صندوق تطوير وإقراض الهيئات المحلية
Municipal Development & Lending Fund

المركز الوطني لإدارة مخاطر الكوارث

Exposure and vulnerability assessment and full module with maps and tools

Deliverable No. (3.2)

August, 2022

These principles were implemented under the supervision of the Municipal Development and Lending Fund (MDLF) and the National Disaster Risk Management Center (NDRMC), as part of the Municipal Development Program – Phase III Cycle II funded by the World Bank

Consultancy Team/ Urban Planning and Disaster Risk Reduction Center (UPDRRC) at An-Najah National University:

- Dr. Jamal Dabbeek
- Dr. Helen Crowley
- Dr. Jalal Dabbeek
- Dr. Anan Jayousi
- Dr. Sameer Shadeed
- Dr. Rami Ziara

Development of web-based map platform and technical support:

- Matteo Nastasi
- Paolo Tormene
- Antonio Ettorre
- Paul Henshaw
- Razi Alsayyed
- Moamar Ishtayyeh

Table of Contents

Preamble

The COVID-19 pandemic across the globe has highlighted the value of making governments, whether at the central or local levels, resilient to emerging complex emergencies, brought about by either natural or man-made hazards. While the impacts of these hazards may be different, there is a clear convergence in the aim of ensuring that communities have the capacities to absorb and recover from the effects of emergencies and disasters. Similarly, governments must equally have the means to mitigate and address the human and economic toll from disasters.

In this regard, the Palestine Liberation Organization, for the benefit of the Palestinian National Authority (PNA), has received an initial financing of EUR 130 Million from the World Bank-International Development Association (IDA), PA, KFW, Denmark, SDC, VNG, GIZ and AFD towards the cost of the 3rd phase of the Municipal Development Program (MDPIII). Part of this funding has been channelled, by the Municipal Development and Lending Fund (MDLF), towards consultancy services on the following assignment: Integrating Resilience in Local Governance in West Bank and Gaza (WB&G). The Urban Planning & Disaster Risk Reduction Centre (UPDRRC), hosted at the An-Najah National University, won the bid to provide these consultancy services, and signed the contract for the assignment on 7th December 2021.

The objectives of the assignment are to lay the foundation for integrating resilience in local governance through the production of technical knowledge, information, and guidelines and the development of the corresponding institutional capacity. To achieve these objectives, the assignment is composed of the following activities:

- Conduct a Multi-Hazard Risk Assessment and Mapping
- Development of Guidelines on Local Resilience Planning
- Formulation of Resilience Plans for Pilot Local Governments
- Formulation of resilience standards for critical infrastructure
- Capacity building of the National Disaster Risk Management Center (NDRMC)

As part of the first objective, this deliverable describes the activities that have been undertaken to model the exposure, vulnerability and risk for multiple hazards that are of particular concern to the West Bank and Gaza (see Deliverable D3.1), namely: earthquake hazards, flood hazards and climate change hazards.

Non-Technical Executive Summary

Introduction

The COVID-19 pandemic across the globe has highlighted the value of making governments, whether at the central or local levels, resilient to emerging complex emergencies, brought about by either natural or man-made hazards. While the impacts of these hazards may be different, there is a clear convergence in the aim of ensuring that communities have the capacities to absorb and recover from the effects of emergencies and disasters. Similarly, governments must equally have the means to mitigate and address the human and economic toll from disasters.

As a first step towards increasing the resilience of local governments to disasters, it has been necessary to assess the most important **hazards** to which people, buildings, and critical infrastructure in the West Bank and Gaza are exposed. The **risk**, i.e. the probability of negative consequences[1], from these hazards can be estimated by combining the likelihood of these hazards with the spatial distribution of people, buildings, and critical infrastructure (i.e. the **exposure**), and the **vulnerability**[2] of the latter. The main outcomes of this multi-hazard risk assessment are a number of maps which have been made available through an online mapping platform: https://map-irlg.najah.edu/portal/home/. This assessment, and in particular the mapping platform, will be used to develop resilience plans and capacity building activities to be carried out with local governments.

Hazard Assessment

A review of past examples of various hazards in the region has highlighted the importance of the following categories of hazard for the region:

- Geophysical hazards e.g., earthquakes, liquefaction, landslides and tsunamis
- Climate change hazards e.g., extreme temperatures and rainfall
- Hydrological hazards e.g., flooding and flash flooding

For example, in 1927 a magnitude 6.3 earthquake caused widespread damage in the region, and in Nablus alone killed 69 people. This earthquake also triggered a landslide that stopped the flow of the Jordan river. Due to climate change, extreme weather conditions are becoming more frequent in the West Bank and Gaza. Significant flooding events occurred in 2008, 2010, 2012, 2013, 2015, 2020 and 2022. These events have caused thousands of people to be displaced from their homes, significant damage and even fatalities.

For each hazard considered, maps have been produced to show the areas where the hazard is expected to be higher or lower across the West Bank and Gaza. These hazards include the strong ground shaking from earthquakes, ground failure from earthquakes and from extreme

[1] e.g. loss of life, collapse of buildings, environmental impact
[2] the inability to resist or respond to a hazard

rainfall, flooding (combining both rainfall and river overflow) and climate change. These hazard maps have all been made available on the IRLG mapping platform: https://map-irlg.najah.edu/tags/hazard/.

Exposure

A mapping of the location of critical infrastructure in the West Bank and Gaza has been undertaken for a number of sectors. These sectors, and their associated assets, are as follows:

- **Safety and Security**: police stations, civil defence buildings, fire stations and town halls
- **Food, Water, Shelter**: wells, mosques, churches and schools
- **Health and Medical**: hospitals, health centres and pharmacies
- **Energy**: substations, lattice steel poles, overhead lines and gas stations
- **Transport**: road network, checkpoints, barrier gates and annexation walls
- **Hazardous Material**: dumping sites

These critical infrastructure maps have all been made available on the mapping platform: https://map-irlg.najah.edu/tags/exposure/.

A more detailed analysis of priority structures, i.e. **hospital, municipality, civil defence and school buildings**, has been carried out by local engineers. A building inspection form was developed to collect important characteristics of these buildings. In total, 67 hospitals (84% national coverage), 55 civil defence buildings (100% national coverage), 20 municipality buildings (for the prioritised local governments), and 170 schools buildings (about 6% national coverage) were inspected by 8 engineers over a period of 12 weeks. A training course was undertaken before the inspections to go through the form and ensure there was a standard application of the assessment form. All of the information collected during these inspections is available on Google spreadsheets[3].

For the buildings within which people live, work and socialise (i.e. residential, industrial and commercial buildings), statistics related to population, housing and establishments from the 2017 census, released by the Palestinian Central Bureau of Statistics (PCBS)[4], have been collected and post-processed using established methodologies from the academic literature. Using this data, it has been possible to develop maps of the total replacement cost (in USD), population and number of buildings within each community in West Bank and Gaza, all of which are available on the mapping platform. In total it has been estimated that there are over 440,000 residential buildings, almost 49,000 commercial buildings and around 20,000 industrial buildings in the West Bank and Gaza. The most densely populated community is Gaza, with 30,000 buildings that house almost 600,000 people.

---

[3] https://docs.google.com/spreadsheets/d/1m-i1jxdKYWgNzylDLVsbEvhikRCqcEf5oW2e-e916DQ/edit#gid=1259170908
https://docs.google.com/spreadsheets/d/1JO6ZHpaS4JGR5d8g8vkLq6Fmcrz5n6pWf5vnoNtzoC0/edit#gid=2020303801

[4] https://www.pcbs.gov.ps/default.aspx

Vulnerability

Different types of **vulnerability** have been assessed in this project, as follows:

- **physical vulnerability** of the buildings, which describes the likelihood of physical damage and associated losses given the hazard, has been assessed for earthquake ground shaking and flood hazards;
- **sector vulnerability**, which identifies the sectors most likely to be adversely affected by a given hazard, has been assessed for climate change hazard;
- **social vulnerability**, which is an assessment of the capacity of populations to reduce disaster risk, to respond to emergencies, and to recover after a damaging event, has been evaluated considering all hazards that can affect the West Bank and Gaza.

Physical vulnerability models have been used for a quantitative risk assessment of the losses (both economic loss and loss of life) from earthquake and flood hazards, as described further below. These models depend on the characteristics of the buildings, such as the number of storeys, construction material and age. Hence, the buildings in the West Bank and Gaza have been grouped into a number of distinct **building classes**, each of which are expected to have similar levels of damage when subjected to a given hazard. For the hospital, municipality, civil defence and school buildings, the information required to assign the most appropriate building class has been obtained from the building surveys. The surveys collect information that can be used for multiple hazards. In this project, an additional exercise for the earthquake ground shaking risk assessment has been undertaken with the collected data, whereby a vulnerability score has been assigned to each building using the characteristics/deficiencies collected during the surveys. This score is used to further distinguish the behaviour of buildings to earthquake ground shaking, even when the buildings belong to the same class, and to allow the buildings to be ranked in terms of their seismic risk.

For the sector vulnerability, the detailed assessment undertaken as part of the National Adaptation Plan was utilised. This assessment was combined with expert judgement in order to provide maps of the spatial variability of the vulnerability of the following **targeted sectors** across the West Bank and Gaza:

- Agriculture (drought and rainfed agriculture)
- Energy (energy production; energy imports; condition of infrastructure)
- Urban and infrastructure (Building conditions; Urban drainage, urbanization)
- Water (flood management)

The social vulnerability has been assessed at the governorate level, using a number of indicators. A group of indicators that are relevant and known to explain the differential capacities of populations to prepare, respond and recover after events were selected based on the academic literature. A total of 32 indicators were collected for 16 Palestinian governorates from the Palestinian Central Bureau of Statistics (PCBS), Ministry of Health (MoH) and Ministry of Education (MoE), and included variables such as percentage of female population, percentage of unemployed, percentange of population without piped water. The indicators were collected together within 6 categories or sub-components: population, health, economy, education, infrastructure and political. The indicators were averaged per sub-component to form **sub-indicators** and then the six sub-indicators were simply summed to form the final **Social Vulnerability Index** for each governorate.

Risk Assessment

The hazard, exposure, and physical vulnerability models have been combined to calculate the **expected annual losses** to residential, commercial and industrial buildings from earthquakes and floods. The Social Vulnerability Index has also been combined with these losses, to produce maps showing the **integrated risk** of the communities in the West Bank and Gaza. The damage and losses for different 4 possible earthquake scenarios that could impact the region have been estimated. The expected annual flooded agricultural land has also been computed by combining the spatial distribution of agricultural land with the flood hazard model.

The expected annual losses to hospitals, civil protection and schools buildings have also been calculated, and these have been combined with the vulnerability scores (based on the specific characteristics/deficiencies collected for each building, as described above) in order to obtain an integrated risk index. A ranking of the buildings from highest to lowest risk has then been undertaken, thus identifying the buildings for which further, more detailed inspections and analyses are required.

A quantitative assessment of the flood risk to agricultural land in each governorate has also been presented, by combining the exposure of agricultural land with the flood hazard model. The final map shows the expected annual flooded agricultural areas (in km^2) for each governorate in the West Bank and Gaza.

For what concerns climate change, an expert-judgement based analysis that identifies the zones across the West Bank and Gaza where multiple sectors are most at risk to climate change hazard has been presented.

The maps with the results of these risk analyses have been made available on the mapping platform: https://map-irlg.najah.edu/tags/risk/.

Future Improvements of Hazard and Risk Studies

An assessment of the capacities (of both central and local institutions, including academia and technical institutions) to maintain and advance the multi-hazard and risk studies. In order to do this, for each component of risk (i.e. hazard, exposure, vulnerability assessment), a summary of the primary needs for maintaining and/or updating the analyses is provided (see table below), followed by the institutions that would be required for any associated data curation, those that would support the technical developments, and any supporting institutions at the local or central level. The summary is preliminary and needs further discussion with relevant stakeholders to better identify roles and responsibilities and gaps in existing capacities.

