrofitting have been presented to local experts and stakeholders involved in the Safer Schools initiative in Mozambique.

7.2 Restitution meetings

The meetings, held on 2018 March 5th and 6th in Maputo, were facilitated by the consultants (Deltares and Consultec), with logistical support from the World Bank / GFDRR, including the preparation of invitation letters, and provision of the venue for the workshop.

The findings of the study were presented during a 2-hour high level event to senior government officials from the Ministry of Education and Human Development. The aim of this meeting was to raise awareness of the importance of enhancing the resilience of schools through risk-informed decision making among the higher management of the ministry.

The Minister, the vice-Minister and MINEDH’s “Conselho Consultivo” / Consulting Board were enthusiastic about the study and had several questions. The Minister’s closing speech incorporated several of the study results and findings.

This high level event was then followed by a 1-day workshop for a (more) technical audience consisting of staff from the Ministry of Education and Human Development, and local experts and stakeholders involved in the Safer Schools initiative in Mozambique. The main objectives of this 1-day workshop were:

1. To present the findings of the risk assessment and cost benefit analysis for retrofitting from this study,
2. To raise awareness about the importance of enhancing the resilience of safer schools,

3. To build capacity on enhancing the resilience of schools.

The presentation of findings was conducted through interactive, themed sessions. It was including presentations of the school surveys and of the related main findings, of the multi-hazard disaster risk assessment, and of the possible retrofitting options. The sessions provided ample time for audience interaction through Q&A and other interactive formats.

The capacity building focused on (i) interpreting risk information and using it in decisions on building or retrofitting schools and (ii) retrofitting schools using the guidance material already developed as part of the Safe Schools initiative and in other programmes and projects.

The technical full-day workshop was a very dynamic meeting, with participation of very interested stakeholders; both staff from MINEDH (several departments) and from other government agencies and international agencies and NGO's.

Through interactive discussions among the stakeholders, the workshop contributed to a widely supported, integral view on the risk of natural hazards to school buildings in Mozambique and provided guidance on how to enhance school safety.

One of the main outcomes of the successful technical workshop was the renewed interest in retrofitting options by the architects of MINEDH-DIEE. This led to a follow-up meeting at DIEE on the following week, with 4 of their senior staff including Director Antonino. This follow-up meeting provided further input and generated further interest in retrofitting for the school sector, to the point that DIEE is now expecting the 'policy notes' to be issued by the WB, so that DIEE can also pursue this line of action in improving classroom conditions in Mozambique.

7.3 Data provision

The results of the risk assessment are delivered in both Excel and .shp files. A consistent folder structure has been established and a naming convention is used for the results of the assessment, taking into account the following parameters (to be completed):

- country (MOZ)
- hazard (EQ, LS, RF, CF, CW)
- return period (0010, 0025, 0050, …)
- climate scenario / time slice (2010, 2050)
- indicator
  - damage class (conventional classrooms, unconventional classrooms, pupils)
  - affected (AFF_CNT)
  - monetary (MON_USD)

The result file looks like MOZ_EQ_RP1000_2010_Pupils_AFF_CNT.tif for instance. These files have been provided to WB / GFDRR at the end of the project.

7.4 Data visualization

The OpenEarth Viewer is a web application for visualizing data, models and tools in a Google Earth interface. The set-up is such that data and models from different projects and cases can be viewed at the same time, which enables the user to see the interaction between different datasets and model results. A number of tools is available to perform (simple) actions on the data or run model simulations on the fly.

General Tool Description

In (hydraulic) engineering studies and research and monitoring programs, many data, models and tools are collected and/or developed. The amount of information that is becoming available in this way is not always easily accessible for its users (i.e. project teams, program partners, clients, stakeholders). The OpenEarth Viewer is a web application that has been developed to facilitate data management and visualization in projects. The OpenEarth Viewer links to an OpenDAP sever where all data are stored and a kml server (Figure 7.1) where the visualizations are stored, following the OpenEarth principles. Tools enable users to perform (simple) actions on the data or run model simulations on the fly (such as the Interactive Design Tool for the Holland Coast).

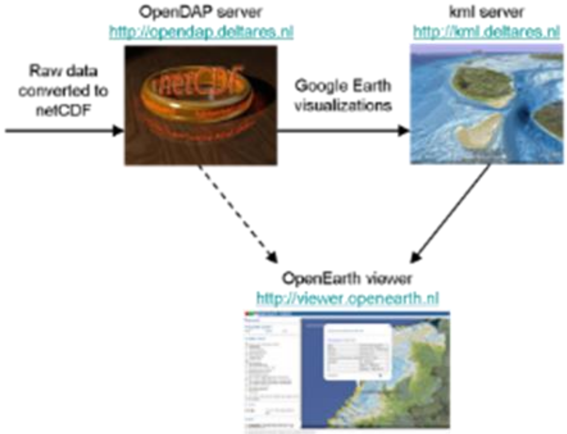

Figure 7.1 Set-up OpenEarth viewer

Usage skills

Since the OpenEarth Viewer is developed for low-end users, effort has been put in keeping the thresholds for its use as low as possible. To improve the accessibility of large amounts of data, this tool provides a versatile generic visualization interface. For user-friendliness, data are presented in a way that is engaging, easily digestible and helping to communicate complex information to non-experts. Large-scale spatial data can easily be visualized in zoomable plots using Google Earth without installing any other software.

Project interest

The infrastructure of the OpenEarth Viewer is such that it can easily be used as the interface for interactive viewing of datasets and results at the same time in a web-based environment. This contributed to the interactive communication of complex risk information to stakeholders, during the workshop with stakeholders. The datasets and results to be accessible with the OpenEarth Viewer consist of the hazard (for seismic hazard, coastal flooding, river flooding, cyclone winds and landslides), exposure (geo-referenced information on the conventional and non-conventional buildings) and of the risk (expected annual damages for all considered hazards, affected pupils and buildings for selected return periods of all considered hazards).

Figure 7.2 shows a Screenshot of the Safer Schools Online Viewer which is accessible through the following link: http://www.openearth.nl/mozambique-viewer/

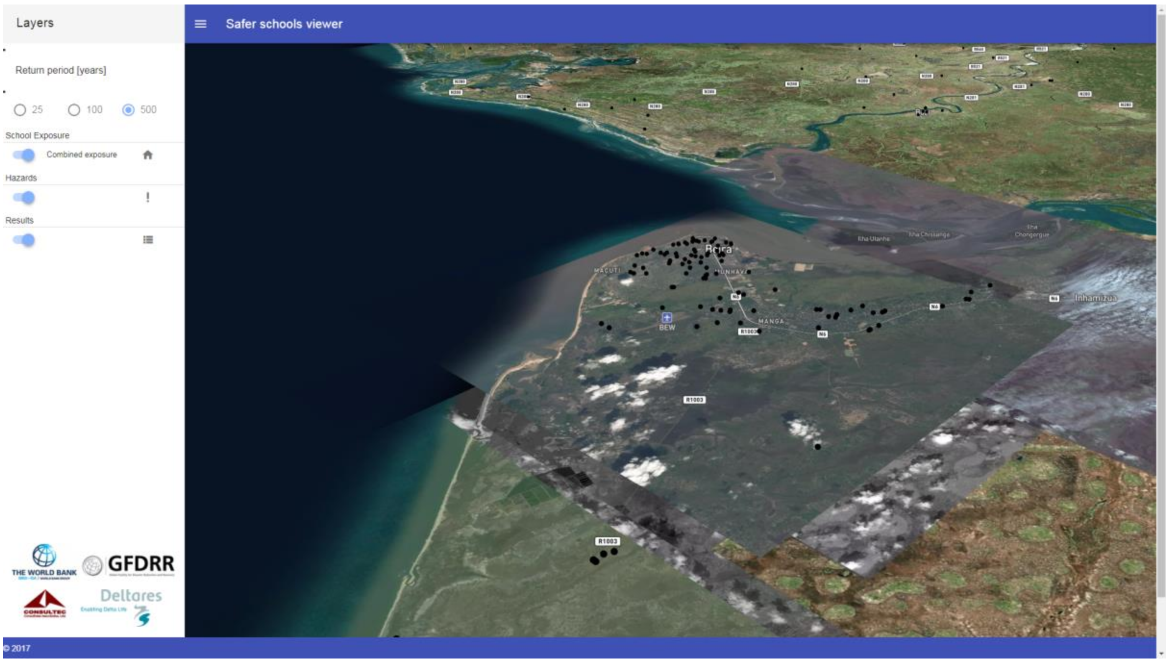

Figure 7.2 Screenshot of the Safer Schools Online Viewer (http://www.openearth.nl/mozambique-viewer/)

8 Conclusions

As part of the Safe Schools initiative and following other programmes and projects, the World Bank / GFDRR has given an assignment to Deltares to better understand the risk to the school sector in Mozambique through a multi-hazard disaster risk assessment of school infrastructure.

The project activities consisted of:

1. a multi-hazard risk assessment, with regard to seismic hazard (EQ), coastal flooding (CF), riverine flooding (FL), cyclone winds (CW) and landslides (LS) affecting the school sector on a national level, and for current climate and under climate change projections;
2. the identification of retrofitting options to protect schools from natural hazards for each identified building typology, and the estimation of costs and benefits of selected options;
3. and awareness raising about the importance of enhancing the resilience of safer schools, and capacity building.

In this assignment, hazard, exposure and vulnerability information is available from previous studies such as the R5 project and the Safer Schools project itself. The execution of the multi-hazard risk assessment is done with the Delft-FIAT model. At national level, the annual expected damage is estimated to be 2,125,000 $/year and 39,000 $/year for conventional and unconventional classrooms, respectively, with a total stock value of affected classrooms of close to USD 1.4 billion. For conventional classrooms, the highest contribution is from coastal flooding (43%), followed by river flooding (37%), cyclone wind (16%) and earthquakes (3%). For unconventional classrooms, the contribution of cyclone wind is more significant and increases to 29%. Further, it is estimated that coastal flood is responsible for 36% of the annual damages, the riverine flood for 29% and the earthquakes for 6%.

Five retrofitting options have been presented, consisting of dry flood proofing, retrofitted roof (additional fixations), fully retrofitted roof (additional fixations and pillars), fully retrofitted buildings (additional fixations and pillars, and entrances protection), and earthquake-proof reinforcement of the building (strengthening of roof and walls).

The cost-benefit analysis of the retrofitting options shows that retrofitting for reduction of the damages from flood risk is economically feasible, as classrooms prone to flooding can be easily identified. However, identifying classrooms for wind retrofitting is much more difficult. Only one option for retrofitting against wind hazard by reinforcement of the roof is economically feasible. All other retrofitting options are not economically viable, unless exposed classrooms can be more precisely identified. For earthquakes there is no economic rationale for retrofitting of the buildings as the risk is very low.

9 References

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Winsemius, H. C., Van Beek, L. P. H., Jongman, B., Ward, P. J., & Bouwman, A. (2013). A framework for global river flood risk assessments. *Hydrology and Earth System Sciences*, *17*(5), 1871-1892. DOI: 10.5194/hess-17-1871-2013

A Survey reports

Mozambique Risk assessment for the School sector
Building Characteristics Survey

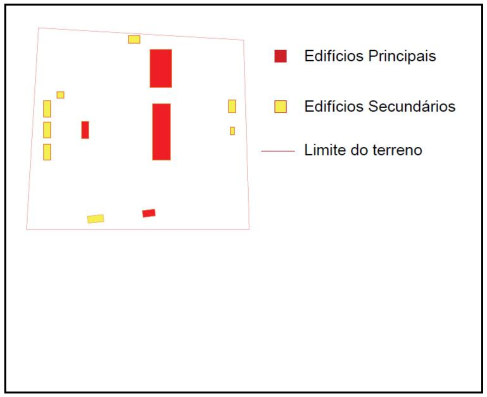
1. General information

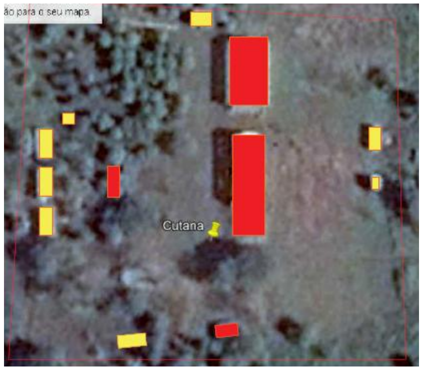
1.1. Reference
School Name: EPC Cutana
District Name: Manhiça

1.2. Location
School Address (if available): ………………………………………
Lat./long.or XY coord. (WGS84): 29º09'20,23 / 32º57'11,54''
Altitude (m): 14

1.3 School complex
Number of buildings: 12
Number of main buildings: 4
Number of ancillary buildings: 8
Number of classrooms: 4
Number of people in school: 350 S + 7 T

Total area of buildings: 532,63 m²
Total area of main buildings: 394.72 m²
Total area of ancillary buildings: 137.91 m²
Schoolyard area: 2 Ha





1.4 Educational typology

Preschool (3-6)		Upper secondary (15-18)	
Primary (6-12)	X	Vocational (varying age)	
Middle school (12-15)		Other	

1.5 Experienced past events

Earthquakes		Fluvial flood		Coastal flood		Cyclones	X	Landslides		Absent		Unknown	

If so, inform about hazard intensities, related losses (US$) and repair timescale: one of the classroom blocks lost the cover sheets and the truss and occurred a demolition of the walls of one of the classroom during last cyclone.

2. Location

2.1. Topography

Flat	X	Rough		Slope		Scarp cliff		Crest top		Valley	

2.2. Context

Urban		Rural	X	Mountain	

2.3. Soil properties

Dune		Red sand		Rock	

If other specify: clay

2.3. Access to school

By footpath		Via traffic street	X	Undefined	

2.5. Schoolyard – Fences

No fence	X	Partially fenced		Fully fenced		Low fence		High fence	

2.5. Schoolyard – Safe areas

For flood	X	For earthquake	X	For wind	

<u>3. Building characteristics</u>

3.1. Typology

Conventional	X	Non-conventional	X

Note: *Conventional* and *non-conventional* types refer to *built with cement, bricks* … and to *built with local materials such as wattle and daub*, respectively

Other specify: <u>two classrooms were built by the community with local material.</u>

3.2. Foundation

None		Dirt/Hay		Cement slab		Cement beams and slab		Other	

If other specify: <u>de uma forma geral os materiais usados são de má qualidade</u>.

Foundation height:

Normal (0.3 m or less)		Knee high (0.5 m)		Waist high (1 m)		Higher than 1 m		Absent		Unknown	X

3.3. Roof cover

Concrete		Mud/Dirt and wood/planks		Corrugated iron	X	Other	X

If other specify: <u>Zinc Sheets</u>

Roof frame:

Concrete		Wood	X	Metallic		Other	

If other specify: ………

If applicable, number of faces for the main roof:

1 face (lean-to)	X	2 faces (pitched)	X	4 faces (hipped)	

3.4. Walls

Bricks with plaster	X	Clay bricks		Soil / Mud		Bamboo/ Wood		Other	

If other specify:

3.5. Exterior elements

Doors	*yes*		Windows	*yes*	

3.6. Interior elements

Partitions		Interior doors		Stairways		Common areas		Ceiling		Water supply		Computers		Library	

Other (technical installations, teaching material …) specify: <u>the school has one borehole</u>.