Summary of capacities for maintaining/updating the multi-hazard risk assessments

Component	Summary of needs for sustaining/ updating analyses	Data collection and curation	Technical expertise	Supporting institutions
Climatological hazards	- Increase weather stations to cover all of the distinct climatological zones in West Bank and Gaza - Develop local high resolution local climate models and future scenarios.	Palestinian Weather Department (PWD)	Water and Environmental Studies Institute (WESI) at An Najah National University and -Other universities or research centres	Water Quality Authority (WQA)
Geophysical hazards	- Compilation of local datasets (with the means for frequent updating) for both West Bank and Gaza: water table depth, mean annual precipitation, distance to rivers, land cover, monthly rainfall data, database of strong motion records, Vs30 data, high resolution Digital Terrain Mode, seismic faults database - Development of a database with georeferenced data on earthquake ground shaking and ground failure (liquefaction and landslides), including associated damage and losses	Earth sciences and seismic engineering unit – An-Najah National university	Earth sciences and Seismic engineering unit – An-Najah National university	-Environmental Quality Authority (EQA)
Flood hazard	- Installation of more rainfall and streamflow gauges - Frequent updating of soil maps and land use/cover maps for both West Bank and Gaza - Development of a database with georeferenced data on flooding (pluvial and fluvial), including associated damage and losses	Palestinian Weather Department (PWD)	Water and Environmental Studies Institute (WESI) at An Najah National University and - Other universities or research centres	-Palestinian Weather Department (PWD) -Minister of Local Government

Component	Summary of needs for sustaining/ updating analyses	Data collection and curation	Technical expertise	Supporting institutions
Exposure modelling	- Continued building inspections (of priority buildings) - Database of historical/heritage buildings and monuments - Expand critical infrastructure data e.g. water and electricity supply networks, telecommunications - Expand agricultural exposure data e.g. subdivide agriculture by crop type and land productivity. Include a database of green houses - Review and checking of collected data and national databases - Compilation of local datasets for the sectors highly vulnerable to climate change	Palestinian Central Bereau of Statistics (PCBS) and relevant ministries Local Government Units (LGUs)	Urban Planning and Disaster Risk Reduction Center – An-Najah National University	-Ministry of Local Government -Ministry of agriculture
Social Vulnerability	- Stakeholder workshops to review variables and weights applied in composite indicators	Palestinian Central Bereau of Statistics (PCBS)	Urban Planning and Disaster Risk Reduction Center – An-Najah National University	-Minister of Social Development -Local Government Units (LGUs)
Physical vulnerability (earthquake ground shaking and flood hazards)	- Development of structural models of typical building classes and priority buildings by local engineers, and subsequent updating of vulnerability models - Calibration of empirical flood vulnerability functions using local data - Account for effects of war in Gaza on the quality of buildings - Develop flood vulnerability functions for different types of agriculture	Earth sciences and seismic engineering unit at An-najah National University	Earth sciences and seismic engineering unit – An-najah National University	- Minister of Public Works and Housing -Minister of National Economy -Water Quality Authority

Risk-Based Ranking of LGUs

The integrated risk maps and the initial ranking of critical infrastructure presented in this report provide a wealth of information that can be used to rank LGUs across the West Bank and Gaza, such that those that should be prioritised for risk reduction/mitigation funding and activities can be identified. Such overall ranking has not been undertaken herein, as it requires further discussion and decisions on how to combine the risk to buildings and critical infrastructure from varying hazards, and potentially how to include other, non-technical, decision variables. However, it is noted that all of the results and data presented herein can be used for such purpose, and the Urban Planning and Disaster Risk Reduction Center (UPDRRC), An-Najah National University is available to support such activities.

1 Introduction

This deliverable describes the activities related to exposure, vulnerability and risk modelling for multiple hazards that are of particular concern to the West Bank and Gaza (see Deliverable D3.1), namely earthquake hazards, flood hazards and climate change hazards.

In Chapter 2, the hazard models and maps that were explored and developed in Deliverable D3.1 are summarised.

Chapter 3 describes the datasets that have been collected and compiled to model the exposure of residential, industrial and commercial buildings, critical infrastructure and priority buildings comprising hospital, civil protection, municipality and school buildings.

Chapter 4 summarises the physical vulnerability models that have been identified for the building classes present in the West Bank and Gaza for seismic and flood risk assessment. This Chapter also reviews the sectors that are particularly vulnerable to climate change, as evaluated during the development of the National Adaptation Plan (NAP). A study of the social vulnerability or a number of sub-indicators related to education, population, economy, health, politics and infrastructure is also presented, for the development of a Social Vulnerability Index.

In Chapter 5, the hazard, exposure, physical vulnerability and social vulnerability models are combined in quantitative regional (integrated) risk assessments for earthquakes and floods. More detailed building-by-building analyses to rank the priority buildings (hospitals, civil protection and schools buildings) using an integrated risk index is also presented. For what concerns climate change, an expert-judgement based analysis that identifies the zones where multiple sectors are most at risk to climate change hazard is provided.

The outputs of the hazard, exposure, vulnerability and risk assessment have been transformed into a number of maps which have been made available through the web-based mapping platform (set up specifically for the project, as described in Chapter 6 herein): https://map-irlg.najah.edu/portal/home/.

2 Hazard Assessment

Deliverable 3.1 has presented the activities that have been undertaken to date in order to identify the key hazards to which the West Bank and Gaza is subjected, and to provide initial assessments of these hazards, both through existing models as well as new methods.

The review of past examples of various hazards in the region highlighted the importance of the following categories of hazard for the region:

- Geophysical hazards (earthquakes, liquefaction, landslides and tsunamis)
- Climate change hazards (especially related to extreme temperatures and rainfall)
- Hydrological hazards (flooding and flash flooding)
- Pollution and environmental hazards (affecting the water, ecosystems, air and soil)

Furthermore, the exacerbating effects of the recent COVID-19 global pandemic as well as war and siege on these hazards has been demonstrated, and the need to qualitatively account for these effects in the risk assessment has been identified.

The focus of the subsequent chapters of the deliverable was to identify existing and new methods and models that can be used both to map the hazard/susceptibility of the first three categories of hazard and to provide the necessary input for the quantitative risk assessment that has been undertaken in this deliverable. A number of hazard maps have been produced for the web-based map platform, which are further presented and described in Chapter 6.

Table 2.1. summarises the key characteristics of the priority hazards maps presented in Deliverable 3.1, including the spatial resolution, hazard metric, return period and type of assessment.

Table 2.1: Summary of the main multi-hazard maps from Deliverable D3.1

Hazard	Type of assessment	Hazard metric	Return period (years)	Spatial resolution
Ground shaking hazard	Probabilistic - quantitative	Peak ground acceleration	475	Contour interpolated from regular grid (5 x 5 km)

Hazard	Type of assessment	Hazard metric	Return period (years)	Spatial resolution
Liquefaction	Semi-quantitative	4 susceptibility categories (negligible, low, moderate, high)	N/A	15 arc seconds (approx. 500m) (Note that original input layers have a 30 arc second resolution, but they have been linearly interpolated to 15 arc seconds)
Landslides – rainfall triggered	Semi-quantitative	3 susceptibility categories (negligible, low moderate)	Triggered by 100 year extreme monthly rainfall (in mm)	7.5 arc seconds (approx. 250m)
Landslides-earthquake triggered	Semi-quantitative	4 susceptibility categories (negligible, low moderate, high)	Triggered by 475 year return period seismic hazard map	7.5 arc seconds (approx. 250m)
Tsunami	Quantitative	Maximum design runup (metres)	2500 years	N/A
Climate change (historical analysis)	Semi-quantitative	Climate change hazard susceptibility maps based on historical trends of precipitation and temperature	N/A	N/A
Climate change (projections)	Semi-quantitative	3 projection scenarios representative of all projections by the IPCC AR5	N/A	National

Hazard	Type of assessment	Hazard metric	Return period (years)	Spatial resolution
Floods	Quantitative	(a) Mean annual flood depth (b) Runoff depth	(a) 100 years (b) 10, 25, 50, 100	(a) 90 metres (b) interpolated between stations

3 Exposure Modelling

An exposure model capable of characterising the vulnerability and geographical distribution of the elements exposed to natural hazards is a fundamental component to assess disaster risk. This chapter presents the efforts that have been undertaken to collect exposure data and develop exposure models for the buildings in the West Bank and Gaza.

3.1 Residential, Commercial and Industrial Buildings

The residential, commercial and industrial exposure models developed in this section are statistics-based. A method that is usually used when detailed building-by-building information is not available or accessible (Crowley et al. 2020). The model depends primarily on the aggregate statistics available from the national census, which is combined with existing knowledge about buildings and construction to produce a model that can characterise buildings' vulnerability and spatial distribution of the assets at a geographical unit scale, i.e. city, governorate or region.

The existing exposure models for the West Bank and Gaza that can be used in multi-hazard risk assessment are either limited in quantity and quality or the level of detail. Most of these models are developed on a global scale, one example is the global exposure database developed for the Global Assessment Report (GAR) of the United Nations International Strategy for Disaster Reduction (UNISDR). This database was developed for multi-hazard risk assessment and includes information about the economic value, physical characteristics and population distribution for both urban and rural areas on a grid with a 5x5 km^2 spatial resolution (and 1x1 km^2 near coastal areas - De Bono et al., 2014). Another example is the global exposure database from the Global Earthquake Model (GEM) Foundation (so-called GED4GEM) which provides an open geospatial inventory of buildings and populations at 1x1 km^2 spatial resolution (Gamba et al., 2012). Despite their usefulness, the details are insufficient for decision-making at the sub-national level. At the local level, Grigoratos et al. (2016) and Monteiro et al. (2016) developed an exposure model for Nablus, one of the largest cities in Palestine. The exposure dataset was developed using the 2007 national housing and population census, field surveys and information from the existing literature. Despite the importance of such local studies, they are limited to a single city or region.

At the national scale, Dabbeek and Silva (2020) proposed an exposure model for the West Bank and Gaza developed for the purpose of multi-hazard risk assessment. The model was developed at the governorate level (2nd administrative boundary), then distributed spatially to a resolution of 38m using a downscaling method that uses built-up areas of the global human settlements layer (GHSL - Pesaresi et al. 2015). The exposure model presented here is an update of the model proposed in Dabbeek and Silva (2020). Table 3.1 illustrates key improvements in the new model compared to the existing version. The updated model uses the 2017 population and housing census, which is the most recent to-date. Between 2007 and 2017, buildings increased by 160 thousand (34%), and the population increased by one million (27%). In terms of spatial resolution, the updated model captures buildings and population at the community level - urban, rural and refugee camps (599 communities), while the previous version was more coarse and developed at governorate level (16 governorates). The new model uses more variables about buildings, including materials of the external walls, building type, number of floors and construction year. Moreover, the models consider two additional occupancy times for the population, i.e., day and transit, as in previous models only the night time was considered. The presence of people inside buildings is dynamic; depending on the time of the day, the population inside buildings can change as people travel between home and their workplaces. This feature can help estimate the number of the affected population depending on the time of the disaster. Finally, the updated model added two new building categories: commercial and industrial buildings, which are not covered in the Dabbeek and Silva (2020) study.

Table 3.1: Comparison between Dabeek and Silva (2020) model and updated model.

	Dabbeek and Silva (2020)	**This study**
Census year	2007	2017
Administrative division	2nd - 16 governorates	3rd - (599) communities
Settlement type	Rural, urban	rural, urban and camps
Census variables	building type, wall material	building type, wall material and number of floors
Commercial and Industrial buildings	not considered	Considered
Occupancy times	night population	day, night and transit population

The detailed methodology used to develop the exposure model is detailed in Dabbeek and Silva (2020). The following sections provide summaries on the main steps and assumptions used in the development of this model.

3.1.1 Collecting census information

The main information about building counts and population numbers was collected from the Palestinian Central Bureau of Statistics (PCBS)[5]. The first census was established in 1997, followed by 2007 and lastly in 2017. The 2017 census used in this section provides information about populations, housing and establishments in the West Bank and Gaza. We collected information about buildings, establishments and population counts from the census. For the residential sector, we used the number of completed buildings used for habitation and mixed (habitation and work). Building counts were collected by type, the material of external walls and the number of floors according to PCBS classification. Buildings include houses, villas, and apartment buildings in addition to other marginal buildings, which include tents, caravans, barracks and independent rooms. External wall material includes: old stone, adobe clay, cement block, concrete, and cleaned stone. The number of floors is divided into five floors and a separate category for buildings higher than six floors. Commercial and industrial exposure information, was collected from the PCBS' establishments census,which defines establishments as a building usually constructed for non-residential purposes, e.g., mosques, schools, hospitals, factories, hotels, or a number of stores or multi-storey buildings originally intended for the entire work only, such as office buildings or commercial markets. The study collected the number of operating establishments in the private sector, non-governmental organisations and governamental companies. Establishments were collected by type of economic activity, divided into 20 main activities. Table 3.2 lists these activities and classifies them into two categories; commercial and industrial. In the proposed model, COM refers to commercial and IND to industrial. Education and human health activities denoted as COM 10 and 11 respectively were not included in the commercial sector to avoid duplication as these buildings were modelled separately as part of critical infrastructure assets. In addition to the type of economic activity, we collected information about the distribution of establishments by employment size.

Table 3.2: Operating establishments by economic activity.