3.7. General observations

in general the quality of the buildings is bad, including the conventional buildings.

4. Pictures - Location and schoolyard

Observation: Classroom block 1

Observation: Damaged classroom block

Observation: Classroom made by local material

Observation: teacher house

Observation: teacher house

Observation: sanitary block

Observation: damaged classroom block

Observation: wood truss .

Observation: cover sheets.

Observation: cracks in the classroom block 1

Observation: Cover sheets on the veranda

Observation: Cracks on the foundation protection wall

Mozambique Risk assessment for the School sector
Building Characteristics Survey

1. General information

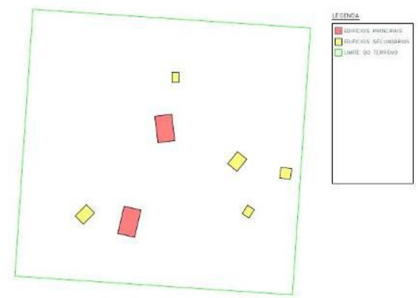
1.1. Reference
School Name: E.P Chilatine.................
District Name: Namaacha....................

1.2. Location
School Address (if available): ....
Lat. 26° 19´ 33 .50 / long. 32° 23´ 16.00
Altitude (m): ....

Number of buildings: 7
Number of main buildings: 5
Number of ancillary buildings: 2
Number of classrooms: 2
Number of people in school: 33

Total area of buildings: 89.28 m2
Total area of main buildings: 80.16 m2
Total area of ancillary buildings: 9.12 m2
Schoolyard area: 10000 m2

Floor plan



Google Earth view

1.4 Educational typology

Preschool (3-6)		Upper secondary (15-18)	
Primary (6-12)	x	Vocational (varying age)	
Middle school (12-15)		Other	

1.5 Experienced past events

Earthquakes		Fluvial flood		Coastal flood		Cyclones	x	Landslides		Absent		Unknown	

If so, inform about hazard intensities, related losses (US$) and repair timescale: A few roof sheets and roof structure were destroyed during last cyclone. Community made some repair. There is no cost recording.

2. Location

2.1. Topography

Flat	x	Rough		Slope		Scarp cliff		Crest top		Valley	

2.2. Context

Urban		Rural	x	Mountain	

2.3. Soil properties

Dune		Red sand	x	Rock	

If other specify: sand

2.3. Access to school

By footpath		Via traffic street	x	Undefined	

2.5. Schoolyard – Fences

No fence	x	Partially fenced		Fully fenced		Low fence		High fence	

2.5. Schoolyard – Safe areas

For flood	x	For earthquake	x	For wind	

3. Building characteristics

3.1. Typology

Conventional		Non-conventional	x

Note: *Conventional* and *non-conventional* types refer to *built with cement, bricks …* and to *built with local materials such as wattle and daub*, respectively

Other specify: ………

3.2. Structural – Foundation

None		Dirt/Hay		Cement slab		Cement beams and slab		Other	

If other specify: ………

Foundation height:

Normal (0.3 m or less)		Knee high (0.5 m)		Waist high (1 m)		Higher than 1 m		Absent		Unknown	X

3.3. Structural – Roof

Concrete		Mud/Dirt and wood/planks		Corrugated iron	x	Other	

If other specify: Zinc sheets

Roof frame:

Concrete		Wood	x	Metallic		Other	

If other specify: ………

If applicable, number of faces for the main roof:

1 face (lean-to)	x	2 faces (pitched)		4 faces (hipped)	

3.4. Structural – Walls

Bricks with plaster		Clay bricks		Soil / Mud	x	Bamboo/ Wood	x	Other	

If other specify: ………

3.5. Exterior elements

Doors		*No*	Windows		*No*

3.6. Interior elements

Partitions		Interior doors		Stairways		Common areas		Ceiling		Water supply	x	Computers		Library	

Other (technical installations, teaching material …) specify : Water tank only, no network; Solar Panel used for cellular phones charging.

……

……

3.7. General observations

These buildings are exposed to strong winds; the construction is very poor. The buildings are not appropriate to be used as classrooms.

4. Pictures - Location and schoolyard

Observation: Access to the school

Observation: Classrooms

Observation: Courtyard view

Observation: Interior of the classroom

Observation: Connection Detail

Observation: Detail of the roof

Observation: Teachers' houses

Observation: Fixing detail

Observation: House with solar panel

Mozambique Risk assessment for the School sector
Building Characteristics Survey

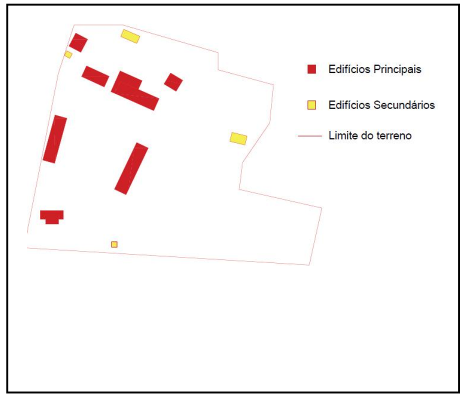
1. General information

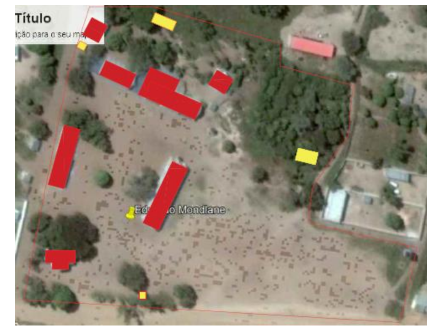
1.1. Reference
School Name: EPC Eduardo Mondlane
District Name: Marracuene

1.2. Location
School Address (if available): ……………………………………
Lat./long.or XY coord. (WGS84): 25º44´39,43'' / 32º34'38,10´´
Altitude (m): 60

1.3 School complex
Number of buildings: 11
Number of main buildings:7
Number of ancillary buildings: 4
Number of classrooms: 13
Number of people in school: 4300 S + 76T

Total area of buildings: 1.203,19 m²
Total area of main buildings: 1.067,76 m²
Total area of ancillary buildings: 135,43 m²
Schoolyard area: 2Ha





1.4 Educational typology

Preschool (3-6)		Upper secondary (15-18)	
Primary (6-12)	X	Vocational (varying age)	
Middle school (12-15)		Other	

1.5 Experienced past events

Earthquakes		Fluvial flood		Coastal flood		Cyclones	X	Landslides		Absent		Unknown	

If so, inform about hazard intensities, related losses (US$) and repair timescale: the damaged buildings have already been repaired. There is no cost recording.

2. Location

2.1. Topography

Flat	X	Rough		Slope		Scarp cliff		Crest top		Valley	

2.2. Context

Urban		Rural	X	Mountain	

2.3. Soil properties

Dune		Red sand		Rock	

2.3. Access to school

By footpath		Via traffic street	X	Undefined	

If other specify: White sand

2.5. Schoolyard – Fences

No fence	X	Partially fenced		Fully fenced		Low fence		High fence	

2.5. Schoolyard – Safe areas

For flood	X	For earthquake	X	For wind	

3. Building characteristics

3.1. Typology

Conventional	X	Non-conventional	

Note: *Conventional* and *non-conventional* types refer to *built with cement, bricks* … and to *built with local materials such as wattle and daub*, respectively

Other specify: ………

3.2. Foundation

None		Dirt/Hay		Cement slab	X	Cement beams and slab		Other	

If other specify: ………

Foundation height:

Normal (0.3 m or less)		Knee high (0.5 m)		Waist high (1 m)		Higher than 1 m		Absent		Unknown	X

3.3. Roof cover

Concrete		Mud/Dirt and wood/planks		Corrugated iron	X	Other	X

If other specify: <u>fiber cement sheets</u>

Roof frame:

Concrete		Wood	X	Metallic	X	Other	

If other specify: <u>the steel roof structure must to be analysed</u>

If applicable, number of faces for the main roof:

1 face (lean-to)	X	2 faces (pitched)	X	4 faces (hipped)	

3.4. Walls

Bricks with plaster	X	Clay bricks		Soil / Mud		Bamboo/ Wood		Other	

If other specify: ………

3.5. Exterior elements

Doors	*yes*		Windows	*yes*	

3.6. Interior elements

Partitions		Interior doors		Stairways		Common areas		Ceiling		Water supply		Computers		Library	

Other (technical installations, teaching material …) specify: <u>the school has water and electricity.</u>

3.7. General observations

In general the school is in good conditions. The roof structure of one of the buildings should be revised.

4. Pictures - Location and schoolyard

Observation: Administrative block

Observation: Classroom 1

Observation: Classroom 2

Observation: Classroom 3

Observation: Classroom 4

Observation: Classroom 5

Obser: roof steel structure to upgrade (no enough slope)

Observation: Detail of roof steel structure to upgrade

Observation: Detail of wood beam fixing

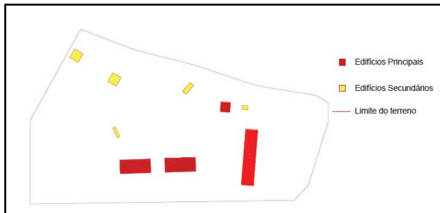
Observation: wood roof structure

Mozambique Risk assessment for the School sector
Building Characteristics Survey

1. General information

1.1. Reference
School Name: EPC Chibututuine
District Name: Manhiça

1.2. Location
School Address (if available): ....
Lat./long.or XY coord. (WGS84): 25º25'07,38'' / 32º43'56,46''
Altitude (m): 43



1.3 School complex
Number of buildings: 9
Number of main buildings: 4
Number of ancillary buildings: 5
Number of classrooms: 12
Number of people in school: 780 S + 24 T

Total area of buildings: 1443.44 m²
Total area of main buildings:1.217,38 m²
Total area of ancillary buildings: 226.06 m²
Schoolyard area: 3 Ha

1.4 Educational typology

Preschool (3-6)		Upper secondary (15-18)	
Primary (6-12)	X	Vocational (varying age)	
Middle school (12-15)	X	Other	

1.5 Experienced past events

Earthquakes		Fluvial flood		Coastal flood		Cyclones	X	Landslides		Absent		Unknown	

If so, inform about hazard intensities, related losses (US$) and repair timescale: <u>one of the classroom block lost the roof structure and cover sheets during the last cyclone.</u>

2. Location

2.1. Topography

Flat	X	Rough		Slope		Scarp cliff		Crest top		Valley	

2.2. Context

Urban		Rural	X	Mountain	

2.3. Soil properties

Dune		Red sand		Rock	

If other specify: <u>white sand</u>

2.3. Access to school

By footpath		Via traffic street	X	Undefined	

2.5. Schoolyard – Fences

No fence	X	Partially fenced		Fully fenced		Low fence		High fence	

2.5. Schoolyard – Safe areas

For flood	X	For earthquake	X	For wind	

3. Building characteristics

3.1. Typology

Conventional	X	Non-conventional	

Note: *Conventional* and *non-conventional* types refer to *built with cement, bricks* … and to *built with local materials such as wattle and daub*, respectively

Other specify: ………

3.2. Foundation

None		Dirt/Hay		Cement slab	X	Cement beams and slab		Other	

If other specify: ………

Foundation height:

Normal (0.3 m or less)		Knee high (0.5 m)		Waist high (1 m)		Higher than 1 m		Absent		Unknown	X

3.3. Roof cover

Concrete		Mud/Dirt and wood/planks		Corrugated iron	X	Other	

If other specify:

Roof frame:

Concrete		Wood		Metallic	X	Other	

If other specify: ………

If applicable, number of faces for the main roof:

1 face (lean-to)		2 faces (pitched)	X	4 faces (hipped)	

3.4. Walls

Bricks with plaster	X	Clay bricks		Soil / Mud		Bamboo/ Wood		Other	

If other specify: ………

3.5. Exterior elements

Doors	*yes*		Windows	*yes*	

3.6. Interior elements

Partitions	X	Interior doors	X	Stairways		Common areas		Ceiling		Water supply		Computers		Library	

Other (technical installations, teaching material …) specify : <u>the school has one borehole and buildings have electricity.</u>

3.7. General observations

Only one building need the replacement of the roof structures and the cover sheets. Replace of the steel structure and the cover sheets

4. Pictures - Location and schoolyard

Observation: Classroom damaged

Observation: Classroom damaged

Observation: Classroom damaged

Observation: Classroom damaged steel structure

Observation: Classroom damaged steel structure

Observation: Classroom

Observation: Classroom steel structure.

Observation: Administrative block

Observation: teacher house

Mozambique Risk assessment for the School sector
Building Characteristics Survey

1. General information

1.1. Reference
School Name: E.Primaria de Macanda

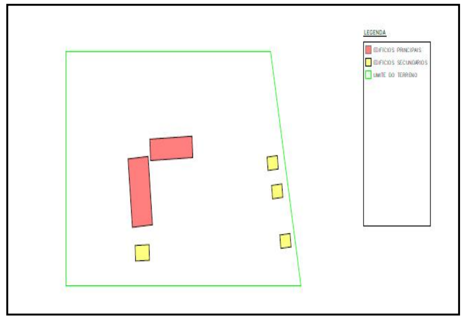
District Name: Namaacha

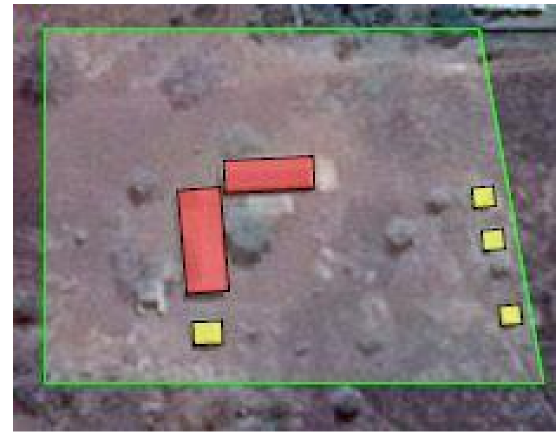
1.2. Location
School Address (if available): ....
Lat. 26° 5´ 42.50s / long. 32° 9´2.70 (WGS84):

Altitude (m): ....

1.3 School complex
Number of buildings: 6
Number of main buildings: 2
Number of ancillary buildings: 4
Number of classrooms: 5
Number of people in school: 430

Total area of buildings: 416m2
Total area of main buildings: 343.39m2
Total area of ancillary buildings: 70.768m2
Schoolyard area: 8000m2





1.4 Educational typology

Preschool (3-6)		Upper secondary (15-18)	
Primary (6-12)	x	Vocational (varying age)	
Middle school (12-15)		Other	

1.5 Experienced past events

Earthquakes		Fluvial flood		Coastal flood		Cyclones	x	Landslides		Absent		Unknown	

If so, inform about hazard intensities, related losses (US$) and repair timescale: There is a building transformed into classrooms, with the roof destroyed by a strong wind. It was replaced by the community. There is no cost recording.

2. Location

2.1. Topography

Flat	x	Rough		Slope		Scarp cliff		Crest top		Valley	

2.2. Context

Urban		Rural	x	Mountain	

2.3. Soil properties

Dune		Red sand	x	Rock	

If other specify: sand

2.3. Access to school

By footpath		Via traffic street	x	Undefined	

2.5. Schoolyard – Fences

No fence	x	Partially fenced		Fully fenced		Low fence		High fence	

2.5. Schoolyard – Safe areas

For flood	x	For earthquake	x	For wind	

3. Building characteristics

3.1. Typology

Conventional	x	Non-conventional	

Note: *Conventional* and *non-conventional* types refer to *built with cement, bricks* … and to *built with local materials such as wattle and daub*, respectively

Other specify: ………

3.2. Structural – Foundation

None		Dirt/Hay		Cement slab		Cement beams and slab		Other	

If other specify: ………

Foundation height:

Normal (0.3 m or less)		Knee high (0.5 m)		Waist high (1 m)		Higher than 1 m		Absent		Unknown	x

3.3. Structural – Roof

Concrete		Mud/Dirt and wood/planks		Corrugated iron	x	Other	

If other specify: ………

Roof frame:

Concrete		Wood	x	Metallic	x	Other	

If other specify: The main building has a metallic roof frame in good conditions.

If applicable, number of faces for the main roof:

1 face (lean-to)		2 faces (pitched)	x	4 faces (hipped)	

3.4. Structural – Walls

Bricks with plaster	x	Clay bricks		Soil / Mud		Bamboo/ Wood		Other	

If other specify: Some ancillary buildings without plaster

3.5. Exterior elements

Doors	*Yes*		Windows	*Yes*	

3.6. Interior elements

Partitions	x	Interior doors	x	Stairways		Common areas		Ceiling		Water supply		Computers		Library	

Other (technical installations, teaching material …) specify: The school uses water from the neighborhood, lack of doors in several rooms, windows broken.

3.7. General observations

Some classes have lessons under a big tree next to the classroom building. Replacement of the second building roof. The main building has a solid metallic roof structure

4. Pictures - Location and schoolyard

Observation: Acess to the school

Observation: Main building

Observation: courtyard

Observation: View of the roof structure

Observation: Structural elements connection detail

Observation: Gable Detail

Observation: Roof damaged

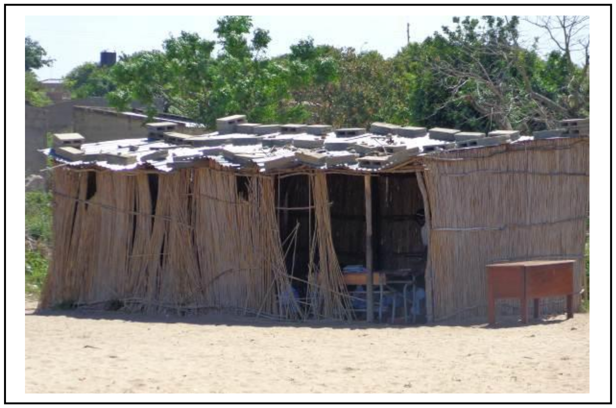
Observation: Addition area of the classroom

Observation: Detail of purlins and rafters

Observation: Room without cover

Observation: Detail of wooden structure

Observation: Detail of fastening elements



Mozambique Risk assessment for the School sector
Building Characteristics Survey

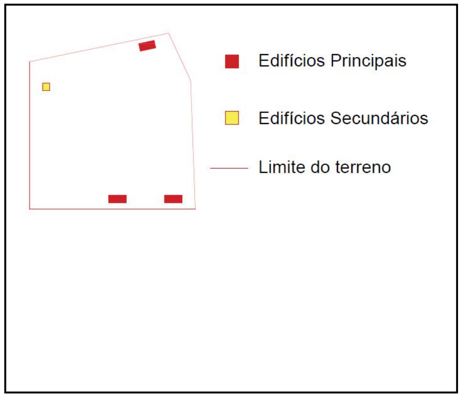
1. General information

1.1. Reference
School Name: EP de Muvecha
District Name: Marracuene

1.2. Location
School Address (if available): ....
Lat./long.or XY coord. (WGS84): 25º38'31,48''/32º40'58,08''
Altitude (m): 34

1.3 School complex
Number of buildings: 4
Number of main buildings: 3
Number of ancillary buildings: 1
Number of classrooms: 3
Number of people in school: 472 S + 6 T

Total area of buildings: 73,49 m²
Total area of main buildings: 65,82 m²
Total area of ancillary buildings: 7,67 m²
Schoolyard area: 0,5 Ha



1.4 Educational typology

Preschool (3-6)		Upper secondary (15-18)	
Primary (6-12)	X	Vocational (varying age)	
Middle school (12-15)		Other	

1.5 Experienced past events

Earthquakes		Fluvial flood		Coastal flood		Cyclones		Landslides		Absent		Unknown	

If so, inform about hazard intensities, related losses (US$) and repair timescale: ....

2. Location

2.1. Topography

Flat	X	Rough		Slope		Scarp cliff		Crest top		Valley	

2.2. Context

Urban		Rural	X	Mountain	

2.3. Soil properties

Dune		Red sand		Rock	

2.3. Access to school

By footpath	X	Via traffic street		Undefined	

If other specify: white sand

2.5. Schoolyard – Fences

No fence	X	Partially fenced		Fully fenced		Low fence		High fence	

2.5. Schoolyard – Safe areas

For flood	X	For earthquake	X	For wind	

3. Building characteristics

3.1. Typology

Conventional		Non-conventional	X

Note: *Conventional* and *non-conventional* types refer to *built with cement, bricks …* and to *built with local materials such as wattle and daub*, respectively

Other specify: the school was built by the community using local materials.

3.2. Foundation

None	X	Dirt/Hay		Cement slab		Cement beams and slab		Other	

If other specify: ………

Foundation height:

Normal (0.3 m or less)		Knee high (0.5 m)		Waist high (1 m)		Higher than 1 m		Absent		Unknown	

3.3. Roof cover

Concrete		Mud/Dirt and wood/planks		Corrugated iron	X	Other	

If other specify:

Roof frame:

Concrete		Wood		Metallic		Other	

If other specify: ………

If applicable, number of faces for the main roof:

1 face (lean-to)	X	2 faces (pitched)		4 faces (hipped)	

3.4. Walls

Bricks with plaster		Clay bricks		Soil / Mud		Bamboo/ Wood	X	Other	X

If other specify:

3.5. Exterior elements

Doors		*No*	Windows		*No*

3.6. Interior elements

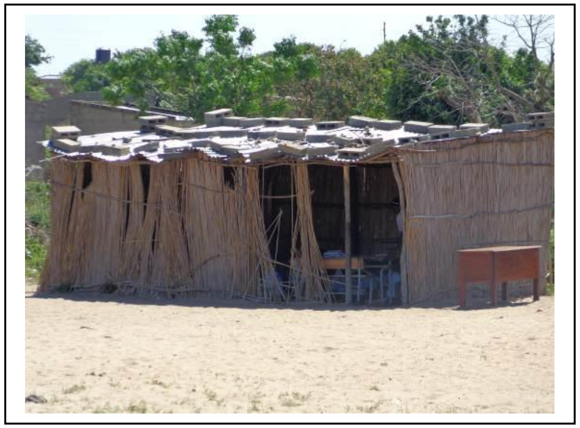
Partitions		Interior doors		Stairways		Common areas		Ceiling		Water supply		Computers		Library	

Other (technical installations, teaching material …) specify: school has no water and no electricity.

3.7. General observations

Due to the poor condition of the school, no upgrading actions have been considered. The school has no conditions to resist to any hazard. A new school must be build according the "projecto de escolas seguras".

4. Pictures - Location and schoolyard



Observation: Classroom 1

Observation: Classroom 2

Observation: Sanitary block.

Picture of school

Mozambique Risk assessment for the School sector
Building Characteristics Survey

1. General information

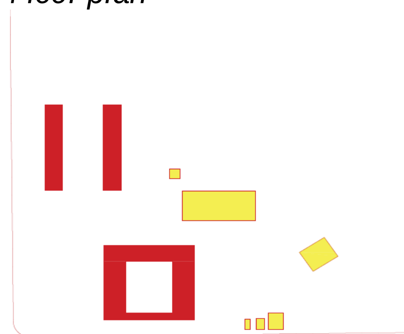
1.1. Reference
School Name: E. S. de Chokwé
District Name: Chokwé

1.2. Location
School Address (if available): Av. De Moçambique No.144
Lat./long.or XY coord. (WGS84): 24°31'45.3" / 33°00'11.9"
Altitude (m): 40 m

1.3 School complex
Number of buildings: 8
Number of main buildings: 3
Number of ancillary buildings: 5
Number of classrooms: 23
Number of people in school: 4288

Total area of buildings: 2370 m2
Total area of main buildings: 1386 m2
Total area of ancillary buildings: 904 m2
Schoolyard area: 35.562 m2

Floor plan



Google Earth view

1.4 Educational typology

Preschool (3-6)		Upper secondary (15-18)	X
Primary (6-12)		Vocational (varying age)	
Middle school (12-15)		Other	

1.5 Experienced past events

Earthquakes		Fluvial flood	X	Coastal flood		Cyclones		Landslides		Absent		Unknown	

If so, inform about hazard intensities, related losses (US$) and repair timescale: After the 2013 floods minor repairs and paintings were done in the buildings. there is no cost recording

2. Location

2.1. Topography

Flat	X	Rough		Slope		Scarp cliff		Crest top		Valley	

2.2. Context

Urban	X	Rural		Mountain	

2.3. Soil properties

Dune		Red sand		Rock	

If other specify: Clay sands

2.3. Access to school

By footpath		Via traffic street	X	Undefined	

2.5. Schoolyard – Fences

No fence		Partially fenced		Fully fenced	X	Low fence		High fence	

2.5. Schoolyard – Safe areas

For flood		For earthquake	X	For wind	X

3. Building characteristics

3.1. Typology

Conventional	X		Non-conventional	

Note: *Conventional* and *non-conventional* types refer to *built with cement, bricks* … and to *built with local materials such as wattle and daub*, respectively

Other specify: ………

3.2. Structural – Foundation

None		Dirt/Hay		Cement slab		Cement beams and slab	X	Other	

If other specify: ………

Foundation height:

Normal (0.3 m or less)		Knee high (0.5 m)		Waist high (1 m)		Higher than 1 m		Absent		Unknown	X

3.3. Structural – Roof

Concrete	X	Mud/Dirt and wood/planks		Corrugated iron	X	Other	

If other specify: ………

Roof frame:

Concrete		Wood	X	Metallic		Other	

If other specify: ………

If applicable, number of faces for the main roof:

1 face (lean-to)	X	2 faces (pitched)	X	4 faces (hipped)	X

3.4. Structural – Walls

Bricks with plaster	X	Clay bricks		Soil / Mud		Bamboo/ Wood		Other	

If other specify: ………

3.5. Exterior elements

Doors	*yes*		Windows	*yes*	

3.6. Interior elements

Partitions	X	Interior doors	X	Stairways	X	Common areas	X	Ceiling	X	Water supply	X	Computers	X	Library	

Other (technical installations, teaching material …) specify: <u>One building of 2 floors with water supply network and electricity. It has sports facilities</u>

3.7. General observations

Windows, doors and water supply network, operate with deficiency after suffering the damages caused by the floods. The roof of the old buildings is asbestos cement and needs to be replaced. After the floods of 1977 the administrative building was completely destroyed. The fence has also suffered constant falls whenever there has been a flood

During floods, the entire village is under water. There are no options for protecting of existing constructions. We propose the use of the second floor compartments for storing material and school files. For new schools, it seems that water proofing will not succeed, as water may cover all the first floor building. Build a secure block, 2 floors high in every existing and future schools, seems to be the better option.

4. Pictures - Location and schoolyard

Observation: Fence

Observation: School's main access area

Observation: central area of the school in the main building

Observation: side view of main building

Observation: rear view of the main building

Observation: new blocks of classrooms

Observation: Gym building

Observation: Volleyball court and canteen

Observation: small buildings for ancillary services

Observation: Floor traces of the old administrative building destroyed by 1979 and 2000 floods

Observation: Sealing wall reconstructed after the destruction by the 2013 floods

Observation: Concrete rain gutter erected to protect the bottom of roof sheet

Picture of school

Mozambique Risk assessment for the School sector
Building Characteristics Survey

1. General information

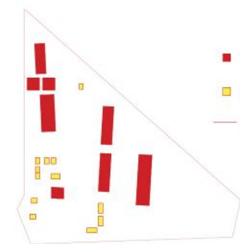
1.1. Reference
School Name: E. P. 1 e 2, 4 DE OUTUBRO
District Name: XAI-XAI

1.2. Location
School Address (if available):
Lat./long.or XY coord. (WGS84): 25°03’32.8” / 33°42’25”
Altitude (m): 45 meter

1.3 School complex
Number of buildings: 16
Number of main buildings: 5
Number of ancillary buildings: 11
Number of classrooms: 15
Number of people in school: 1624

Total area of buildings: 1.046 m2
Total area of main buildings: 491 m2
Total area of ancillary buildings: 555 m2
Schoolyard area: 4.036 m2

Floor plan



Google Earth view

1.4 Educational typology

Preschool (3-6)		Upper secondary (15-18)	
Primary (6-12)	X	Vocational (varying age)	
Middle school (12-15)	X	Other	

1.5 Experienced past events

Earthquakes		Fluvial flood		Coastal flood		Cyclones	X	Landslides		Absent		Unknown	

If so, inform about hazard intensities, related losses (US$) and repair timescale: Lots of roof sheets flown during last cyclone. Roof sheets were recovered very near the school and were resettled by the community. There is no cost recording.