Economic Activity	**Activity code**
Mining and quarrying	IND1
Manufacturing	IND2
Electricity, gas, steam and air conditioning supply	IND3
Water supply; sewerage, waste management and remediation activities	IND4
Construction	IND5
Wholesale and retail trade; repair of motor vehicles and motorcycles	COM1

[5] https://www.pcbs.gov.ps/default.aspx

Economic Activity	Activity code
Transportation and storage	COM2
Accommodation and food service activities	COM3
Information and communication	COM4
Financial and insurance activities	COM5
Real estate activities	COM6
Professional, scientific and technical activities	COM7
Administrative and support service activities	COM8
Public administration and defense; compulsory social security	COM9
Education	COM10
Human health and social work activities	COM11
Arts, entertainment and recreation	COM12
Other service activities	COM13
Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use	COM14
Activities of extraterritorial organisations and bodies	COM15

3.1.2 Identification of the most common building classes

The most common building classes were classified according to a set of building features that reflect the expected vulnerability against floods and earthquakes. The predominant construction classes were identified from published literature. 50 unique building classes were determined according to the construction material, lateral load resisting system, ductility level, code level and number of stories, presence of soft stories and basements. A sample of the most predominant types of construction in the region is illustrated in Table 3.3.

Table 3.3: Predominant construction types in West Bank and Gaza

Description	Photo	Ref
A traditional, non-engineered, low-rise construction practice (1-3 stories). The main lateral load-resisting system consists of bearing walls with unreinforced concrete strip foundation. The interior masonry walls consist of plain concrete (system #1) or two stone masonry walls filled with plain concrete (system #2). The exterior bearing walls consist of stone masonry facing with a plain concrete backup. Wall thickness ranges from 400 to 500 mm (system #1) to 300-mm thickness in system #2. This practice was mostly used between 1950s to the 1970s. This construction is not practised at the present time. It can be found in both urban and rural areas.		World Housing Encyclopedia , report 49[6]
Reinforced concrete frame with infill walls designed for gravity loading, low and medium-rise from 1 to 7 stories. This building typology appeared around 1980 and is still commonly used in most countries in the region. The lateral load resisting system consists of reinforced concrete columns, beams and a concrete slab. Infill walls are made of concrete hollow blocks, cast in place concrete or decorative stone or plaster. Only a few are designed considering seismic provisions.		World Housing Encyclopedia , report 48[7]
Typically reinforced concrete infilled frame with a soft story, due to missing infill walls everywhere (top photo) or in part of the floor (bottom photo).		SASPARM 2.0 project, Deliverable D.A.7[8]

[6] https://cerem.ufp.pt/reports:report_49
[7] https://cerem.ufp.pt/reports:report_48
[8] http://sasparm2.najah.edu/wp-content/uploads/2016/04/DA7_Technical_Report.pdf

Description	Photo	Ref
		

3.1.3 Mapping census information to building classes

Each of the identified building classes is converted into a string using the GEM taxonomy system for buildings. This string describes the various structural and nonstructural physical attributes that are relevant to characterise vulnerability to earthquakes, floods and other hazards. Table 3.4 illustrates how a building is converted using the GEM taxonomy system; the full glossary can be found at https://taxonomy.openquake.org/.

Table 3.4: Example of using GEM building taxonomy

CR+CIP/LFINF+CDL+DUL/H4/SOS+HBEX:1						
CR+CIP	LFINF	CDL	DUL	H4	SOS	HBEX:1
Reinforced concrete, cast in place	Infilled frame	Low code	Low ductility	4 floors	Soft story	one basement

After converting all possible building types into building classes, a mapping scheme is developed to establish a relationship with information about buildings collected from the census. A mapping scheme assigns possible weight to structural class conditional to variables provided in the census. For example, house buildings can only be one or two stories high as defined by PCBS, hence only one and two stories buildings are assigned to this category. The weights assigned for each structural system are either based on actual percentages found in the census e.g., distribution of building types by number of floors or based on other studies and expert judgement e.g., levels of ductility of the lateral resisting systems. The mapping schemes were developed separately for each residential sector (i.e. urban, rural and refugee camps) as building types can vary due to urbanisation level and socioeconomic conditions in these groups (see example in Table 3.5). A more detailed discussion on the building code practice in the West Bank and Gaza can be found in Dabbeek and Silva (2020).

For commercial and industrial buildings, one mapping scheme at the national scale was developed. The mapping scheme takes economic activity and establishments employment size into consideration when assigning building classes types (see example in Table 3.6). The full mapping schemes can be found in Appendix 1.

Table 3.5: Sample of mapping scheme for residential buildings in urban communities.

Material of external walls	**Building type**		
	Villa	House	Apartment
Cleaned Stone	1% CR+CIP/LFINF+CDL+DUL/H1 36% CR+CIP/LFINF+CDL+DUL/H2 9% CR+CIP/LFINF+CDL+DUL/H2/SOS 19% CR+CIP/LFINF+CDL+DUL/H3 5% CR+CIP/LFINF+CDL+DUL/H3/SOS 4% MUR+STDRE/LWAL+DNO/H1 6% MUR+STDRE/LWAL+DNO/H2 5% CR+CIP/LFINF+CDL+DUM/H1 5% CR+CIP/LFINF+CDL+DUM/H2 5% CR+CIP/LFINF+CDL+DUM/H3 4% CR+CIP/LFINF+CDL+DUM/H4 1% CR+CIP/LFINF+CDL+DUM/H4/SOS	36% CR+CIP/LFINF+CDL+DUL/H1 44% CR+CIP/LFINF+CDL+DUL/H2 4% CR+CIP/LFINF+CDL+DUM/H1 6% CR+CIP/LFINF+CDL+DUM/H2 4% MUR+STDRE/LWAL+DNO/H1 6% MUR+STDRE/LWAL+DNO/H2	8% CR+CIP/LFINF+CDL+DUL/H2 2% CR+CIP/LFINF+CDL+DUL/H2/SOS 34% CR+CIP/LFINF+CDL+DUL/H3 10% CR+CIP/LFINF+CDL+DUL/H3/SOS 3% CR+CIP/LFINF+CDL+DUM/H2 11% CR+CIP/LFINF+CDL+DUM/H3 11% CR+CIP/LFINF+CDL+DUL/H4 4% CR+CIP/LFINF+CDL+DUL/H4/SOS 5% CR+CIP/LFINF+CDL+DUM/H4 3% CR+CIP/LDUAL+CDL+DUL/H5 2% CR+CIP/LDUAL+CDL+DUL/H5/SOS 2% CR+CIP/LDUAL+CDL+DUM/H5 1% CR+CIP/LDUAL+CDL+DUM/H6+ 2% CR+CIP/LDUAL+CDL+DUL/H6+ 2% CR+CIP/LDUAL+CDL+DUL/H6+/SOS

Table 3.6: Sample of mapping scheme for industrial buildings.

Economic activity	**Employment size group**			
	1-4 (micro small)	5-9 (small)	10-19 (medium)	20+ (large)
Mining and quarrying (IND1)	21% IND1-MS/CR+CIP/LFINF+CDL+DUL/H1 3.5% IND1-MS/MUR+STDRE/LWAL+DNO/H1 32.5% IND1-MS/S/LFM+CDL+DUL/H1 32.5% IND1-MS/S/LFM+CDL+DUM/H1 6.3% IND1-MS/CR+CIP/LFINF+CDL+DUL/H2	21% IND1-S/CR+CIP/LFINF+CDL+DUL/H1 3.5% IND1-S/MUR+STDRE/LWAL+DNO/H1 32.5% IND1-S/S/LFM+CDL+DUL/H1 32.5% IND1-S/S/LFM+CDL+DUM/H1 6.3% IND1-S/CR+CIP/LFINF+CDL+DUL/H2	21% IND1-M/CR+CIP/LFINF+CDL+DUL/H1 35% IND1-M/S/LFM+CDL+DUL/H1 35% IND1-M/S/LFM+CDL+DUM/H1 6.3% IND1-M/CR+CIP/LFINF+CDL+DUL/H2 2.7% IND1-M/CR+CIP/LFINF+CDL+DUM/H2	21% IND1-L/CR+CIP/LFINF+CDL+DUL/H1 35% IND1-L/S/LFM+CDL+DUL/H1 35% IND1-L/S/LFM+CDL+DUL/H1 6.3% IND1-L/CR+CIP/LFINF+CDL+DUL/H2 2.7% IND1-L/CR+CIP/LFINF+CDL+DUL/H2

	2.7% IND1-MS/CR+CIP/LFINF+CDL+DUM/H2 1.5% IND1-MS/MUR+STDRE/LWAL+DNO/H2	2.7% IND1-S/CR+CIP/LFINF+CDL+DUM/H2 1.5% IND1-S/MUR+STDRE/LWAL+DNO/H2		

3.1.4 Estimation of building replacement cost

Quantifying the floor area and replacement cost is essential to calculate economic losses. For the residential sector, the buildings are first converted to dwellings using the number of floors per building and dwellings per floor, as illustrated in Equation 3.1.

N_dwellings = (n_buildings x n_stories per building x n_dwellings per floor) (3.1)

Table 3.7: Average dwellings per floor.

Number of floors	Average dwellings per floor	Comment	Average number of establishments per building
H1	1	single-family.	1
H2	1	single-family.	2
H3	2	mostly each floor for a single-family.	3
H4	2	mostly each floor for a single-family.	8
H5	3	mostly three dwellings per floor.	10
H6+	3	mostly three dwellings per floor.	12

In the case of the commercial and industrial sectors, establishments are converted to buildings using assumptions based on economic activity. Table 3.7 illustrates the assumed number of establishments per building, except for manufacturing, which assumes that one establishment equals one building.

Average dwelling area according to PCBS is 130 m^2 for urban and rural areas and 100 m^2 for refugee camps. For commercial and industrial, the establishment floor area is estimated from the employment size: 100 m^2 for micro-small, 150 m^2 for small, 300 m^2 for medium and 500 m^2 for large establishments. The last step to calculate the total replacement cost is to multiply the total built area by unit replacement cost. Replacement cost refers to the construction cost of a new building with the same characteristics but according to the current design regulations, without considering the price of the land or the market value. The replacement cost per m^2, was estimated based on previous studies and expert feedback from the construction industry. The costs reported in Table 3.8 are based on 22/July/2022. The values used for conversion in Table 3.8 are mainly based on the available literature and the feedback of local experts.

Table 3.8: Average unit construction cost per occupancy and region.

Region	**Average Construction Cost (USD/m^2)**		
	Residential	Commercial	Industrial
West Bank	1015	1305	1305
Gaza*	711	914	914
*Construction cost are lower mainly due to lower labot costs and construction material. For example, stone-cladding is more expensive and less used in Gaza			

3.1.5 Modelling population

Occupancy times are divided into three periods: day, night and transit. Total population and working population in each community are multiplied by percentages reported in PAGER population distribution model (Jaiswal and Wald, 2010) to determine the proportion of population inside buildings during day, night and transit times for residential and non-residential buildings.

3.1.6 Georeferencing

Buildings are georeferenced using the community and governorate boundaries from the Palestinian portal for spatial information in Palestine, GeoMolg[9]. Each building is assigned spatial coordinates at the geometric centroid of the community boundaries. For more extensive hazards i.e., earthquakes, the resolution of the 3rd community is sufficient, as shown in (Dabbeek et al. 2021), nonetheless for more localized hazards e.g., floods and landslides, such resolution might introduce bias in risk results. Accordingly, the exposure model was disaggregated at an evenly spaced grid with a 38x38 m^2 spatial resolution. The number of buildings assigned to each grid cell was estimated based on satellite imagery using a downscaling method described in Dabbeek and Silva (2020).

3.1.7 Summary results

Using the above methodology, the study estimates that there are around 510k building stock in West Bank and Gaza which would entail a replacement cost of around 154.7 billion USD (abput 12 times the national GDP). The majority (86%) of buildings are residential, of which 61% are located in urban communities, 18% in rural communities and 7% in refugee camps. The commercial sector constitutes about 10% of the buildings while the industrial sector constitutes 4% of the buildings. West Bank and Gaza has a total population of 4.5 million. The distribution of population residing inside buildings is 98% at night time, 68% in transit time and 37% in day

[9] https://geomolg.ps/L5/index.html?viewer=A3.V1

time. Table 3.9 summarises the number of buildings, total replacement cost and population by occupancy time.

Table 3.9:Summary of the residential, commercial and industrial exposure.

Occupancy	Number of buildings (thousands)	Replacement cost (M USD)	Population (thousands)		
			day*	night*	transit*
residential - camp	36.16	7730.23	129.24	375.57	265.88
residential - rural	94.09	27316.64	235.01	682.9	483.45
residential - urban	311.31	102778.33	1135.77	3356.2	2276.81
commercial	48.93	13973.24	123.67	5.82	12.51
industrial	20.18	2972.10	22.49	1.06	2.27
* Day time (10 am-5 pm), Night time (10 pm-5 am), and Transit time (5 am-10 am and 5pm-10 pm)					

In terms of building materials, the results show that reinforced concrete is the predominant construction material, representing about 87% of the building stock. The second most common type of construction (about 8%) is masonry, with most of the buildings being unreinforced masonry. Other informal structures such as adobe and light wood frames represent less than 1% of the buildings. Steel structures represent 3% of the total building stock mostly in the industrial and commercial sector. About 84% of the structures are found to be non-ductile or with low ductility, thus reflecting the lack of enforcement of design regulations in the region. About 93% of the building stock consists of 1 to 3 stories buildings, and only 7% have 4 stories and above. Figure 3.1 illustrates the distribution of macro building classes (i.e. based only on main material) by occupancy. Maps of the distribution buildings stock replacement value for residential, commercial and industrial sectors are illustrated in Figure 3.2, 3.3 and 3.4.

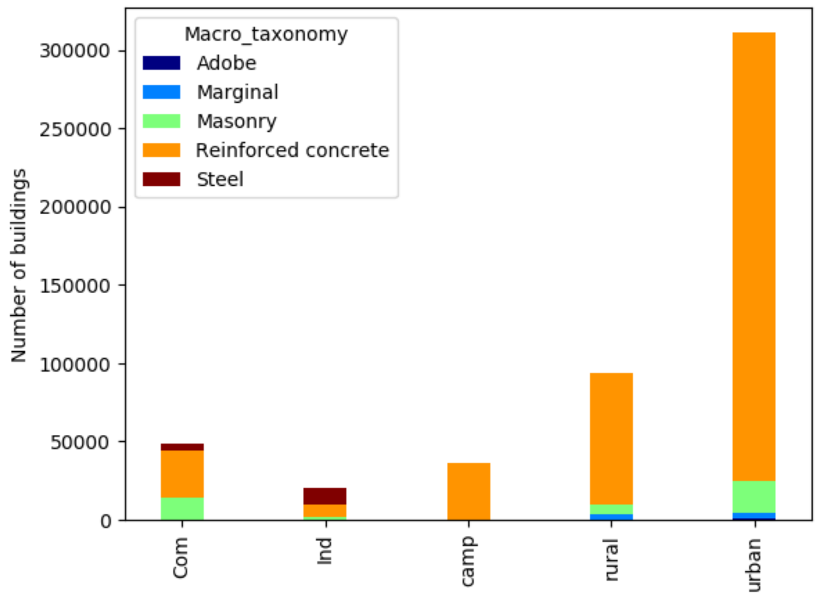


Figure 3.1: Distribution of macro building classes by occupancy calss (commercial, industrial, residential-urbn, residential-rural, residential-camp) for all buildings in West Bank and Gaza.

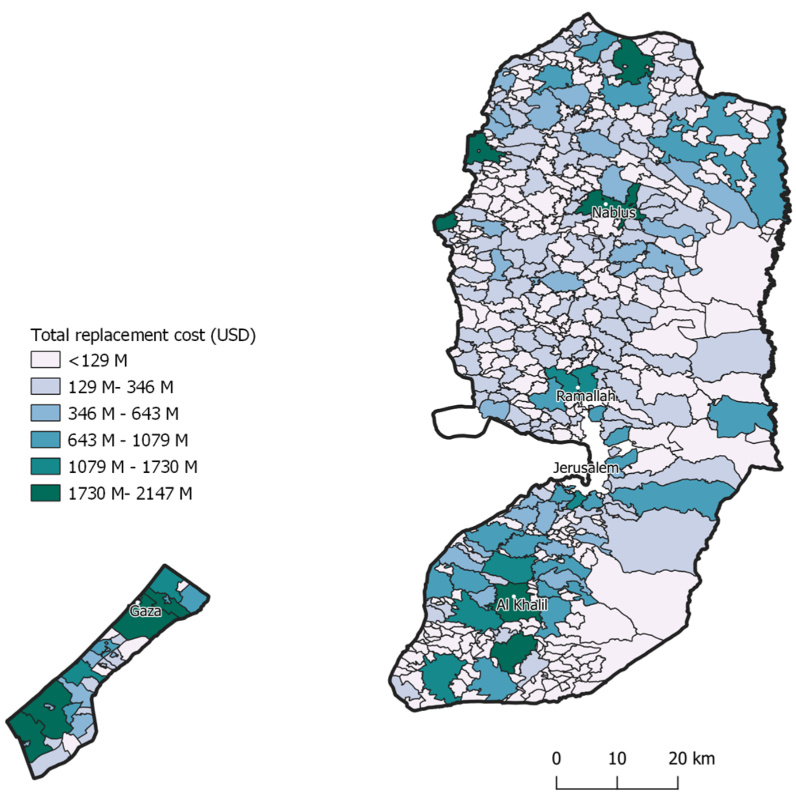


Figure 3.2: Map of the building stock total replacement value for residential buildings.

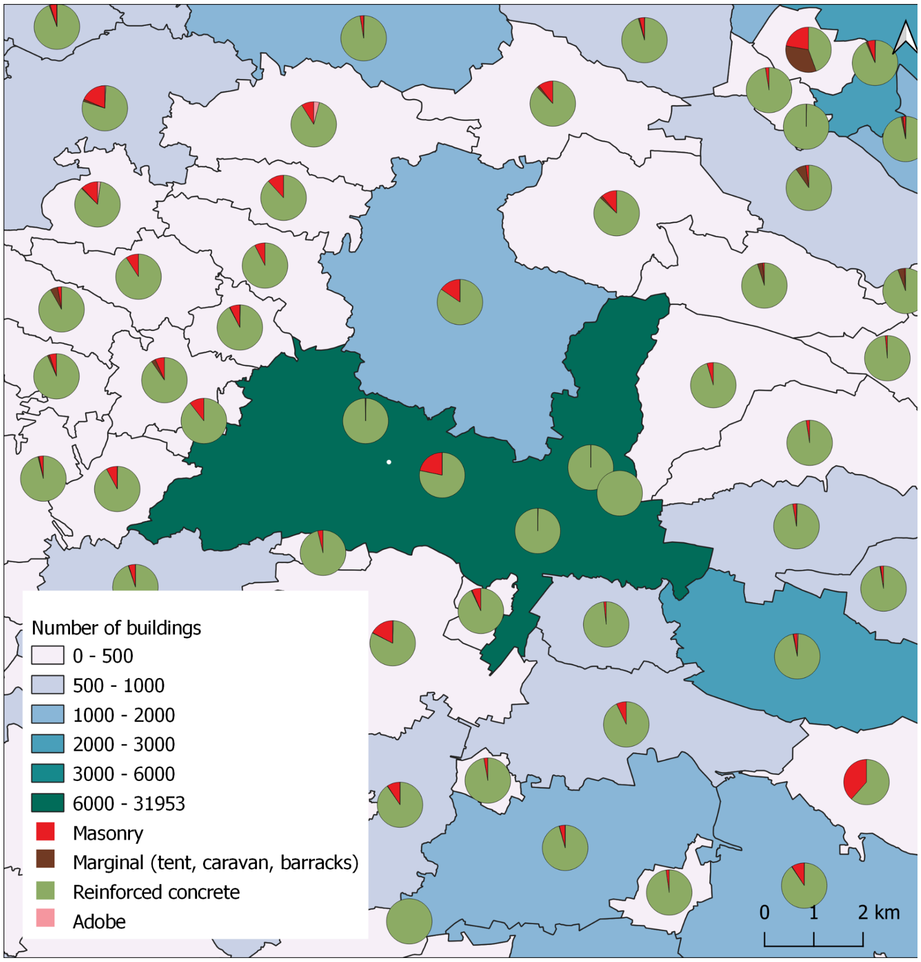
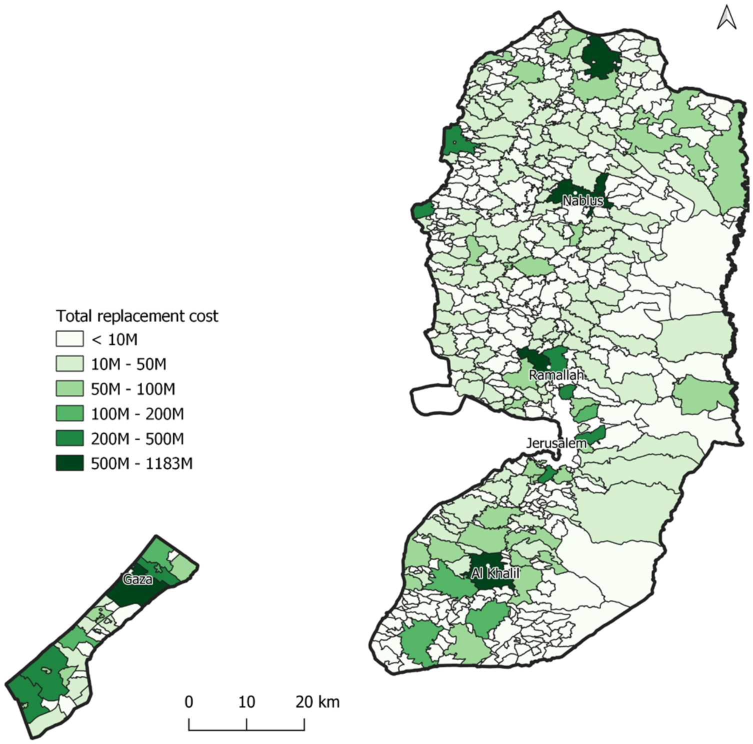


Figure 3.3: Number of residential buildings and distribution of structural system by construction material in Nablus governorate.



Total replacement cost
< 10M
10M - 50M
50M - 100M
100M - 200M
200M - 500M
500M - 1183M
Nablus
Ramallah
Jerusalem
Al Khalil
Gaza
0
10
20 km

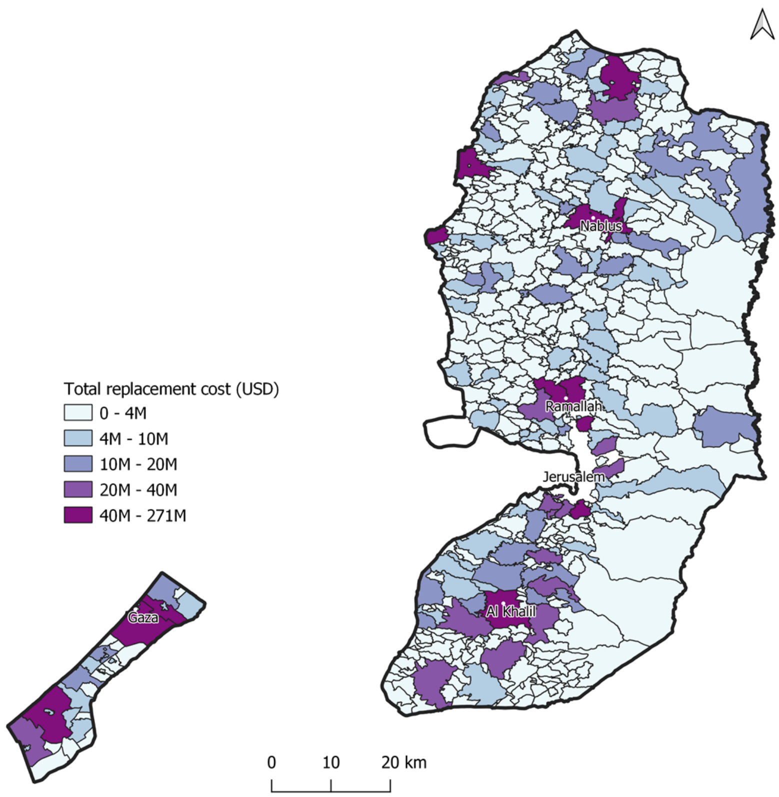


Figure 3.4: Map of the building stock total replacement value for the commercial (top) and industrial (bottom) sectors.

3.2 Critical Infrastructure

Critical infrastructure (CI) is a term used to describe the assets that are essential to the health, safety, security and economic wellbeing of communities. Failure of CI is known to cause severe disruption and sometimes cascading effects after emergency events. The first step towards assessing the level of protection, preparedness and resilience of these systems to natural hazards is exposure modelling of CI. This includes identifying the location, physical and functional features of every asset as well as the interdependence between assets and other CI sectors. CI is divided into seven sectors inspired by the United States of America's Federal Emergency Management Agency (FEMA) classification of community lifelines (FEMA 2020). That includes:

- Safety and Security
- Food, Water, Shelter
- Health and Medical
- Energy
- Communications

- Transportation
- Hazardous materials

Every sector stands for a combination of facilities (hospitals, fire stations, local governments) or services (telecommunications, energy and transport) that should remain operational in normal conditions and after major incidents or disasters.