2. Location

2.1. Topography

Flat	X	Rough		Slope		Scarp cliff		Crest top		Valley	

2.2. Context

Urban	X	Rural		Mountain	

2.3. Soil properties

Dune		Red sand		Rock	

If other specify: Sand

2.3. Access to school

By footpath		Via traffic street	X	Undefined	

2.5. Schoolyard – Fences

No fence	X	Partially fenced		Fully fenced		Low fence		High fence	

2.5. Schoolyard – Safe areas

For flood	X	For earthquake	X	For wind	

3. Building characteristics

3.1. Typology

Conventional	X	Non-conventional	

Note: *Conventional* and *non-conventional* types refer to *built with cement, bricks …* and to *built with local materials such as wattle and daub*, respectively

Other specify: ………

3.2. Structural – Foundation

None		Dirt/Hay		Cement slab		Cement beams and slab	X	Other	

If other specify: ………

Foundation height:

Normal (0.3 m or less)		Knee high (0.5 m)	X	Waist high (1 m)		Higher than 1 m		Absent		Unknown	X

3.3. Structural – Roof

Concrete		Mud/Dirt and wood/planks		Corrugated iron	X	Other	

If other specify: ………

Roof frame:

Concrete		Wood	X	Metallic		Other	

If other specify: ………

If applicable, number of faces for the main roof:

1 face (lean-to)		2 faces (pitched)	X	4 faces (hipped)	

3.4. Structural – Walls

Bricks with plaster	X	Clay bricks		Soil / Mud		Bamboo/ Wood		Other	

If other specify: ………

3.5. Exterior elements

Doors	*yes*		Windows	*yes*	

3.6. Interior elements

Partitions	X	Interior doors	X	Stairways		Common areas		Ceiling		Water supply		Computers		Library	

Other (technical installations, teaching material …) specify: The school has electrical power installation

3.7. General observations

Non Conventional blocks were erected after the last cyclone. They have no conditions to resist to a new cyclone. For the conventional buildings remove the existing roof sheet. Repair the roof structure based on the Safe Schools Catálogo - Ciclones. Install new roof sheets. For the non-conventional buildings, due to the poor construction, no upgrading is recommended.

4. Pictures - Location and schoolyard

Observation: school access area

Observation: A classroom block

Observation: A classroom block with roof repairs

Observation: Non-conventional building classroom

Observation: Classroom built by the community

Observation: Administrative block

Observation: Sanitary facilities

Observation: bush fence

Observation: Roof structure in one of the classroom blocks

Observation: No sheet roofs in health facilities

Observation: Roof in the non-conventional classroom

Observation: cracking between the wall and roof sheet due the effect of wind

Picture of school

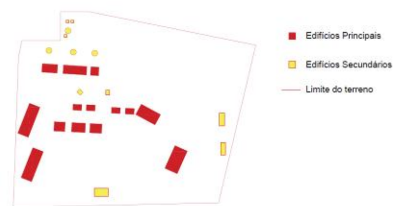
Mozambique Risk assessment for the School sector
Building Characteristics Survey

1. General information

1.1. Reference
School Name: E. P. 1 e 2 CHONGUENE
District Name: CHONGOENE

1.2. Location
School Address (if available):
Lat./long.or XY coord. (WGS84): 25°03'32.8" / 33°42'25"
Altitude (m): 45 meter

Floor plan



Google Earth view

1.3 School complex
Number of buildings: 21
Number of main buildings: 6
Number of ancillary buildings: 15
Number of classrooms: 19
Number of people in school: 2158

Total area of buildings: 1.608 m2
Total area of main buildings: 1.361 m2
Total area of ancillary buildings: 247 m2
Schoolyard area: 23.874 m2

1.4 Educational typology

Preschool (3-6)		Upper secondary (15-18)	
Primary (6-12)	X	Vocational (varying age)	
Middle school (12-15)	X	Other	

1.5 Experienced past events

Earthquakes		Fluvial flood		Coastal flood		Cyclones	X	Landslides		Absent		Unknown	

If so, inform about hazard intensities, related losses (US$) and repair timescale: Roof of classroom blocks damaged by the cyclones. Rehabilitation works were carried out through projects that made classroom blocks more resistant to cyclones. Unavailability information on the amounts involved and deadlines for execution

2. Location

2.1. Topography

Flat	X	Rough		Slope		Scarp cliff		Crest top		Valley	

2.2. Context

Urban	X	Rural		Mountain	

2.3. Soil properties

Dune		Red sand		Rock	

If other specify: Sand

2.3. Access to school

By footpath		Via traffic street	X	Undefined	

2.5. Schoolyard – Fences

No fence	X	Partially fenced		Fully fenced		Low fence		High fence	

2.5. Schoolyard – Safe areas

For flood	X	For earthquake	X	For wind	

3. Building characteristics

3.1. Typology

Conventional	X	Non-conventional	X

Note: *Conventional* and *non-conventional* types refer to *built with cement, bricks* … and to *built with local materials such as wattle and daub*, respectively

Other specify: ………

3.2. Structural – Foundation

None		Dirt/Hay		Cement slab		Cement beams and slab	X	Other	

If other specify: ………

Foundation height:

Normal (0.3 m or less)		Knee high (0.5 m)	X	Waist high (1 m)		Higher than 1 m		Absent		Unknown	X

3.3. Structural – Roof

Concrete		Mud/Dirt and wood/planks		Corrugated iron	X	Other	

If other specify: ………

Roof frame:

Concrete		Wood	X	Metallic		Other	

If other specify: ………

If applicable, number of faces for the main roof:

1 face (lean-to)		2 faces (pitched)	X	4 faces (hipped)	

3.4. Structural – Walls

Bricks with plaster	X	Clay bricks		Soil / Mud		Bamboo/ Wood		Other	

If other specify: ………

3.5. Exterior elements

Doors	*yes*		Windows	*yes*	

3.6. Interior elements

Partitions	X	Interior doors	X	Stairways		Common areas		Ceiling		Water supply		Computers		Library	

Other (technical installations, teaching material …) specify: ……………………

3.7. General observations

School has 9 conventional classrooms and 10 non-conventional classrooms. Requalify the roof of conventional buildings as per the safe school project. Two of the classroom blocks have recently been repaired using the solutions for cyclone-resistant, especially by introducing concrete gutters at the extremity/bottom of the roof sheet avoiding the wind. Construct new blocks of classrooms to replace existing non-conventional classrooms.

4. Pictures - Location and schoolyard

Observation: Classroom block next to school entrance

Observation: The two blocks of classroom rehabilitated after hit by the cyclone

Observation: School yard

Observation: Classroom in metallic structure, built by a NGO

Observation: Old classroom block still in operation, but in an advanced state of degradation

Observation: Non-conventional building classrooms

Observation: Detail of gutter constructed to collect rainwater and also to protect the roof sheet from winds

Observation: Reinforced roof structure to support the action of wind

Observation: Ceiling in advanced state of degradation

Observation: Roof of a non-conventional classroom

Observation: Roof of a metal structure classroom block

Observation: High deposit/hole for water supply, not in use

Picture of school

Mozambique Risk assessment for the School sector
Building Characteristics Survey

1. General information

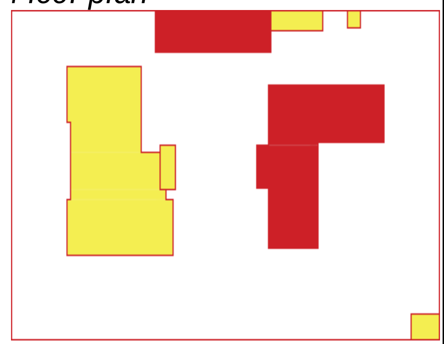
1.1. Reference
School Name: E. P. 1 e 2 grau de Xai-xai
District Name: Xai-xai

1.2. Location
School Address (if available): ....
Lat./long.or XY coord. (WGS84): 25°38'23.2" / 33°38'23.2"
Altitude (m): 4 meters

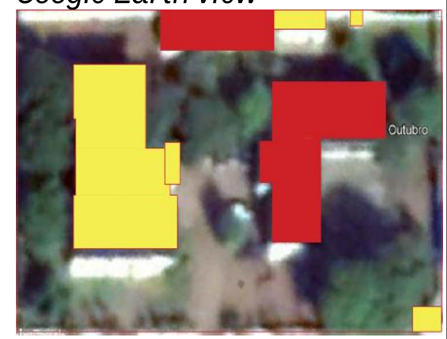
1.3 School complex
Number of buildings: 5
Number of main buildings: 3
Number of ancillary buildings: 2
Number of classrooms: 8
Number of people in school: 877

Total area of buildings: 1352 m2
Total area of main buildings: 1195 m2
Total area of ancillary buildings: 157 m2
Schoolyard area: 12591 m2

Floor plan



Google Earth view



1.4 Educational typology

Preschool (3-6)		Upper secondary (15-18)	
Primary (6-12)	X	Vocational (varying age)	
Middle school (12-15)	X	Other	

1.5 Experienced past events

Earthquakes		Fluvial flood	X	Coastal flood		Cyclones		Landslides		Absent		Unknown	

If so, inform about hazard intensities, related losses (US$) and repair timescale: Minor repairs and paintings after the floods of 2000. There is no price record on these works.

2. Location

2.1. Topography

Flat	X	Rough		Slope		Scarp cliff		Crest top		Valley	

2.2. Context

Urban	X	Rural		Mountain	

2.3. Soil properties

Dune		Red sand		Rock	

If other specify: Sand

2.3. Access to school

By footpath		Via traffic street	X	Undefined	

2.5. Schoolyard – Fences

No fence		Partially fenced		Fully fenced	X	Low fence		High fence	

2.5. Schoolyard – Safe areas

For flood		For earthquake	X	For wind	

3. Building characteristics

3.1. Typology

Conventional	X	Non-conventional	

Note: *Conventional* and *non-conventional* types refer to *built with cement, bricks …* and to *built with local materials such as wattle and daub*, respectively

Other specify: ………

3.2. Structural – Foundation

None		Dirt/Hay		Cement slab		Cement beams and slab	X	Other	

If other specify: ………

Foundation height:

Normal (0.3 m or less)		Knee high (0.5 m)		Waist high (1 m)		Higher than 1 m		Absent		Unknown	X

3.3. Structural – Roof

Concrete		Mud/Dirt and wood/planks		Corrugated iron		Other	X

If other specify: fiber cement sheets

Roof frame:

Concrete		Wood	X	Metallic		Other	

If other specify: ………

If applicable, number of faces for the main roof:

1 face (lean-to)		2 faces (pitched)		4 faces (hipped)	X

3.4. Structural – Walls

Bricks with plaster	X	Clay bricks		Soil / Mud		Bamboo/ Wood		Other	

If other specify: ………

3.5. Exterior elements

Doors	*yes*		Windows	*yes*	

3.6. Interior elements

Partitions		Interior doors		Stairways		Common areas		Ceiling		Water supply		Computers		Library	

Other (technical installations, teaching material …) specify: The School has water supply, sewage and electricity. It also has a sports field.

3.7. General observations

Because of the floods, the water supply network, sewage and electric power doors and windows, work with disability. During floods, all the village may become under water. There is no options to protect existing constructions. We propose to build a secure block, 2 floors high, inside the school yard or in another higher location, to be used to store important files and equipment during floods period.

4. Pictures - Location and schoolyard

Observation: Main access to school

Observation: Administrative and classroom block

Observation: Secretarial and classroom block

Observation: overview of the two main blocks

Observation: side and back view of the Administrative and classroom block

Observation: side and back view of the secretary block and classroom

Observation: Auxiliary services
(classroom block and canteen)

Observation: playground

Observation: school exterior - fence

Observation: Corridor with ceiling in advanced state of degradation

Observation: water leaking on ceiling.

Observation: Roof structure

Picture of school

Mozambique Risk assessment for the School sector
Building Characteristics Survey

1. General information

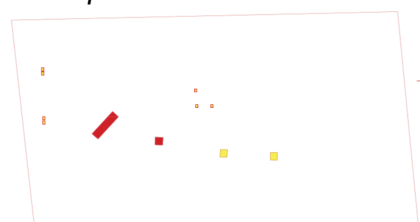
1.1. Reference
School Name: E.S. Javanhane
District Name: Gujá

1.2. Location
School Address (if available): N/A
Lat./long.or XY coord. (WGS84): 24°34’17.2” / 33°11’27.7”
Altitude (m): 46 metros

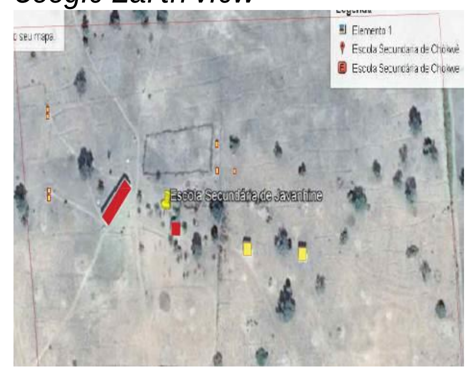
1.3 School complex
Number of buildings: 12
Number of main buildings: 2
Number of ancillary buildings: 10
Number of classrooms: 4
Number of people in school: 645

Total area of buildings: 565 m2
Total area of main buildings: 367 m2
Total area of ancillary buildings: 198 m2
Schoolyard area: 100.000 m2

Floor plan



Google Earth view



1.4 Educational typology

Preschool (3-6)		Upper secondary (15-18)	X
Primary (6-12)		Vocational (varying age)	
Middle school (12-15)		Other	

1.5 Experienced past events

Earthquakes		Fluvial flood		Coastal flood		Cyclones	X	Landslides		Absent		Unknown	

If so, inform about hazard intensities, related losses (US$) and repair timescale: No information available

2. Location

2.1. Topography

Flat	X	Rough		Slope		Scarp cliff		Crest top		Valley	

2.2. Context

Urban		Rural	X	Mountain	

2.3. Soil properties

Dune		Red sand		Rock	

If other specify: Sand

2.3. Access to school

By footpath		Via traffic street	X	Undefined	

2.5. Schoolyard – Fences

No fence		Partially fenced		Fully fenced		Low fence		High fence	

2.5. Schoolyard – Safe areas

For flood	X	For earthquake	X	For wind	

3. Building characteristics

3.1. Typology

Conventional	X	Non-conventional	

Note: *Conventional* and *non-conventional* types refer to *built with cement, bricks …* and to *built with local materials such as wattle and daub*, respectively

Other specify: ………

3.2. Structural – Foundation

None		Dirt/Hay		Cement slab	X	Cement beams and slab		Other	

If other specify: ………

Foundation height:

Normal (0.3 m or less)		Knee high (0.5 m)	X	Waist high (1 m)		Higher than 1 m		Absent		Unknown	X

3.3. Structural – Roof

Concrete		Mud/Dirt and wood/planks		Corrugated iron	X	Other	

If other specify: Zinc Sheets

Roof frame:

Concrete		Wood	X	Metallic		Other	

If other specify: ………

If applicable, number of faces for the main roof:

1 face (lean-to)		2 faces (pitched)		4 faces (hipped)	

3.4. Structural – Walls

Bricks with plaster		Clay bricks		Soil / Mud		Bamboo/ Wood		Other	X

If other specify: solid blocks of “hydroform” type, without plaster

3.5. Exterior elements

Doors	*yes*		Windows	*yes*	

3.6. Interior elements

Partitions	X	Interior doors	X	Stairways		Common areas		Ceiling		Water supply		Computers		Library	

Other (technical installations, teaching material …) specify: The walls were constructed with massive blocks of the “hydroform” type, without mortar of settlement. Do not offer security.