The locations of CI assets were compiled mainly from Geomolg, OpenStreetMap (OSM) and the United Nations Office for the Coordination of Human Affairs (UN-OCHA). Geomolg is a public platform for official geospatial information hosted by the Ministry of Local Government (MoLG 2020). OSM is an open, collaborative effort which provides spatial information worldwide. In order to extract the OSM for West Bank and Gaza, several spatial queries were performed using Overpass-turbo engine (https://overpass-turbo.eu/). The assets collected for every sector of CI are summarized in Table 3.10 in terms of variables found, data spatial extent and source. The collected information has been compiled in QGIS software. The next section provides map samples of the collected datasets. Further development of the maps would be to populate the datasets with the necessary information for vulnerability and risk assessment

The 22 CI assets are listed in Table 3.10. Given the limited time and budget, priority has been given to schools, hospitals, town halls and civil defence buildings in this project, so as to further characterize them in terms of their physical attributes, economic value, and occupancy levels, thus allowing them to be explicitly included in the probabilistic risk assessment. Individual building inspections of these buildings have also been carried out, as described further in Section 3.4.

Table 3.10: List of critical infrastructure

Sector	Assets	Variables	Spatial coverage	Source
Safety and Security	Police	Location, code, name	West Bank and Gaza	OpenStreetMap
	Civil Defence	Location, name	West Bank and Gaza	Palestinian civil defence[10]
	Fire Stations	Location, code, name	West Bank and Gaza	OpenStreetMap
	Townhall	Location, name	West Bank and Gaza	OpenStreetMap
Food, Water, Shelter	Wells	Location, English and Arabic name, water use	West Bank	Geomolg

[10] https://www.pcd.ps/

Sector	Assets	Variables	Spatial coverage	Source
	Mosques	Location, Arabic name	West Bank	Geomolg
	Churches	Location, name	West Bank and Gaza	OpenStreetMap
	Schools	Location, name, owner, gender, directorate, number of floors, floor area, establishment date, number of students	West Bank and Gaza	Ministry of Education & OCHA
Financial	Banks	Location, code, name	West Bank and Gaza	OpenStreetMap
Health and Medical	Medicine Storage	Location, code, name	West Bank and Gaza	OpenStreetMap
	Hospitals	Location, name, sector, contact, service type, number of beds	West Bank and Gaza	OCHA & Ministry of Health
	Health Centers	Location, English and Arabic name, work hours, contact,	West bank and Gaza	OCHA
	Pharmacy	Location, code, name	West Bank and Gaza	OpenStreetMap
Energy	Steel Poles 161KV	Location, Length	West Bank	Geomolg
	Electrical Substation 161-33KV	Location	West Bank	Geomolg
	Gasoline Station	Location, code, name	West Bank and Gaza	OpenStreetMap
Communication	Telephone Center	Location, code, name	West Bank and Gaza	OpenStreetMap
Transport	Check Points and Gates	Location, English name, opening period	West Bank	Geomolg and OCHA
	Separation Wall	Location	West Bank	OCHA
	Road Network[1]	Location, type	West Bank and Gaza	Ministry of Transportation

Sector	Assets	Variables	Spatial coverage	Source
Hazardous Material	Dumping sites	Location, Type	West Bank	Geomolg

3.3 Preliminary Mapping of Critical Infrastructure

3.3.1 Safety and Security

The Palestine Civil Police is a government agency, and it is a part of the Palestinian security forces. It carries out the mission of maintaining security and public order in major Palestinian cities and urban areas, in addition to ensuring the protection of persons and property. An example of the safety and security sector is illustrated in Figure 3.5 for Hebron governorate, which contains 3 fire stations, 8 civil defence centres and 18 police stations.

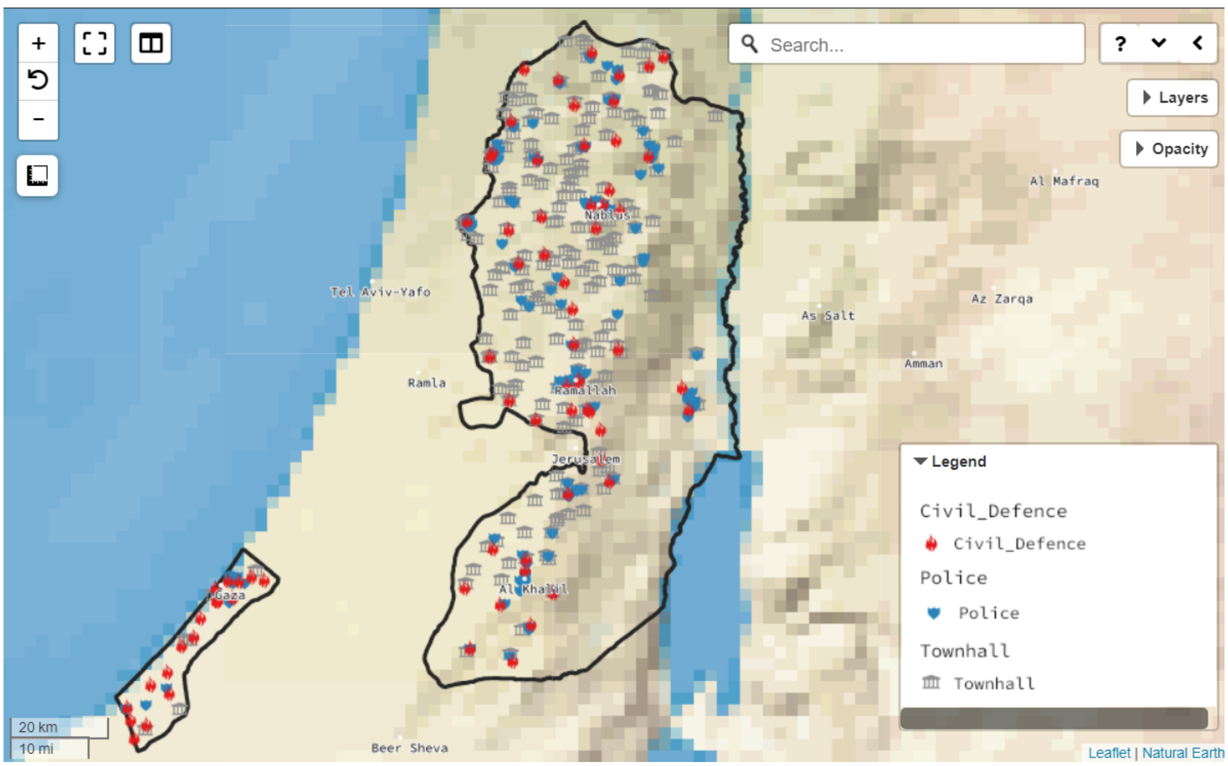


Figure 3.5: Screenshot showing Safety and Security layers for West Bank and Gaza

3.3.2 Food, Water, Shelter

Water

Water sources that are confined to the Palestinian Territories include groundwater pumped from wells and exploited from springs, and water purchased from the Israeli water source (Mekorot). The total available for water from both sources reached 389.5 million cubic meters in 2018 (PCBS, 2020).

Schools

Refers to any educational institution, whether primary school, middle school, high school, middle community college, university or any institute after high school that provides regular education or recognized by the official authorities, except kindergartens. The number of schools in Palestine (public and private schools) reached about 3,037 of which 2,300 are in the West Bank and 737 are in the Gaza Strip (PCBS, 2020).

Places of worship

The number of mosques operating in Palestine until the end of 2017 was about 3,064. Of which 2,102 mosques are in the West Bank and 962 mosques are in Gaza (Aliqtisadi, 2020). Meanwhile, the number of churches functioning until the end of 2011 was 162, of that 159 are in the West Bank and three are in Gaza (PCBS, 2020).

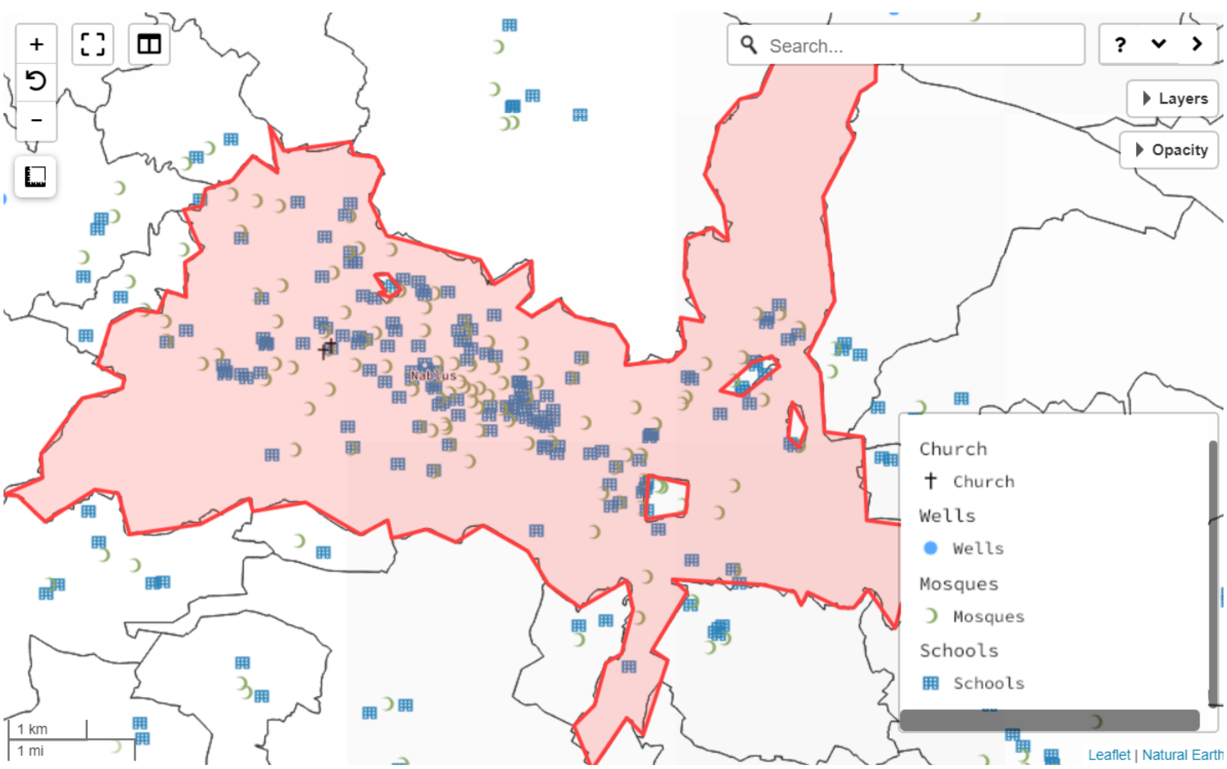


Figure 3.6:Distribution of churches, mosques, schools and water wells in Nablus city.

3.3.3 Health and medical

Hospitals

In the year 2018, the number of hospitals operating in Palestine reached 82, of which 52 (63.4%) in the West Bank, including East Jerusalem and 30 in Gaza. The total bed capacity in Palestine is 6,440 with a bed rate of 1.33 for every 1000 citizens: of which 3,897 are in the West Bank and 2,543 are in Gaza (PCBS 2020). The Ministry of Health has 3,531 beds (54.9% of total hospital beds) of in Palestine distributed on 28 hospitals (Wafa, 2020).

Pharmacies

As of the end of 2019, the number of pharmacies in the West Bank was 1,084, with a ratio of one pharmacy for every 2,755 citizens (Wafa, 2020).

Healthcare centres

The number of primary health care centres under the supervision of the Ministry of Health in Palestine was 475 centres up to 2019. Figure 3.7 illustrates a map of the health and medical sector in West Bank and Gaza.