3.7. General observations

The “hydroform” type blocks are in bad condition. The proposal is to demolish existing buildings and build new buildings based on projects - safe schools. Due to the poor conditions, we do not propose any upgrading on the current conditions.

4. Pictures - Location and schoolyard

Observation: school access without gate

Observation: Administrative block

Observation: Material in the school grounds to construct a new classroom block

Observation: Wood structure and roofing sheets

Observation: Part of the roof damaged by cyclone

Observation: Blocks in an advanced state of degradation

Observation: cracks in the pavement

Observation: Cracks i wall/truss support

Observation: Crack at the edge of the window

Observation: Erosion in the foundations of the walk around the building

Observation: State of sanitary facilities

Observation: Water fountain

Picture of school

Mozambique Risk assessment for the School sector
Building Characteristics Survey

1. General information

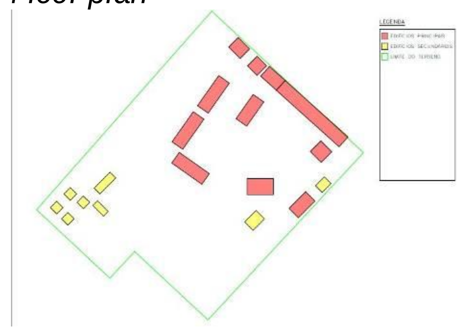
1.1. Reference
School Name: E.Secundária de Cumbana
District Name: Jangamo

1.2. Location
School Address (if available): ....
Lat. 24°08´22.3´´/long.35°13´19.2´´
Altitude (m): ....

1.3 School complex
Number of buildings: 18
Number of main buildings: 10
Number of ancillary buildings: 8
Number of classrooms: 26
Number of people in school: 3.218

Total area of buildings: 1.759m2
Total area of main buildings: 1.693
Total area of ancillary buildings: 66
Schoolyard area: 20.601m2

Floor plan



Google Earth view

1.4 Educational typology

Preschool (3-6)		Upper secondary (15-18)	
Primary (6-12)		Vocational (varying age)	
Middle school (12-15)	x	Other	

1.5 Experienced past events

Earthquakes		Fluvial flood		Coastal flood		Cyclones	x	Landslides		Absent		Unknown	

If so, inform about hazard intensities, related losses (US$) and repair timescale: Lots of roof sheets flown during last cyclone. Roof sheets were recovered and resettled by the community. There is no cost recording.

2. Location

2.1. Topography

Flat	x	Rough		Slope		Scarp cliff		Crest top		Valley	

2.2. Context

Urban		Rural	x	Mountain	

2.3. Soil properties

Dune		Red sand		Rock	

If other specify: Sand

2.3. Access to school

By footpath		Via traffic street	X	Undefined	

2.5. Schoolyard – Fences

No fence		Partially fenced		Fully fenced	x	Low fence		High fence	

2.5. Schoolyard – Safe areas

For flood	x	For earthquake	x	For wind	

3. Building characteristics

3.1. Typology

Conventional	x	Non-conventional	

Note: *Conventional* and *non-conventional* types refer to *built with cement, bricks* … and to *built with local materials such as wattle and daub*, respectively

Other specify: ………

3.2. Structural – Foundation

None		Dirt/Hay		Cement slab		Cement beams and slab		Other	

If other specify: ………

Foundation height:

Normal (0.3 m or less)		Knee high (0.5 m)		Waist high (1 m)		Higher than 1 m		Absent		Unknown	x

3.3. Structural – Roof

Concrete		Mud/Dirt and wood/planks		Corrugated iron		Other	x

If other specify: 1 building with fiber cement sheets. Zinc sheets in others

Roof frame:

Concrete		Wood	x	Metallic	x	Other	

If other specify: ………

If applicable, number of faces for the main roof:

1 face (lean-to)		2 faces (pitched)	x	4 faces (hipped)	

3.4. Structural – Walls

Bricks with plaster	x	Clay bricks		Soil / Mud		Bamboo/ Wood		Other	

If other specify: ………

3.5. Exterior elements

Doors	*Yes*		Windows	*Yes*	

3.6. Interior elements

Partitions	x	Interior doors	x	Stairways		Common areas		Ceiling		Water supply		Computers	x	Library	x

Other (technical installations, teaching material …) specify: ………

……

……

3.7. General observations

There is one colonial building with ceiling. The roof have no conditions to resist to a new cyclone or strong wind. Remove the existing roof sheet. Repair the roof structure based on the Safe Schools Catalog - Cyclones. Install new roof sheets. There are 2 buildings in good conditions.

4. Pictures - Location and schoolyard

Observation: access gates

Observation: View of school buildings

Observation: school courtyard

Observation: Classrooms block

Observation: Roof sheet after cyclone

Observation: Roof structure in one classroom block

Observation: Detail of damaged roof sheet

Observation: Detail of the roof structure

Observation: Detail of the roof structure

Observation: Classrooms block

Observation: Obsolete building

Observation: Old and new w.c

Picture of school

Mozambique Risk assessment for the School sector
Building Characteristics Survey

1. General information

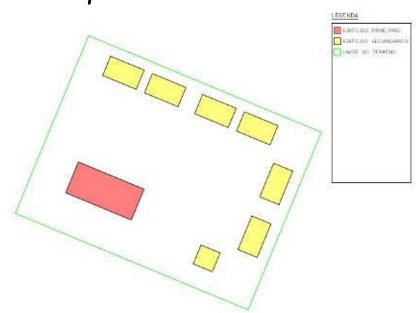
1.1. Reference
School Name: E.P Manhanza
District Name: Inhambane

1.2. Location
School Address (if available):
Lat.26°19´34.0´´S/long.32°23´16.7E
Altitude (m): ………

1.3 School complex
Number of buildings: 8
Number of main buildings: 1
Number of ancillary buildings: 7
Number of classrooms: 7
Number of people in school: 456

Total area of buildings: 360 m2
Total area of main buildings: 170m2
Total area of ancillary buildings: 190m2
Schoolyard area: 4200

Floor plan



Google Earth view

1.4 Educational typology

Preschool (3-6)		Upper secondary (15-18)	
Primary (6-12)	x	Vocational (varying age)	
Middle school (12-15)		Other	

1.5 Experienced past events

Earthquakes		Fluvial flood		Coastal flood		Cyclones	x	Landslides		Absent		Unknown	

If so, inform about hazard intensities, related losses (US$) and repair timescale: Lots of roof sheets flown during last cyclone. Roof sheets were recovered and resettled without proper techniques. There is no cost recording.

2. Location

2.1. Topography

Flat		Rough		Slope	x	Scarp cliff		Crest top		Valley	

2.2. Context

Urban		Rural	x	Mountain	

2.3. Soil properties

Dune		Red sand		Rock	

If other specify: Sand

2.3. Access to school

By footpath	x	Via traffic street		Undefined	x

2.5. Schoolyard – Fences

No fence		Partially fenced	x	Fully fenced		Low fence		High fence	

2.5. Schoolyard – Safe areas

For flood	x	For earthquake	x	For wind	

3. Building characteristics

3.1. Typology

Conventional	x	Non-conventional	x

Note: *Conventional* and *non-conventional* types refer to *built with cement, bricks …* and to *built with local materials such as wattle and daub*, respectively

Other specify: ………

3.2. Structural – Foundation

None		Dirt/Hay		Cement slab		Cement beams and slab		Other	

If other specify: ………

Foundation height:

Normal (0.3 m or less)		Knee high (0.5 m)		Waist high (1 m)		Higher than 1 m		Absent		Unknown	X

3.3. Structural – Roof

Concrete		Mud/Dirt and wood/planks		Corrugated iron	x	Other	

If other specify: Zinc Sheets

Roof frame:

Concrete		Wood	x	Metallic		Other	

If other specify: ………

If applicable, number of faces for the main roof:

1 face (lean-to)		2 faces (pitched)	x	4 faces (hipped)	

3.4. Structural – Walls

Bricks with plaster	x	Clay bricks		Soil / Mud		Bamboo/ Wood		Other	x

If other specify: Zinc sheets

3.5. Exterior elements

Doors	*Yes*		Windows	*Yes*	

3.6. Interior elements

Partitions		Interior doors	x	Stairways		Common areas		Ceiling		Water supply		Computers		Library	

Other (technical installations, teaching material …) specify: ………
……
……

3.7. General observations

The roof structure has no conditions to resist to a new cyclone. Difficult access by vehicle. For the conventional buildings remove the existing roof sheet. Repair the roof structure based on the Safe Schools Catalog - Cyclones. Install new roof sheets. For the non-conventional buildings, due to the poor construction, no upgrading is recommended.

4. Pictures - Location and schoolyard

Observation: School access area

Observation: Classroom Blocks

Observation: View of schoolyard

Observation: Cracking between wall and roof structure

Observation: Purlin detail in Director office

Observation: Roof in the conventional classroom

Observation: External wall cracks

Observation: Internal cracks

Observation: Cracks between wall and roof

Observation: Non conventional buildings

Observation: Non conventional classrooms

Observation: Sanitary facilities

Picture of school

Mozambique Risk assessment for the School sector
Building Characteristics Survey

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1. General information

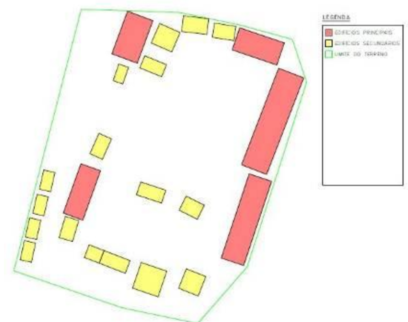
1.1. Reference
School Name: E.P Rumbana
District Name: Maxixe

1.2. Location
School Address (if available): ....
Lat . 23°49´53.80”/long.35°20´42.40”
Altitude (m): ....

1.3 School complex
Number of buildings: 23
Number of main buildings: 5
Number of ancillary buildings: 15+3
Number of classrooms: 22
Number of people in school: 2.216

Total area of buildings: 1.440 m2
Total area of main buildings: 1.233 m2
Total area of ancillary buildings: 207 m2
Schoolyard area: 6.600 m2

Floorplan



Google Earth view

1.4 Educational typology

Preschool (3-6)		Upper secondary (15-18)	
Primary (6-12)	x	Vocational (varying age)	
Middle school (12-15)	x	Other	

1.5 Experienced past events

Earthquakes		Fluvial flood		Coastal flood		Cyclones	x	Landslides		Absent		Unknown	

If so, inform about hazard intensities, related losses (US$) and repair timescale: Roof sheets flown during last cyclone. Roof sheets were recovered and resettled by the community. There is no cost recording.

2. Location

2.1. Topography

Flat	x	Rough		Slope		Scarp cliff		Crest top		Valley	

2.2. Context

Urban		Rural	x	Mountain	

2.3. Soil properties

Dune		Red sand		Rock	

If other specify: Sand

2.3. Access to school

By footpath		Via traffic street	x	Undefined	

2.5. Schoolyard – Fences

No fence		Partially fenced		Fully fenced	x	Low fence		High fence	

2.5. Schoolyard – Safe areas

For flood	x	For earthquake	x	For wind	

3. Building characteristics

3.1. Typology

Conventional	x	Non-conventional	x

Note: *Conventional* and *non-conventional* types refer to *built with cement, bricks* … and to *built with local materials such as wattle and daub*, respectively

Other specify: ………

3.2. Structural – Foundation

None		Dirt/Hay		Cement slab		Cement beams and slab		Other	

If other specify: ………

Foundation height:

Normal (0.3 m or less)		Knee high (0.5 m)		Waist high (1 m)		Higher than 1 m		Absent		Unknown	X

3.3. Roof

Concrete		Mud/Dirt and wood/planks		Corrugated iron	x	Other	

If other specify: Zinc Sheets

Roof frame:

Concrete		Wood	x	Metallic		Other	

If other specify: ………

If applicable, number of faces for the main roof:

1 face (lean-to)		2 faces (pitched)	x	4 faces (hipped)	

3.4. Structural – Walls

Bricks with plaster	x	Clay bricks		Soil / Mud		Bamboo/ Wood		Other	

If other specify: Non conventional buildings with metallic wall sheets

3.5. Exterior elements

Doors	*Yes*		Windows	*Yes*	

3.6. Interior elements

Partitions	x	Interior doors	x	Stairways		Common areas		Ceiling		Water supply		Computers		Library	

Other (technical installations, teaching material …) specify: ……
……
……

3.7. General observations

The school has 10 classrooms built with non – conventional material. The main buildings have fixing problems in the roof structure. Remove roof sheet of the conventional buildings. Repair the roof structure following the Safe Schools Catalogo - Cyclones. Fix new roof sheets. For the non-conventional buildings, new constructions are recommended.

4. Pictures - Location and schoolyard

Observation: View of school, access gate, fence

Observation: View of main building

Observation: View of the classrooms

Observation: Damaged roof

Observation: Roof of the classroms

Observation: Roof covering the veranda

Observation: Classrooms

Observation: Roof of non conventional classroom

Observation: Non conventional Building

Observation: Cracking repaired

Observation: Cracking between the wall and roof

Observation: Sanitary facilities

Picture of school

Mozambique Risk assessment for the School sector
Building Characteristics Survey

1. General information

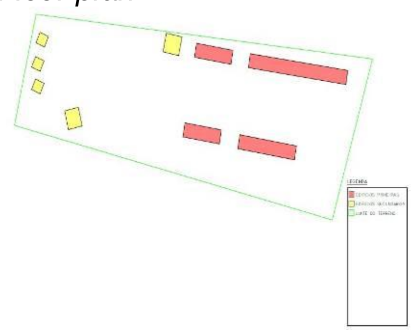
1.1. Reference
School Name: E.S. Eduardo Mondlane
District Name: Morrumbene

1.2. Location
School Address (if available): ....
Lat. 23°39´9.80´´S/long.35°19´57.00E
Altitude (m):

1.3 School complex
Number of buildings: 9
Number of main buildings: 4
Number of ancillary buildings: 5
Number of classrooms: 10
Number of people in school: 4379

Total area of buildings: 927.25m2
Total area of main buildings: 828m2
Total area of ancillary buildings: 99.25
Schoolyard area: 33.000m2

Floor plan



Google Earth view

1.4 Educational typology

Preschool (3-6)		Upper secondary (15-18)	
Primary (6-12)		Vocational (varying age)	
Middle school (12-15)	x	Other	

1.5 Experienced past events

Earthquakes		Fluvial flood		Coastal flood		Cyclones	x	Landslides		Absent		Unknown	

If so, inform about hazard intensities, related losses (US$) and repair timescale: The school was hit by this year cyclone Dineo. Lots of roof sheets flown during last cyclone. Roof sheets were recovered very near the school and were resettled by the community. There is no cost recording.

2. Location

2.1. Topography

Flat	x	Rough		Slope		Scarp cliff		Crest top		Valley	

2.2. Context

Urban		Rural	x	Mountain	

2.3. Soil properties

Dune		Red sand		Rock	

If other specify: Sand

2.3. Access to school

By footpath		Via traffic street	x	Undefined	

2.5. Schoolyard – Fences

No fence	x	Partially fenced		Fully fenced		Low fence		High fence	

2.5. Schoolyard – Safe areas

For flood		For earthquake		For wind	

3. Building characteristics

3.1. Typology

Conventional	x	Non-conventional	

Note: *Conventional* and *non-conventional* types refer to *built with cement, bricks* … and to *built with local materials such as wattle and daub*, respectively

Other specify: ………

3.2. Structural – Foundation

None		Dirt/Hay		Cement slab		Cement beams and slab		Other	

If other specify: ………

Foundation height:

Normal (0.3 m or less)		Knee high (0.5 m)		Waist high (1 m)		Higher than 1 m		Absent		Unknown	x

3.3. Structural – Roof

Concrete		Mud/Dirt and wood/planks		Corrugated iron	x	Other	

If other specify: Zinc Sheets

Roof frame:

Concrete		Wood	x	Metallic		Other	

If other specify: ………

If applicable, number of faces for the main roof:

1 face (lean-to)		2 faces (pitched)	x	4 faces (hipped)	

3.4. Structural – Walls

Bricks with plaster	x	Clay bricks		Soil / Mud		Bamboo/ Wood		Other	

If other specify: ………

3.5. Exterior elements

Doors	*Yes*		Windows	*Yes*	

3.6. Interior elements

Partitions	x	Interior doors		Stairways		Common areas		Ceiling		Water supply		Computers	x	Library	

Other (technical installations, teaching material …) specify: The school has Electricity

3.7. General observations

The school reused the same damaged cover plates. The roof is not correctly fixed. For the conventional buildings remove the existing roof sheet. Repair the roof structure based on the Safe Schools Catalog - Cyclones. Install new roof sheets.

4. Pictures - Location and schoolyard

Observation: Access entrance

Observation: View of school buildings

Observation: View of schoolyard

Observation: View of the veranda

Observation: View of the roof sheet

Observation: View of the roof sheet

Observation: Roof structure in one of the classroom

Observation: View of the roof sheet

Observation: Classroom Block

Observation: Administrative block

Observation: Roof structure in one of the rooms

Observation: Detail of roof sheet connection

Picture of school

Mozambique Risk assessment for the School sector
Building Characteristics Survey

1. General information

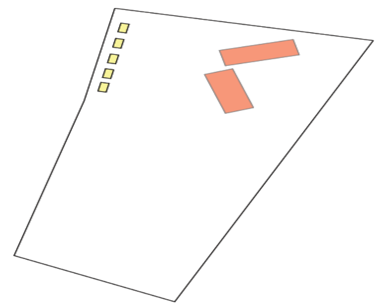
1.1. Reference
School Name: E. P. 1 e 2 - CHIORORUA
District Name: GONDOLA

1.2. Location
School Address (if available):
Lat./long.or XY coord. (WGS84):18°58'26.6" / 33°41'59.2"
Altitude (m): ....

1.3 School complex
Number of buildings: 7
Number of main buildings: 2
Number of ancillary buildings: 5
Number of classrooms: 6
Number of people in school: 377

Total area of buildings: 484 m2
Total area of main buildings: 448 m2
Total area of ancillary buildings: 36 m2
Schoolyard area: 2371 m2

Floor plan



Google Earth view

1.4 Educational typology

Preschool (3-6)		Upper secondary (15-18)	
Primary (6-12)	X	Vocational (varying age)	
Middle school (12-15)	X	Other	

1.5 Experienced past events

Earthquakes		Fluvial flood		Coastal flood		Cyclones	X	Landslides		Absent		Unknown	

If so, inform about hazard intensities, related losses (US$) and repair timescale: the community repaired damages in the old building. In the meantime, provincial education directorate – Chimoio, built a new building. Value USD 35,000, construction duration 90 days.

2. Location

2.1. Topography

Flat	X	Rough		Slope		Scarp cliff		Crest top		Valley	

2.2. Context

Urban		Rural	X	Mountain	

2.3. Soil properties

Dune		Red sand		Rock	

If other specify: sand

2.3. Access to school

By footpath		Via traffic street	X	Undefined	

2.5. Schoolyard – Fences

No fence	X	Partially fenced		Fully fenced		Low fence		High fence	

2.5. Schoolyard – Safe areas

For flood	X	For earthquake	X	For wind	

3. Building characteristics

3.1. Typology

Conventional	X	Non-conventional	

Note: *Conventional* and *non-conventional* types refer to *built with cement, bricks* … and to *built with local materials such as wattle and daub*, respectively

Other specify: ………

3.2. Structural – Foundation

None		Dirt/Hay		Cement slab		Cement beams and slab	X	Other	

If other specify: ………

Foundation height:

Normal (0.3 m or less)		Knee high (0.5 m)		Waist high (1 m)		Higher than 1 m		Absent		Unknown	X

3.3. Structural – Roof

Concrete		Mud/Dirt and wood/planks		Corrugated iron	X	Other	

If other specify: ………

Roof frame:

Concrete		Wood	X	Metallic		Other	

If other specify: ………

If applicable, number of faces for the main roof:

1 face (lean-to)		2 faces (pitched)	X	4 faces (hipped)	

3.4. Structural – Walls

Bricks with plaster	X	Clay bricks		Soil / Mud		Bamboo/ Wood		Other	

If other specify: ………

3.5. Exterior elements

Doors	*yes*		Windows	*yes*	

3.6. Interior elements

Partitions	X	Interior doors	X	Stairways		Common areas		Ceiling		Water supply		Computers		Library	

Other (technical installations, teaching material …) specify:

3.7. General observations

For the old conventional buildings remove the existing roof sheet. Repair the roof structure based on the Safe Schools Catalog - Cyclones. For the new conventional buildings, repair the roof structure based on the Safe Schools Catalog – Cyclones.

4. Pictures - Location and schoolyard

Observation: School grounds

Observation: New administrative and classroom block

Observation: Old classroom block

Observation: Roof structure of the new classroom block

Observation: Roof structure of the old classroom block

Observation: sanitary facilities

Picture of school

Mozambique Risk assessment for the School sector
Building Characteristics Survey

1. General information

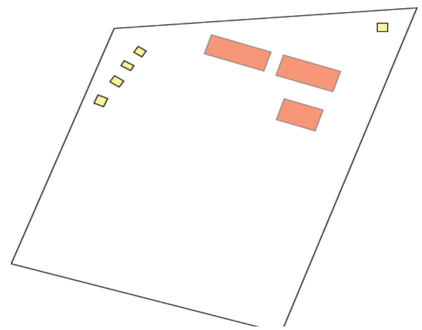
1.1. Reference
School Name: E. P. 1 e 2 - SELVA
District Name: VANDUZI

1.2. Location
School Address (if available):
Lat./long.or XY coord. (WGS84): 19°02'50" / 33°13'37.8"
Altitude (m): 653 meter

1.3 School complex
Number of buildings: 8
Number of main buildings: 3
Number of ancillary buildings: 5
Number of classrooms: 7
Number of people in school: 581

Total area of buildings: 706 m2
Total area of main buildings: 641 m2
Total area of ancillary buildings: 65 m2
Schoolyard area: 13986 m2

Floor plan



Google Earth view

1.4 Educational typology

Preschool (3-6)		Upper secondary (15-18)	
Primary (6-12)	X	Vocational (varying age)	
Middle school (12-15)	X	Other	

1.5 Experienced past events

Earthquakes		Fluvial flood		Coastal flood		Cyclones	X	Landslides		Absent		Unknown	

If so, inform about hazard intensities, related losses (US$) and repair timescale: The damages that occur as a result of the cyclone have not yet been repaired

2. Location

2.1. Topography

Flat	X	Rough		Slope		Scarp cliff		Crest top		Valley	

2.2. Context

Urban		Rural	X	Mountain	

2.3. Soil properties

Dune		Red sand		Rock	

If other specify: sand

2.3. Access to school

By footpath		Via traffic street	X	Undefined	

2.5. Schoolyard – Fences

No fence	X	Partially fenced		Fully fenced		Low fence		High fence	

2.5. Schoolyard – Safe areas

For flood	X	For earthquake		For wind	

3. Building characteristics

3.1. Typology

Conventional	X	Non-conventional	

Note: *Conventional* and *non-conventional* types refer to *built with cement, bricks* … and to *built with local materials such as wattle and daub*, respectively

Other specify: ………

3.2. Structural – Foundation

None		Dirt/Hay		Cement slab		Cement beams and slab	X	Other	

If other specify: ………

Foundation height:

Normal (0.3 m or less)		Knee high (0.5 m)		Waist high (1 m)		Higher than 1 m		Absent		Unknown	X

3.3. Structural – Roof

Concrete		Mud/Dirt and wood/planks		Corrugated iron	X	Other	X

If other specify: Asbestos cement

Roof frame:

Concrete		Wood	X	Metallic	X	Other	

If other specify: ………

If applicable, number of faces for the main roof:

1 face (lean-to)	X	2 faces (pitched)	X	4 faces (hipped)	

3.4. Structural – Walls

Bricks with plaster	X	Clay bricks		Soil / Mud		Bamboo/ Wood		Other	

If other specify: ………

3.5. Exterior elements

Doors	*yes*		Windows	*yes*	

3.6. Interior elements

Partitions	X	Interior doors	X	Stairways		Common areas	X	Ceiling		Water supply		Computers		Library	

Other (technical installations, teaching material …) specify: The two new buildings have electrical installation and wait for the connection to the village network. The two new buildings have some roof sheets not fixed on the correct way, due to the cyclone effect.

3.7. General observations

Director of school referred some signs of damage resulting from earthquake in the old building (cracks and broken glass). For Consultec engineer, this was not clear. It seems some damage that occurs with time. The complete structure of the two new buildings is metallic. For the new conventional building, repair the roof structure based on the Safe Schools Catalog – Cyclones. The old building Should be demolished and in its place built a new building based on the catalogs of Safe Schools Catalog – Cyclones. This village is situated in an earthquake zone. No damages were noted, but reinforcements should be made in future buildings. The old building should be demolished and in its place built a new building based on Safe Schools Catalog – Earthquakes

4. Pictures - Location and schoolyard

Observation: School grounds

Observation: posterior view of two new blocks school

Observation: view of school blocks (old and new)

Observation: cover in fiber cement sheets.

Observation: corrugated sheets in new building

Observation: cracks are supposed to be caused by an earthquake in the old building

Picture of school

Mozambique Risk assessment for the School sector
Building Characteristics Survey

1. General information

1.1. Reference
School Name: E. P. NHAURANGA
District Name: MACATE

1.2. Location
School Address (if available):
Lat./long.or XY coord: (WGS84): 19°21'09.2" / 33°22'11.2"
Altitude (m): 621 meter

1.3 School complex
Number of buildings: 5
Number of main buildings: 1
Number of ancillary buildings: 4
Number of classrooms: 5
Number of people in school: 340

Total area of buildings: 176 m2
Total area of main buildings: 170 m2
Total area of ancillary buildings: 106 m2
Schoolyard area: 30.000 m2

Floor plan

Google Earth view

1.4 Educational typology

Preschool (3-6)		Upper secondary (15-18)	
Primary (6-12)	X	Vocational (varying age)	
Middle school (12-15)		Other	

1.5 Experienced past events

Earthquakes		Fluvial flood		Coastal flood		Cyclones	X	Landslides		Absent		Unknown	

If so, inform about hazard intensities, related losses (US$) and repair timescale: Main building destroyed by the action of the cyclone has not yet been repaired. Students have lessons in the non-conventional construction building.

2. Location

2.1. Topography

Flat	X	Rough		Slope		Scarp cliff		Crest top		Valley	

2.2. Context

Urban		Rural	X	Mountain	

2.3. Soil properties

Dune		Red sand		Rock	

If other specify: Sand

2.3. Access to school

By footpath		Via traffic street	X	Undefined	

2.5. Schoolyard – Fences

No fence	X	Partially fenced		Fully fenced		Low fence		High fence	

2.5. Schoolyard – Safe areas

For flood	X	For earthquake	X	For wind	

3. Building characteristics

3.1. Typology

Conventional	X	Non-conventional	X

Note: *Conventional* and *non-conventional* types refer to *built with cement, bricks* ... and to *built with local materials such as wattle and daub*, respectively

Other specify: ....

3.2. Structural – Foundation

None		Dirt/Hay		Cement slab		Cement beams and slab	X	Other	

If other specify: ....

Foundation height:

Normal (0.3 m or less)		Knee high (0.5 m)		Waist high (1 m)		Higher than 1 m		Absent		Unknown	X

3.3. Structural – Roof

Concrete		Mud/Dirt and wood/planks		Corrugated iron	X	Other	

If other specify: ....

Roof frame:

Concrete		Wood	X	Metallic		Other	

If other specify: ....

If applicable, number of faces for the main roof:

1 face (lean-to)		2 faces (pitched)	X	4 faces (hipped)	

3.4. Structural – Walls

Bricks with plaster	X	Clay bricks		Soil / Mud		Bamboo/ Wood		Other	X

If other specify: The walls of one of the classroom block are metallic sheet.

3.5. Exterior elements

Doors	*yes*	*no*	Windows	*yes*	*no*

3.6. Interior elements

Partitions	X	Interior doors	X	Stairways		Common areas		Ceiling		Water supply		Computers		Library	

Other (technical installations, teaching material ...) specify: ....
....
....

3.7. General observations

The entire roof of the main building should be replaced by a new one. Non-Conventional blocks were erected after the last cyclone. They have no conditions to resist to a new cyclone. For the conventional buildings remove the existing roof sheet. Repair the roof structure based on the Safe Schools Catálogo - Ciclones. Install new roof sheets. For the non-conventional buildings, due to the poor construction, no upgrading is recommended.

4. Pictures - Location and schoolyard

Observation: school access area

Observation: Administrative and classroom block with roof destroyed by a Cyclone

Observation: School grounds

Observation: Non-conventional construction classroom

Observation: construction by community of a classroom block next to the main building

Observation: Sanitary facilities

Observation: front view of main building

Observation: One of the classrooms after cyclone

Observation: Roof sheets on the veranda, after cyclone

Observation: Inside non-conventional building classrooms

Observation: Non-Conventional Classroom roof

Observation: rear view of the main building

Picture of school

Mozambique Risk assessment for the School sector
Building Characteristics Survey

1. General information

1.1. Reference
School Name: E. P. NHAMUTOERA
District Name: MACATE

1.2. Location
School Address (if available):
Lat./long.or XY coord. (WGS84): 19°22'52.92 / 33°30'14.3"
Altitude (m): 575 meter

1.3 School complex
Number of buildings: 2
Number of main buildings: 2
Number of ancillary buildings: 0
Number of classrooms: 3
Number of people in school: 202

Total area of buildings: 184 m2
Total area of main buildings: 184 m2
Total area of ancillary buildings: 0
Schoolyard area: 25.900 m2

Floor plan

Google Earth view

1.4 Educational typology

Preschool (3-6)		Upper secondary (15-18)	
Primary (6-12)	X	Vocational (varying age)	
Middle school (12-15)		Other	

1.5 Experienced past events

Earthquakes	Fluvial flood	Coastal flood	Cyclones	Landslides	Absent	Unknown
			X			

If so, inform about hazard intensities, related losses (US$) and repair timescale: There is no record on school repair work

2. Location

2.1. Topography

Flat	Rough	Slope	Scarp cliff	Crest top	Valley
X					

2.2. Context

Urban	Rural	Mountain
	X	

2.3. Soil properties

Dune	Red sand	Rock
	X	

If other specify: ....