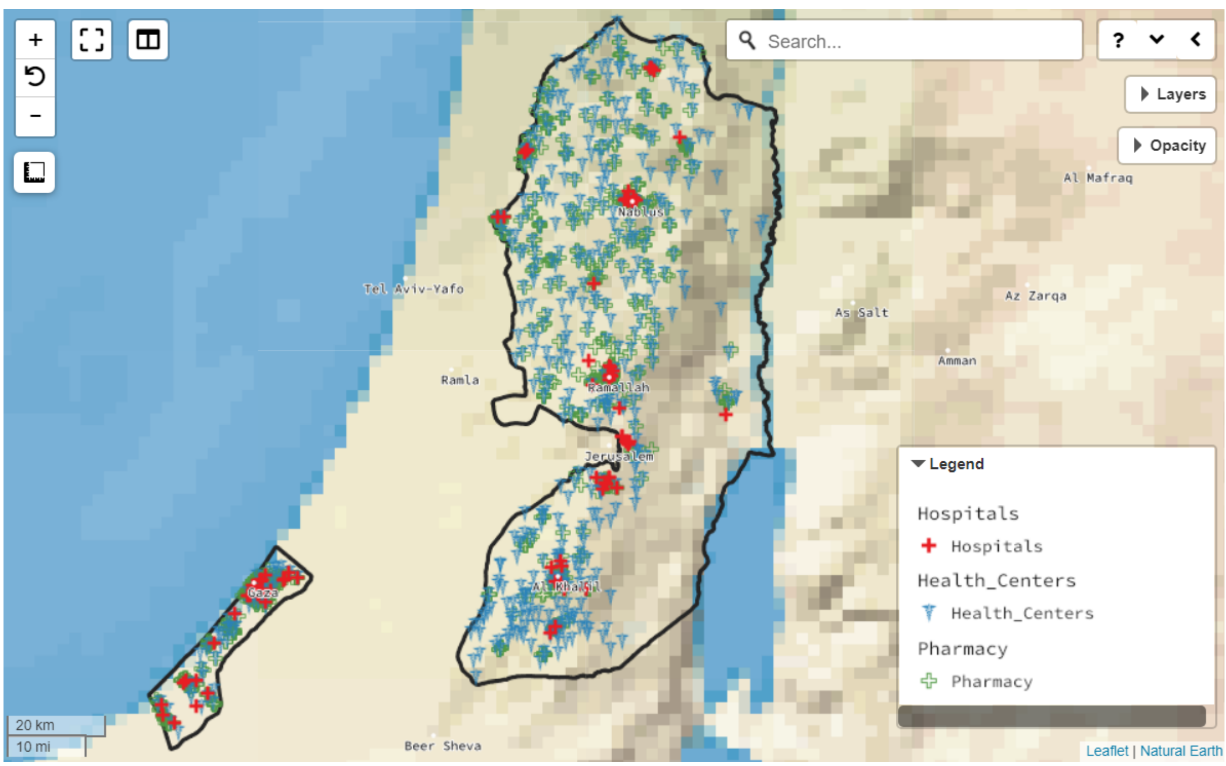


Figure 3.7: Map of hospitals, healthcare centers and pharmacies in West Bank and Gaza.

3.3.4 Energy

The majority (89%) of electricity in Palestine is imported, 8% is purchased from local providers and 3% is produced from renewables (i.e., solar, biomass and wind). The imported electricity is supplied through 3 main lines (overhad lines) to the Palestinian sub-stations as shown in Figure 3.8 (PCBS, 2020) and distributed with the local supply in the same grid. .

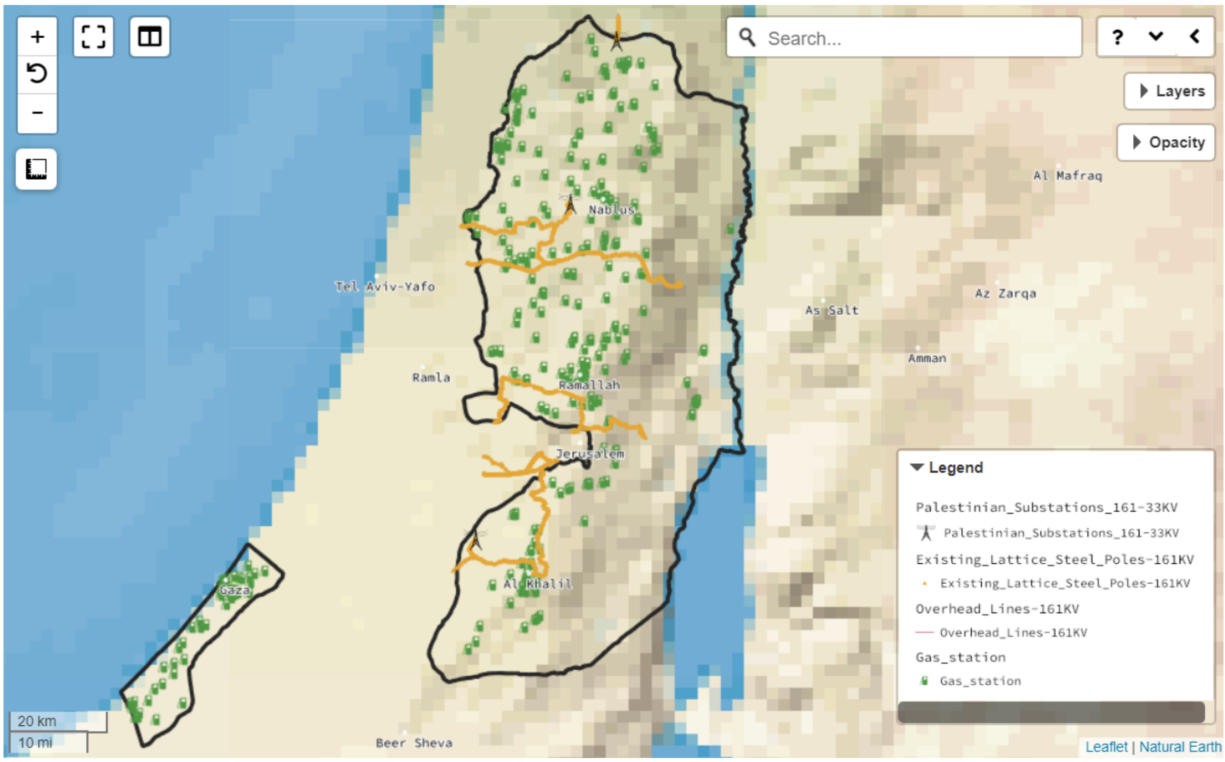


Figure 3.8: Screenshot showing energy sector layers for West Bank and Gaza

3.3.5 Transport

The transportation sector has witnessed a remarkable development since the establishment of the Palestinian National Authority (PNA). The data indicates that the total length of the paved road network in the West Bank is 3,461 km until the end of 2019, of which 1,628 are local roads, 1,157 are regional roads, and 676 main roads (PCBS, 2020)[11].Figure 3.9 illustrated distribution of roads networks by road type according to the Ministry of Transport classification (MoT) . oads/transportation connectivity and ease of access is obstructed by Israeli checkpoints (of which some can be temporarily or permanently closed), moreover the roads in some regions are crossed by the separation wall. Barrier gates for entry and exit are few and are under Israeli

---

[11] PCBS road network classification: *Main Road* a road that serves for national or inter district traffic, including road extension within a locality. *Regional Road*: a road that is branching off from, or lining, main roads. It includes along the road within a locality. *Local Road*: a road that serves the internal traffics within a locality.

control. Further, the functionality of the road network in Palestine should be seen also in relation to Oslo agreement divisions which define control rules of governance and security.

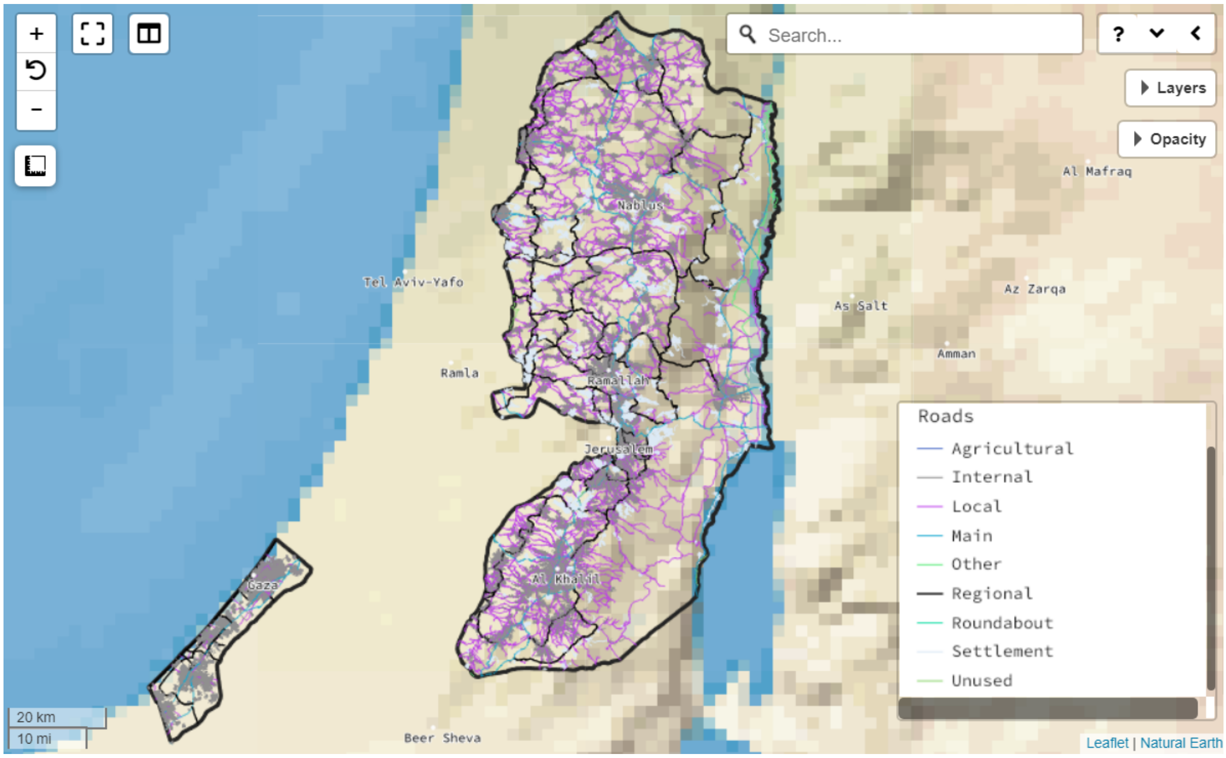


Figure 3.9: Distribution of road networks according to the Ministry of Transport classification in West Bank and Gaza.

3.3.6 Hazardous material

Dumping sites refer to the sites used for solid waste disposal including municipal, industrial, household, agricultural, medical and hazardous waste[12]. . Most of the dumping sites in West Bank and Gaza are managed by local authorities, few are managed by local contractors and Israeli occupation. Most dumping sites have no licence, health monitoring and environmental supervision. The distribution of dumping sites in the West Bank is illustrated in Figure 3.10.

[12] https://www.pcbs.gov.ps/Downloads/book746.pdf

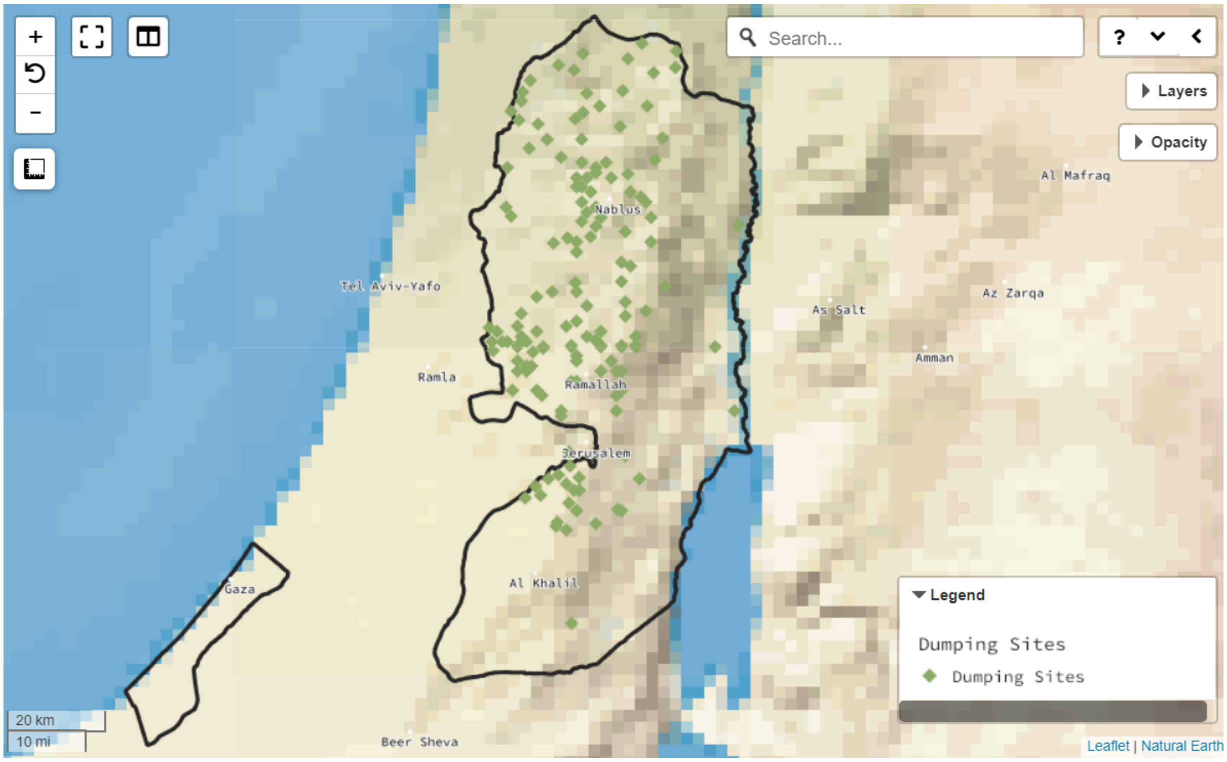


Figure 3.10: Distribution of dumping sites in the West Bank.