2.3. Access to school

By footpath	Via traffic street	Undefined
	X	

2.5. Schoolyard – Fences

No fence	Partially fenced	Fully fenced	Low fence	High fence
X				

2.5. Schoolyard – Safe areas

For flood	For earthquake	For wind
X	X	

3. Building characteristics

3.1. Typology

Conventional	X	Non-conventional	X

Note: *Conventional* and *non-conventional* types refer to *built with cement, bricks …* and to *built with local materials such as wattle and daub*, respectively

Other specify: ………

3.2. Structural – Foundation

None		Dirt/Hay		Cement slab	X	Cement beams and slab		Other	

If other specify: ………

Foundation height:

Normal (0.3 m or less)		Knee high (0.5 m)		Waist high (1 m)		Higher than 1 m		Absent		Unknown	X

3.3. Structural – Roof

Concrete		Mud/Dirt and wood/planks		Corrugated iron	X	Other	

If other specify: ………

Roof frame:

Concrete		Wood	X	Metallic		Other	

If other specify: ………

If applicable, number of faces for the main roof:

1 face (lean-to)		2 faces (pitched)	X	4 faces (hipped)	

3.4. Structural – Walls

Bricks with plaster	X	Clay bricks		Soil / Mud		Bamboo/ Wood		Other	X

If other specify: The walls of the classroom block are metal sheet

3.5. Exterior elements

Doors	*yes*		Windows	*yes*	

3.6. Interior elements

Partitions	X	Interior doors	X	Stairways		Common areas		Ceiling		Water supply		Computers		Library	

Other (technical installations, teaching material …) specify: <u>The walls of the classroom block are metallic sheet</u>

3.7. General observations

Existing buildings cannot be considered safe. They should be destroyed at any hazard condition. We would propose to be constructed new buildings. Construct new building to replace the existing ones.

4. Pictures - Location and schoolyard

Observation: Road access to school

Observation: Classrooms block

Observation: Administrative block

Observation: Structure, roof sheet and walls sheet of classroom block

Observation: School grounds

Observation: Sanitary facilities

Picture of school

Mozambique Risk assessment for the School sector
Building Characteristics Survey

1. General information

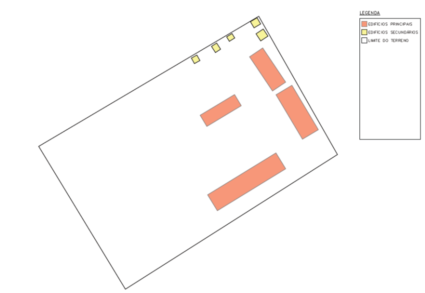
1.1. Reference
School Name: E. P. 1 e 2 - MATAKENHA
District Name: CHIMOIO

1.2. Location
School Address (if available): Bairro Tembwé No. 2985
Lat./long.or XY coord. (WGS84): 19°05’14.5” / 33°26’58.6”
Altitude (m): 681 meter

1.3 School complex
Number of buildings: 6
Number of main buildings: 2
Number of ancillary buildings: 4
Number of classrooms: 9
Number of people in school: 1836

Total area of buildings: 661 m2
Total area of main buildings: 626 m2
Total area of ancillary buildings: 35 m2
Schoolyard area: 11.180 m2

Floor plan



Google Earth view

1.4 Educational typology

Preschool (3-6)		Upper secondary (15-18)	
Primary (6-12)	X	Vocational (varying age)	
Middle school (12-15)	X	Other	

1.5 Experienced past events

Earthquakes		Fluvial flood		Coastal flood		Cyclones	X	Landslides		Absent		Unknown	

If so, inform about hazard intensities, related losses (US$) and repair timescale: Damage on the roof sheet. These damages were repaired by the community

2. Location

2.1. Topography

Flat	X	Rough		Slope		Scarp cliff		Crest top		Valley	

2.2. Context

Urban	X	Rural		Mountain	

2.3. Soil properties

Dune		Red sand	X	Rock	

If other specify: ....

2.3. Access to school

By footpath		Via traffic street	X	Undefined	

2.5. Schoolyard – Fences

No fence	X	Partially fenced		Fully fenced		Low fence		High fence	

2.5. Schoolyard – Safe areas

For flood	X	For earthquake	X	For wind	

3. Building characteristics

3.1. Typology

Conventional	X	Non-conventional	

Note: *Conventional* and *non-conventional* types refer to *built with cement, bricks* … and to *built with local materials such as wattle and daub*, respectively

Other specify: ………

3.2. Structural – Foundation

None		Dirt/Hay		Cement slab		Cement beams and slab	X	Other	

If other specify: ………

Foundation height:

Normal (0.3 m or less)		Knee high (0.5 m)		Waist high (1 m)		Higher than 1 m		Absent		Unknown	X

3.3. Structural – Roof

Concrete		Mud/Dirt and wood/planks		Corrugated iron	X	Other	

If other specify: ………

Roof frame:

Concrete		Wood	X	Metallic		Other	

If other specify: ………

If applicable, number of faces for the main roof:

1 face (lean-to)		2 faces (pitched)	X	4 faces (hipped)	

3.4. Structural – Walls

Bricks with plaster	X	Clay bricks		Soil / Mud		Bamboo/ Wood		Other	

If other specify: ………

3.5. Exterior elements

Doors	*yes*		Windows	*yes*	

3.6. Interior elements

Partitions	X	Interior doors	X	Stairways		Common areas	X	Ceiling		Water supply		Computers		Library	

Other (technical installations, teaching material …) specify: electric power installed. Water connection was recently established by the contractor as part of the construction of another block of classrooms. At the end of the works will start to be used by the school .

3.7. General observations

Work is being carried out on the construction of another block of classrooms, financed by FASE project. Repair the roof structure based on the Safe Schools Catalog - Cyclones. Install new roof sheets.

4. Pictures - Location and schoolyard

Observation: Front view of the main school block

Observation: side view of classroom block

Observation: school grounds

Observation: Roof structure of the classroom block

Observation: Poor repair of the roof structure

Observation: Construction of a new classroom block

Picture of school

Mozambique Risk assessment for the School sector
Building Characteristics Survey

1. General information

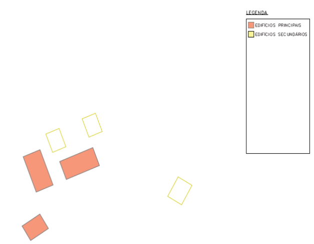
1.1. Reference
School Name: E. P. INCHOPE ESTAÇÃO
District Name: INCHOPE

1.2. Location
School Address (if available):
Lat./long.or XY coord. (WGS84): 19°11'52.8" / 33°53'14.3"
Altitude (m): 259 meter

1.3 School complex
Number of buildings: 3
Number of main buildings: 0
Number of ancillary buildings: 3
Number of classrooms: 4
Number of people in school: 261

Total area of buildings: 170 m2
Total area of main buildings: 0
Total area of ancillary buildings: 170 m2
Schoolyard area: CFM enclosure

Floor plan



Google Earth view

1.4 Educational typology

Preschool (3-6)		Upper secondary (15-18)	
Primary (6-12)	X	Vocational (varying age)	
Middle school (12-15)		Other	

1.5 Experienced past events

Earthquakes		Fluvial flood		Coastal flood		Cyclones	X	Landslides		Absent		Unknown	

If so, inform about hazard intensities, related losses (US$) and repair timescale: <u>After the destruction of the initial school blocks, UNICEF donated two tents that are currently used as classrooms</u>

2. Location

2.1. Topography

Flat	X	Rough		Slope		Scarp cliff		Crest top		Valley	

2.2. Context

Urban		Rural	X	Mountain	

2.3. Soil properties

Dune		Red sand		Rock	

If other specify: Sand

2.3. Access to school

By footpath		Via traffic street	X	Undefined	

2.5. Schoolyard – Fences

No fence	X	Partially fenced		Fully fenced		Low fence		High fence	

2.5. Schoolyard – Safe areas

For flood	X	For earthquake	X	For wind	

3. Building characteristics

3.1. Typology

Conventional	X	Non-conventional	X

Note: *Conventional* and *non-conventional* types refer to *built with cement, bricks* … and to *built with local materials such as wattle and daub*, respectively

Other specify: ………

3.2. Structural – Foundation

None	X	Dirt/Hay		Cement slab		Cement beams and slab		Other	

If other specify: ………

Foundation height:

Normal (0.3 m or less)		Knee high (0.5 m)		Waist high (1 m)		Higher than 1 m		Absent		Unknown	X

3.3. Structural – Roof

Concrete		Mud/Dirt and wood/planks		Corrugated iron	X	Other	X

If other specify: Tents

Roof frame:

Concrete		Wood	X	Metallic		Other	

If other specify: ………

If applicable, number of faces for the main roof:

1 face (lean-to)	X	2 faces (pitched)		4 faces (hipped)	

3.4. Structural – Walls

Bricks with plaster		Clay bricks		Soil / Mud		Bamboo/ Wood		Other	X

If other specify: Bricks without plaster

3.5. Exterior elements

Doors	*yes*		Windows	*yes*	

3.6. Interior elements

Partitions		Interior doors		Stairways		Common areas		Ceiling		Water supply		Computers		Library	

Other (technical installations, teaching material …) specify:

3.7. General observations

The school currently operates in the CFM campus. A new school is being planned by local authorities to be erected. Construct a new building to replace the existing one

4. Pictures - Location and schoolyard

Observation: School access zone

Observation: school secretary

Observation: Tents/classrooms

Observation: Inside one tent/classroom

Observation: Flooring base of a destroyed school block

Observation: Sanitary facilities

Picture of school

Mozambique Risk assessment for the School sector
Building Characteristics Survey

1. General information

1.1. Reference
School Name: E. P. 1 e 2 – 7 DE ABRIL
District Name: CHIMOIO

1.2. Location
School Address (if available):
Lat./long.or XY coord. (WGS84): 19°08'36.4" / 33°28'41.4"
Altitude (m): 729 meter

1.3 School complex
Number of buildings: 14
Number of main buildings: 7
Number of ancillary buildings: 7
Number of classrooms: 32
Number of people in school: 7710

Total area of buildings: 2236 m2
Total area of main buildings: 2167 m2
Total area of ancillary buildings: 69 m2
Schoolyard area: 18.018 m2

Floor plan

Google Earth view

1.4 Educational typology

Preschool (3-6)		Upper secondary (15-18)	
Primary (6-12)	X	Vocational (varying age)	
Middle school (12-15)	X	Other	

1.5 Experienced past events

Earthquakes		Fluvial flood		Coastal flood		Cyclones	X	Landslides		Absent		Unknown	

If so, inform about hazard intensities, related losses (US$) and repair timescale: About 300 USD were used to pay the replacement of the roof sheet that flew as a consequence of a cyclone

2. Location

2.1. Topography

Flat	X	Rough		Slope		Scarp cliff		Crest top		Valley	

2.2. Context

Urban	X	Rural		Mountain	

2.3. Soil properties

Dune		Red sand		Rock	

If other specify: Sand

2.3. Access to school

By footpath		Via traffic street	X	Undefined	

2.5. Schoolyard – Fences

No fence		Partially fenced		Fully fenced	X	Low fence		High fence	

2.5. Schoolyard – Safe areas

For flood	X	For earthquake	X	For wind	

3. Building characteristics

3.1. Typology

Conventional	X	Non-conventional	

Note: *Conventional* and *non-conventional* types refer to *built with cement, bricks* … and to *built with local materials such as wattle and daub*, respectively

Other specify: ………

3.2. Structural – Foundation

None		Dirt/Hay		Cement slab		Cement beams and slab	X	Other	

If other specify: ………

Foundation height:

Normal (0.3 m or less)		Knee high (0.5 m)		Waist high (1 m)		Higher than 1 m		Absent		Unknown	X

3.3. Structural – Roof

Concrete		Mud/Dirt and wood/planks		Corrugated iron	X	Other	

If other specify:

Roof frame:

Concrete		Wood	X	Metallic		Other	

If other specify: ………

If applicable, number of faces for the main roof:

1 face (lean-to)	X	2 faces (pitched)	X	4 faces (hipped)	

3.4. Structural – Walls

Bricks with plaster	X	Clay bricks		Soil / Mud		Bamboo/ Wood		Other	

If other specify: ………

3.5. Exterior elements

Doors	*yes*		Windows	*yes*	

3.6. Interior elements

Partitions	X	Interior doors		Stairways		Common areas	X	Ceiling	X	Water supply	X	Computers		Library	

Other (technical installations, teaching material …) specify: <u>electric power on the school</u>

3.7. General observations

The number of buildings was growing as the needs of the school, and the construction techniques were changing from building to building. Repair the roof structure based on the Safe Schools Catalog - Cyclones. Install new roof sheets.

4. Pictures - Location and schoolyard

Observation: School entrance

Observation: View of the largest classroom block

Observation: School grounds

Observation: extending one classroom block with new room

Observation: structure that appears robust in one of the classroom blocks

Observation: Poor roof structure on the veranda

Observation: cover structure with Zinc Sheets

Observation: cover structure with IBR sheet

Observation: poor condition of the veranda floor

Observation: General view of a classroom block

Observation: Gable wall that apparently protects the roof

Observation: Fence wall destroyed by the effect of wind

B Multi hazard result tables

Conventional Classrooms

National level overview - estimated damage to conventional classrooms (USD)								
	Return Period							Risk
Hazard	10	25	50	100	200	500	1000	AED
RF	not available	15,494,700	18,287,800	20,830,000	24,241,800	28,719,600	32,087,700	788,027
CF	6,944,360	8,598,110	10,200,100	11,921,400	14,568,000	16,698,200	18,290,900	911,384
CY	920,098	3,257,330	4,625,660	6,053,320	8,382,230	11,386,600	15,148,800	349,040
EQ	250,341	430,290	681,527	1,092,120	2,340,230	4,773,370	9,124,070	73,889
Total	**8,114,799**	**27,780,430**	**33,795,087**	**39,896,840**	**49,532,260**	**61,577,770**	**74,651,470**	**2,122,339**

National level overview - estimated number of affected conventional classrooms								
	Return Period							Risk
Hazard	10	25	50	100	200	500	1000	AED
RF	not available	920	1,056	1,190	1,367	1,542	1,665	45
CF	397	470	500	576	646	700	754	48
CY	1,234	2,317	2,317	2,317	2,317	2,317	2,317	199
EQ	-	-	-	-	-	39	408	1
Total	**1,631**	**3,707**	**3,873**	**4,083**	**4,330**	**4,598**	**5,144**	**292**

Non-conventional classrooms

National level overview - estimated damage to non-conventional classrooms (USD)								
	Return Period							Risk
Hazard	10	25	50	100	200	500	1000	AED
RF	not available	227,299	268,771	302,470	348,879	403,570	439,901	11,436
CF	117,507	140,072	159,143	176,434	204,581	223,574	238,956	14,439
CY	55,174	125,666	139,939	155,024	183,599	229,357	289,524	11,534
EQ	3,884	9,207	18,152	35,883	99,994	189,558	329,501	2,223
Total	**176,565**	**502,244**	**586,005**	**669,811**	**837,053**	**1,046,059**	**1,297,882**	**39,631**

National level overview - estimated number of affected non-conventional classrooms								
	Return Period							Risk
Hazard	10	25	50	100	200	500	1000	AED
RF	not available	642	751	830	949	1,068	1,152	32
CF	311	359	389	435	496	531	566	37
CY	1,576	1,730	1,730	1,730	1,730	1,730	1,730	168
EQ	-	-	-	135	463	870	2,509	8
Total	**1,887**	**2,731**	**2,870**	**3,130**	**3,638**	**4,199**	**5,957**	**245**

Number of affected pupils

National level overview - estimated number of affected pupils								
	Return Period							Risk
Hazard	10	25	50	100	200	500	1000	AED
RF	not available	145,874	167,972	187,510	212,207	237,828	255,807	7,093
CF	68,687	81,159	86,794	97,151	109,028	117,396	127,978	8,190
CY	358,687	416,104	416,104	416,104	416,104	416,104	416,104	39,888
EQ	-	-	-	17,871	79,015	165,067	605,497	1,615
Total	**427,374**	**643,137**	**670,870**	**718,636**	**816,354**	**936,395**	**1,405,386**	**56,786**

C Costing of retrofitting options

DEFINIÇÃO DE CUSTOS PARA AS SEGUINTES CONDIÇÕES DE ADAPTAÇÃO:

1. *Dry flood proofing*
2. *Retrofitted roof*
3. *Fully retrofitted roof*
4. *Fully retrofitted buildings*
5. *Earthquake-proof reinforcement of building*

I Dry flood proofing - Impermeabilização de parede e degraus nas entradas (barreira)

Item	Descrição / Descriptin	Unid. / Uniy	Quantidade / Amount	Preço Unitário /Unit price (USD)	preço Total / Total price(USD)
1	Redução da altura da porta	vg	3,00	24,20	72,60
	Door height reduction				
2	Betão simples para execução da barreira de protecção em degraus	m3	1,97	176,80	348,30
	Simple Concrete for execution of the step protection barrier				
3	Cofragem e descofragem da barreira	m2	2,27	42,88	97,34
	Formwork and Stripping of the barrier				
4	Impermeabilização das paredes exteriores	m2	32,40	25,00	810,00
	Waterproofing of exterior walls				
	TOTAL				1.328,23
	Custo por m2 de construção, tomando como base o Bloco de 3 Salas de Aulas com área coberta de 181,44 m2 (25,20x7,20)				7,32

II Retrofitted roof - Melhorar a fixação das chapas de cobertura, Acrescentar Asnas e Colocar Guardafogos

Item	Descrição	Unid.	Quantidade	Preço Unitário	preço Total
1	Fornecimento e assentamento de Asnas	un	6,00	33,14	198,84
	Supply and settlement of roof truss				
3	Fornecimento e assentamento de elementos de fixação em "ganchos do tipo J"	un	840,00	1,93	1.621,20
	supplying and Fixing hooks "type J"				
4	Construção do guardafogo ao longo da borda da cobertura incluido reboco e pintura				
	Placing blocks along the edge of the roof including plastering and painting	ml	16,80	12,50	210,00
	TOTAL				2.030,04
	Custo por m2 de construção, tomando como base o Bloco de 3 Salas de Aulas com área coberta de 181,44 m2 (25,20x7,20)				11,19

III Fully retrofitted roof - Melhorar a fixação das chapas de cobertura, Acrescentar Asnas, Colocar Guardafogos

Item	Descrição / Descriptin	Unid. / Uniy	Quantidade / Amount	Preço Unitário /Unit price (USD)	preço Total / Total price(USD)
1	Fornecimento e assentamento de Asnas	un	6,00	33,14	198,84
	Supply and settlement of roof truss				
3	Fornecimento e assentamento de elementos de fixação em "ganchos do tipo J"	un	840,00	1,93	1.621,20
	supplying and Fixing hooks "type J"				
4	Construção do guardafogo ao longo da borda da cobertura incluido reboco e pintura				
	Placing blocks along the edge of the roof including plastering and painting	ml	16,80	12,50	210,00
4	Execução e aplicação de B25, excluindo cofragem e armadura, em (varanda adicional):				
	Execution and application of B25, excluding formwork and reinforcement , in (additional veranda):				
4.1	sapatas / *base*	m3	1,41	176,80	249,29
4.2	pilares / *columns*	m3	1,56	176,80	275,81
4.3	Lajes / *slab*	m3	3,78	176,80	668,30
5	Fornecimento, corte, dobragem e amarração de varão da classe A400, de diâmetro (varanda adicional):				
	Supply, cutting, folding and mooring of reinforcement A400, in diameter:				
5.1	sapatas / *base*	kg	69,15	2,45	169,42
5.2	pilares / *columns*	kg	267,82	2,45	656,16
6	Execução de cofragem e descofragem com elementos metalicos e elementos de Madeira em (varanda adicional):				
	Execution of formwork with metal elements and wood elements in(additional veranda)::				
6.1	sapatas / *base*	m2	9,36	42,88	401,36
6.2	pilares / *columns*	m2	31,20	42,88	1.337,86
6.3	Lajes / *slab*	m2	31,20	42,88	1.337,86
	TOTAL				7.126,09

	Custo por m2 de construção, tomando como base o Bloco de 3 Salas de Aulas com área coberta de 181,44 m2 (25,20x7,20)	39,28

IV Fully retrofitted buildings - Melhorar a fixação das chapas de cobertura, Acrescentar Asnas, Colocar Guardafogos e acrescentar pilares, Proteger as Portas e Janelas

Item	Descrição / Descriptin	Unid. / Uniy	Quantidade / Amount	Preço Unitário /Unit price (USD)	preço Total / Total price(USD)
1	Fornecimento e assentamento de Asnas	un	6,00	33,14	198,84
	Supply and settlement of roof truss				
3	Fornecimento e assentamento de elementos de fixação em "ganchos do tipo J"	un	840,00	1,93	1.621,20
	supplying and Fixing hooks "type J"				
4	Construção do guardafogo ao longo da borda da cobertura incluido reboco e pintura				
	Placing blocks along the edge of the roof including plastering and painting	ml	16,80	12,50	210,00
4	Execução e aplicação de B25, excluindo cofragem e armadura, em (varanda adicional):				
	Execution and application of B25, excluding formwork and reinforcement , in (additional veranda):				
4.1	sapatas / *base*	m3	1,41	176,80	249,29
4.2	pilares / *columns*	m3	1,56	176,80	275,81
4.3	Lajes / *slab*	m3	3,78	176,80	668,30
5	Fornecimento, corte, dobragem e amarração de varão da classe A400, de diâmetro (varanda adicional):				
	Supply, cutting, folding and mooring of reinforcement A400, in diameter:				
5.1	sapatas / *base*	kg	69,15	2,45	169,42
5.2	pilares / *columns*	kg	267,82	2,45	656,16
6	Execução de cofragem e descofragem com elementos metalicos e elementos de Madeira em (varanda adicional):				
	Execution of formwork with metal elements and wood elements in(additional veranda)::				
6.1	sapatas / *base*	m2	9,36	42,88	401,36
6.2	pilares / *columns*	m2	31,20	42,88	1.337,86
6.3	Lajes / *slab*	m2	31,20	42,88	1.337,86
8	Fornecimento e assentamento de protectores de portas	un	3,00	35,00	105,00
	Supply and installation of door protectors				
9	Fornecimento e assentamento de protectores de janela	un	21,00	50,00	1.050,00
	Supply and installation of Windows protectors				
	TOTAL				8.281,09

	Custo por m2 de construção, tomando como base o Bloco de 3 Salas de Aulas com área coberta de 181,44 m2 (25,20x7,20)	45,64

V Earthquake-proof reinforcement of building - Melhorar a fixação das chapas de cobertura, Acrescentar Asnas, Colocar Guardafogos, acrescentar pilares, Proteger as Portas e Janelasmais, Reforço dos 4 cantos, Reforço das paredes e instalação de cintas sísmicas

Item	Descrição / Descriptin	Unid. / Uniy	Quantidade / Amount	Preço Unitário /Unit price (USD)	preço Total / Total price(USD)
1	Fornecimento e assentamento de Asnas	un	6,00	33,14	198,84
	Supply and settlement of roof truss				
3	Fornecimento e assentamento de elementos de fixação em "ganchos do tipo J"	un	840,00	1,93	1.621,20
	supplying and Fixing hooks "type J"				
4	Construção do guardafogo ao longo da borda da cobertura incluido reboco e pintura				
	Placing blocks along the edge of the roof including plastering and painting	ml	16,80	12,50	210,00
4	Execução e aplicação de B25, excluindo cofragem e armadura, em (varanda adicional):				
	Execution and application of B25, excluding formwork and reinforcement , in (additional veranda):				
4.1	sapatas / *base*	m3	1,41	176,80	249,29
4.2	pilares / *columns*	m3	1,56	176,80	275,81
4.3	Lajes / *slab*	m3	3,78	176,80	668,30
5	Fornecimento, corte, dobragem e amarração de varão da classe A400, de diâmetro (varanda adicional):				
	Supply, cutting, folding and mooring of reinforcement A400, in diameter:				
5.1	sapatas / *base*	kg	69,15	2,45	169,42
5.2	pilares / *columns*	kg	267,82	2,45	656,16
6	Execução de cofragem e descofragem com elementos metalicos e elementos de Madeira em (varanda adicional):				
	Execution of formwork with metal elements and wood elements in(additional veranda)::				
6.1	sapatas / *base*	m2	9,36	42,88	401,36
6.2	pilares / *columns*	m2	31,20	42,88	1.337,86
6.3	Lajes / *slab*	m2	31,20	42,88	1.337,86
8	Fornecimento e assentamento de protectores de portas	un	3,00	35,00	105,00
	Supply and installation of door protectors				
9	Fornecimento e assentamento de protectores de janela	un	21,00	50,00	1.050,00
	Supply and installation of Windows protectors				
10	Execução de betão de limpeza ao traço 1:2,6:2,8, com 50mm de espessura, na base das fundacoes, com uma margem de 50 mm em cada lado	m³	1,35	149,60	201,96
	50 mm blinder to strip foundations, columns				
11	Execução e aplicação de B25, excluindo cofragem e armadura, em:				
	Execution and application of the concrete B25, excluding formwork and reinforcement, in:				
11.1	sapatas / *base*	m³	0,30	176,80	53,04
11.2	pilares / *columns*	m³	0,10	176,80	17,68
11.3	vigas / *beams*	m³	1,80	176,80	318,24
11.4	Lajes / *slab*	m³	3,80	176,80	671,84
12	Fornecimento, corte, dobragem e amarração de varão da classe A400, de diâmetro:			0,00	
	Supply, cutting, folding and mooring of reinforcement A400, in diameter:			0,00	
12.1	6 mm	kg	96,00	2,45	235,01
12.2	10 mm	kg	16,20	2,45	39,66
12.3	12 mm	kg	55,00	2,45	134,64
13	Execução de cofragem e descofragem com elementos metalicos e elementos de Madeira em:			0,00	
	Execution of formwork with metal elements and wood elements of in:				
13.1	sapatas / *base*	m^2	1,15	42,88	49,31
13.2	pilares / *columns*	m^2	1,80	42,88	77,19
13.3	vigas / *beams*	m^2	14,60	42,88	626,06
13.4	Lajes / *slab*	m^2	1,10	42,88	47,17
	TOTAL / *TOTAL*				10.752,88

	TOTAL (CUSTO/M2) / *TOTAL (COST / M2)*	59,26

D CBA Calculations

Present value and internal rate of return for wind hazard retrofitting options[26]

Interest rate	4,5%				Benefits
Description	**Cash Flow**	**IRR**	**PV**	**Costs**	**1**
WIND	0	0	0,0		0
Retrofitting option 2 (25y)	1.335	11,0%	1.193,1	(677)	80
Retrofitting option 2 (12.5y)	329	6,4%	756,4	(677)	80
	0	0	0,0		0
Retrofitting option 3 (25y)	105	0,3%	1.471,0	(2.375)	99
Retrofitting option 3 (12.5y)	(1.135)	-8,5%	932,6	(2.375)	99
	0	0	0,0		0
Retrofitting option 4 (25y)	(264)	-0,8%	1.480,6	(2.760)	100
Retrofitting option 4 (12.5y)	(1.512)	-10,1%	938,6	(2.760)	100
	0	0	0,0		0
Inhambane					
Retrofitting option 3 (25y)	1.828	5,0%	2.492,8	(2.375)	168
Retrofitting option 3 (12.5y)	(274)	-1,8%	1.580,4	(2.375)	168

Present value and internal rate of return for flood and earthquake hazard retrofitting options

Interest rate	4,5%				Benefits
Description	**Cash Flow**	**IRR**	**PV**	**Costs**	**1**
FLOOD	0	0	0,0		0
< 50 cm	12.737	119,1%	7.817,0	(443)	527
< 50 cm (12.5 years)	6.147	119,1%	4.955,8	(443)	527
	0	0	0,0		0
	0	0	0,0		0
	0	0	0,0		0
EARTHQUAKE	0	0	0,0		0
700 gal (25 years)	(3.551)	#NUM!	19,7	(3.584)	1
701 gal (12.5 years)	(3.568)	#NUM!	12,5	(3.584)	1

Number of classrooms per province

Province	# classrooms
Cabo Delgado	3.042,00
Gaza	2.549,00
Inhambane	3.242,00
Manica	3.660,00
Nampula	6.147,00
Niassa	2.883,00
Sofala	3.073,00
Tete	4.450,00
Zambezia	8.121,00
Maputo	2.118,00

[26] *Note: option 2, option 3 and option 4 refer to retrofitted roof, fully retrofitted roof and fully retrofitted buildings, respectively.*