3.4 Priority Buildings - Inspections and Exposure Models

As mentioned in Section 3.2, a number of critical infrastructure has been prioritised for further data collection and study in this project. A building inspection form was developed to collect important characteristics of the hospitals, municipality, civil defence and school buildings during site inspections. Appendix 2 provides the template of this building inspection form which was provided to all inspection teams as a Google Form, such that the data could be easily stored electronically. Appendix 2 also contains the annex of the inspection form which provides a definition of the survey conditions.

The form is divided into 4 main sections, with a number of questions on each, as follows:

- General information: email, date, time, building name, building ID (from the database compiled before the inspections), occupancy, position of building, external walls, building orientation.
- Building information: year of construction, number of storeys (including basements), number of basements, average storey height, floor area, ground floor hydrodynamics, physical conditions, openings, window protection, fire protection.
- Structural information: material of lateral load resisting system, roof, plan irregularity, vertical irregularity, other vulnerability factors, cantilever system, site slope, soil type.
- Additional information: Notes, pictures of building

In total, 67 hospitals (84% national coverage, as those in the Jerusalem 1 community could not be accessed), 55 civil defence buildings (100% national coverage), 20 municipality buildings (for the prioritised local governments), and 170 schools buildings (about 6% national coverage) were inspected by 8 engineers over a period of 12 weeks. A training course was undertaken before the inspections to go through the form and to ensure that there is a standard application of the assessment form.. The whole process took longer than initially planned due to a number of reasons: inspections required long coordination with related stakeholders; permissions in some cases were never given to the date of this report. This shift in the work plan was followed by the high school national secondary exams and school summer holidays which caused additional delays.

The following sections summarise some of the results from the building inspections, whereas the full results can be found in two spreadsheets:

a) schools[13]
b) hospital, municipality and civil protection buildings[14]

https://docs.google.com/spreadsheets/d/1JO6ZHpaS4JGR5d8g8vkLq6Fmcrz5n6pWf5vnoNtzoC0/edit#gid=2020303801 (hospital, municipality and civil protection buildings)

3.4.1 Hospital, Municipality and Civil Protection Buildings

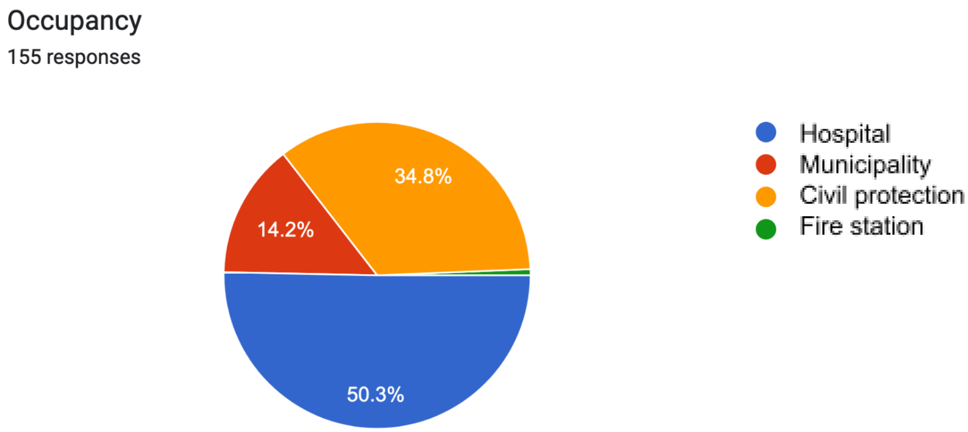
The following sub-sections summarise some of the key statistics for the 155 hospital, municipality and civil protection buildings that have been inspected. The actual properties for each individual building have been used to develop a seismic risk modifier, as discussed further in Section 4.1.2.

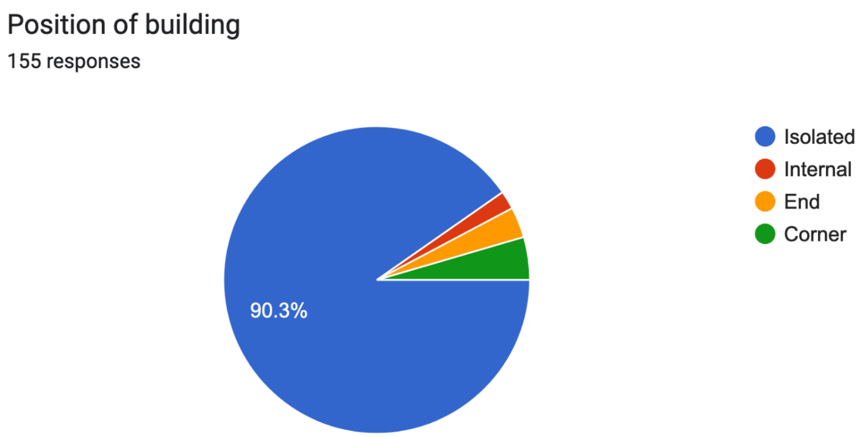
3.4.1.1 General information

The plots below show that around 50% of the 155 inspected buildings were hospitals (it is noted that each hospital building within a hospital complex was individually surveyed). The inspected buildings also include one fire station which is not part of the civil protection building stock, but has been kept due to its important role in disaster response. For what concerns the position of the building within the block, the majority of the buildings were isolated (i.e. standalone structures), but around 10% were connected to other buildings (and are either internal and thus in the middle of a row of buildings, at the end, or on the corner of two rows of buildings).

---

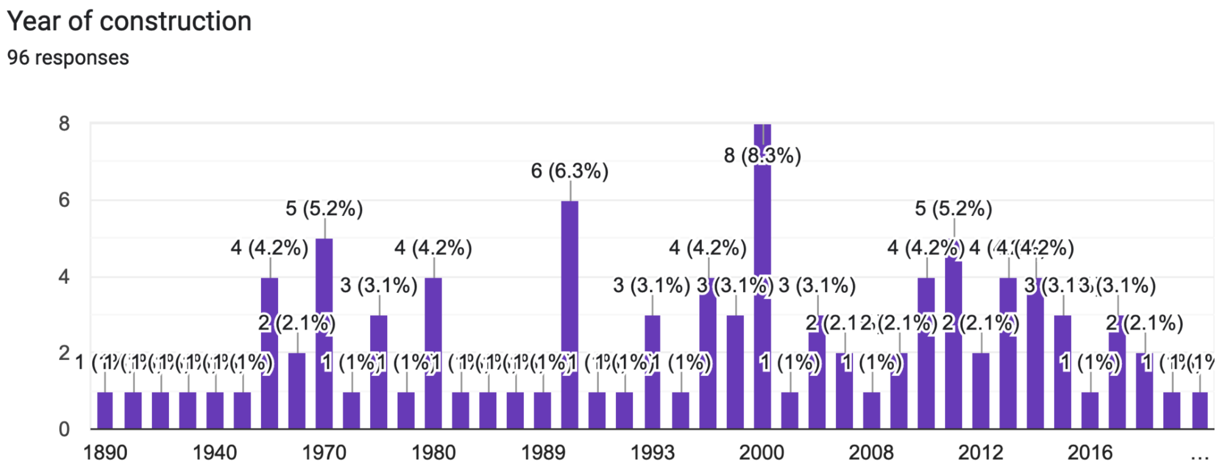
[13] https://docs.google.com/spreadsheets/d/1m-i1jxdKYWgNzylDLVsbEvhikRCqcEf5oW2e-e916DQ/edit#gid=1259170908
[14] https://docs.google.com/spreadsheets/d/1JO6ZHpaS4JGR5d8g8vkLq6Fmcrz5n6pWf5vnoNtzoC0/edit#gid=2020303801

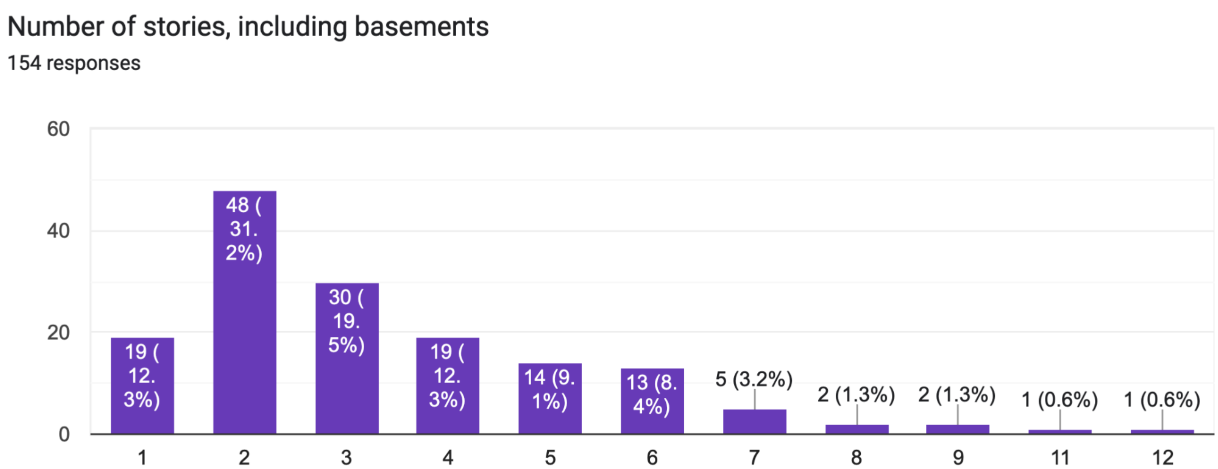




3.4.1.2 Building information

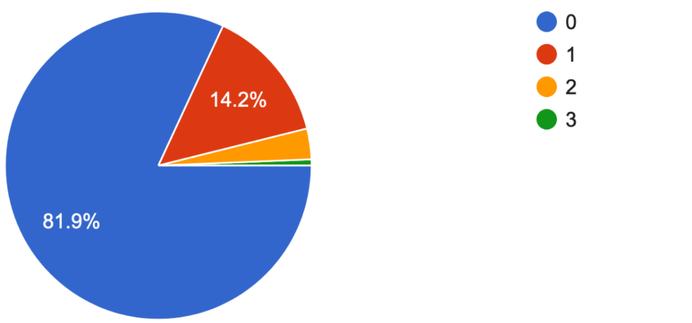
The plots below show that the year of construction of these buildings varied greatly from <1900s to very recently constructed buildings. Buildings built before the year 1980 were not complient to any design and represent the pre-code buildings. Sarting from 1980 to 2014, minimal design (gravity loads) was requested by the local authorities to obtain construction permits. From 2014, seismic regulations (i.e., UBC-97 code) became obligatory for buildings above three stories. Later in 2017, the Jordanian design code was adopted as the national standard for design in West Bank and Gaza. With the exception of school, the Ministry of Education (MoE) has required seismic desing since 2005, accordingly the field survey focused on school buildings with seismic design that were construted before 2005. The modal number of storeys with basements was 2 and over 90% of the buildings had less than 7 storeys. Only 20% of buildings were found to have basements. Storey heights of between 3 and 4 metres were most common. At least 92% of the buildings were in a good or very good condition, though 8% were found to be in poor condition. On the whole the openings were small to moderate in size, and the fire protection was typically provided via buildings with fire extinguishers rather than more sophisticated sprinkler systems.





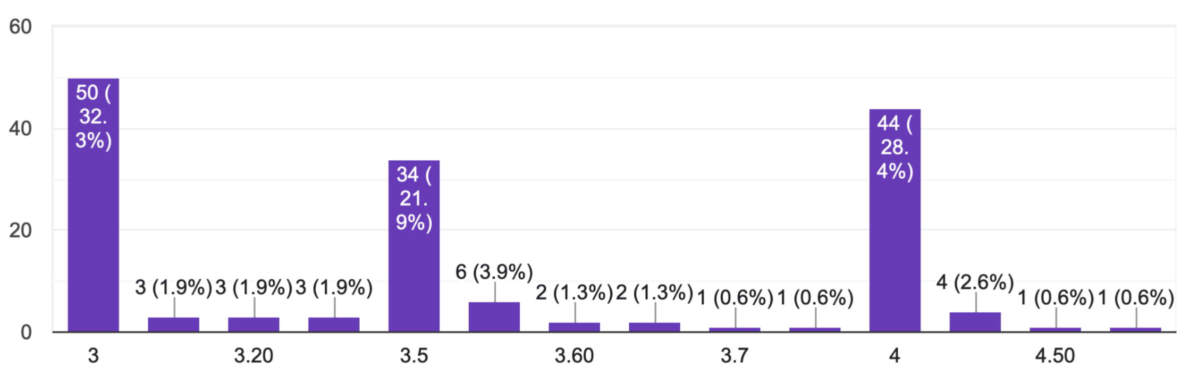
Number of basements

155 responses



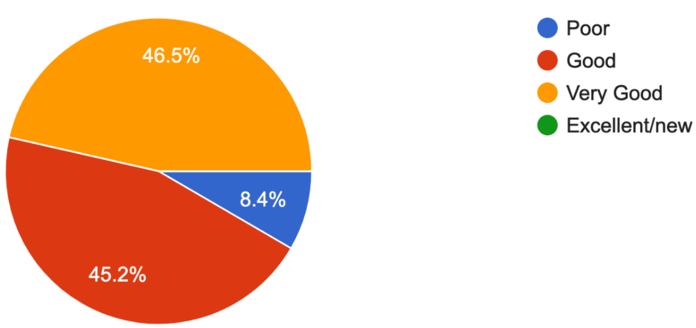
Average story height (m)

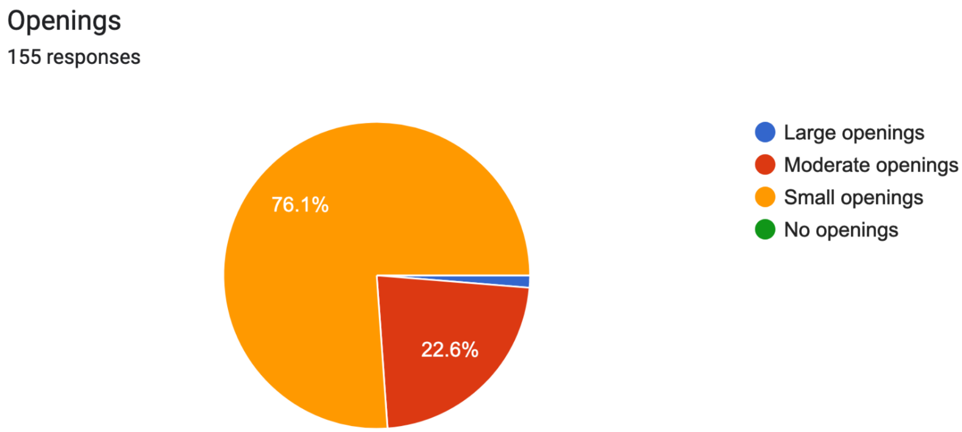
155 responses

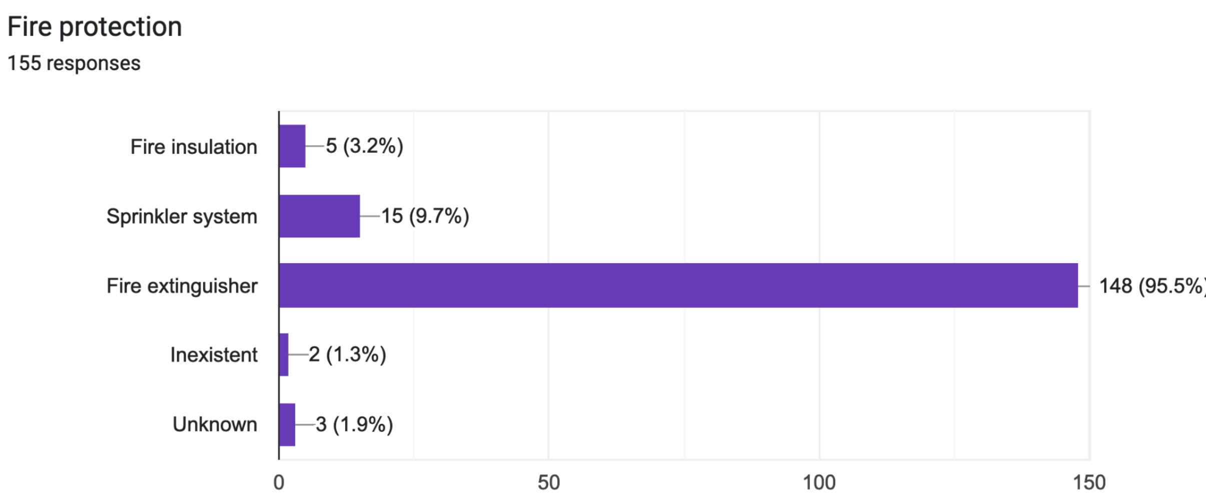


Physical conditions

155 responses





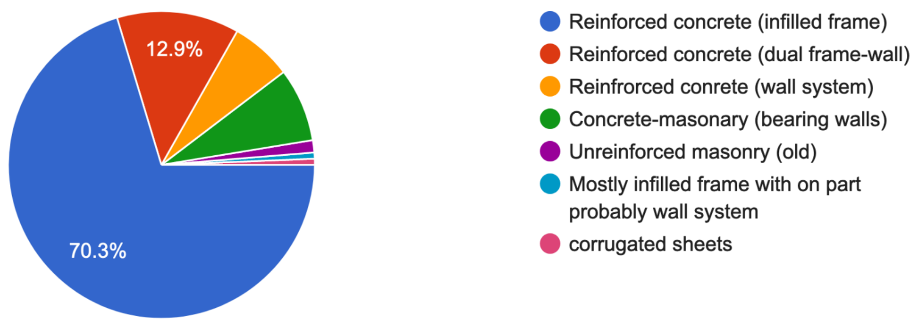


3.4.1.3 Structural information

The predominant material for these buildings was reinforced concrete, with infilled frames being the most common lateral load resisting system, followed by dual frame-wall and wall systems. Around 10% were mixed concrete and unreinforced masonry. Some form of plan irregularity was found in over 80% of the buildings, with torsional irregularity being the most common. In terms of vertical irregularity, only around 60% were reported to have such features, with the most predominant being constructed with setbacks and changes in the vertical structure (with new construction on top of old). Many buildings had parapets and unsafe entrances, which could be a hazard for people escaping the buildings during earthquakes. Pounding was reported to be an issue in around 10%, which agrees with the aforementioned statistic that 90% of the buildings were isolated from other buildings. Cantilever systems were present in half of the inspected buildings, which were mostly on lowland/flat ground or with a moderate slope, and a third of the buildings were on soft soils (note that the acronyms in the plot below refer to the codes used in the latest seismic design code).

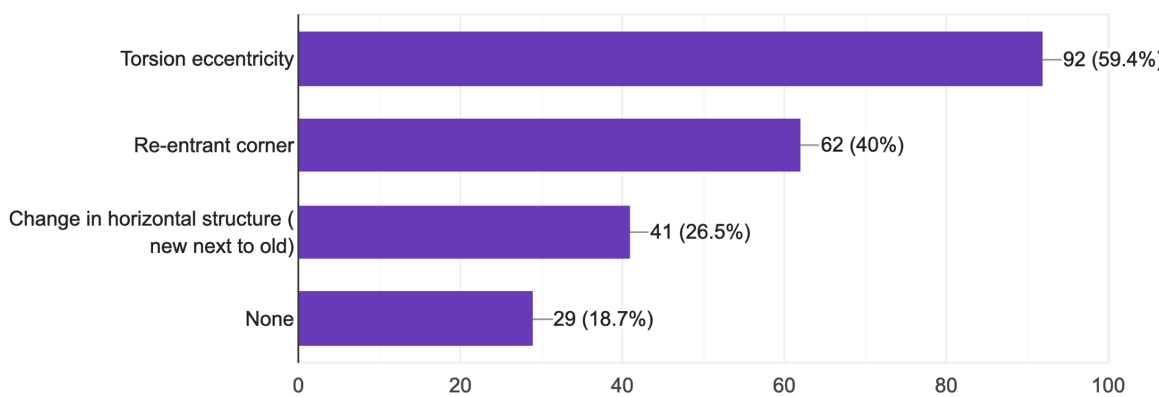
Material of lateral load resisting system

155 responses



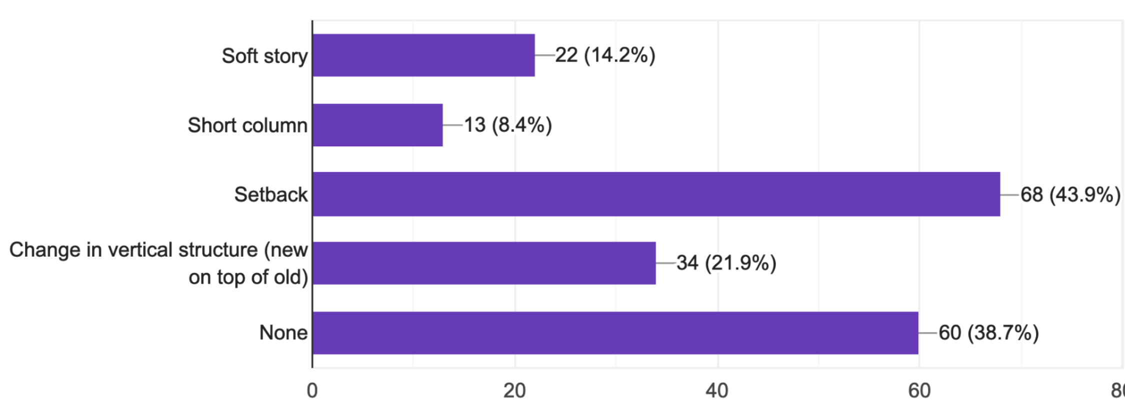
Plan irregularity

155 responses



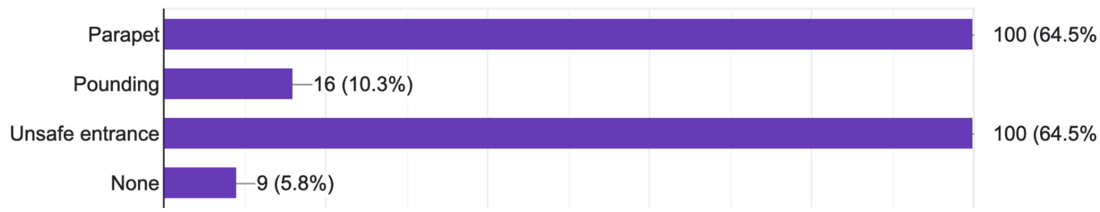
Vertical irregularity

155 responses



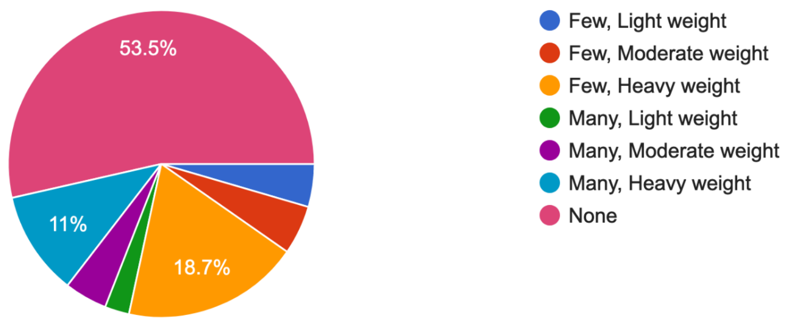
Other vulnerability factors

155 responses



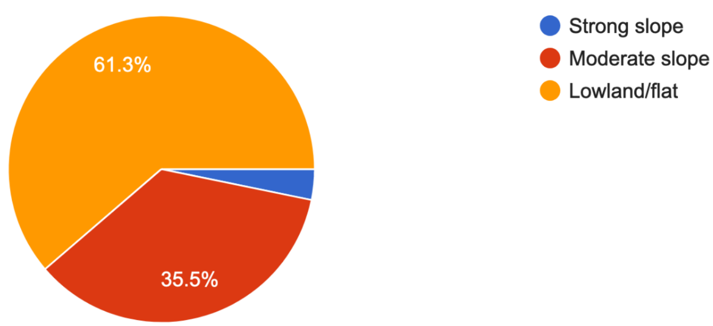
Cantilever system

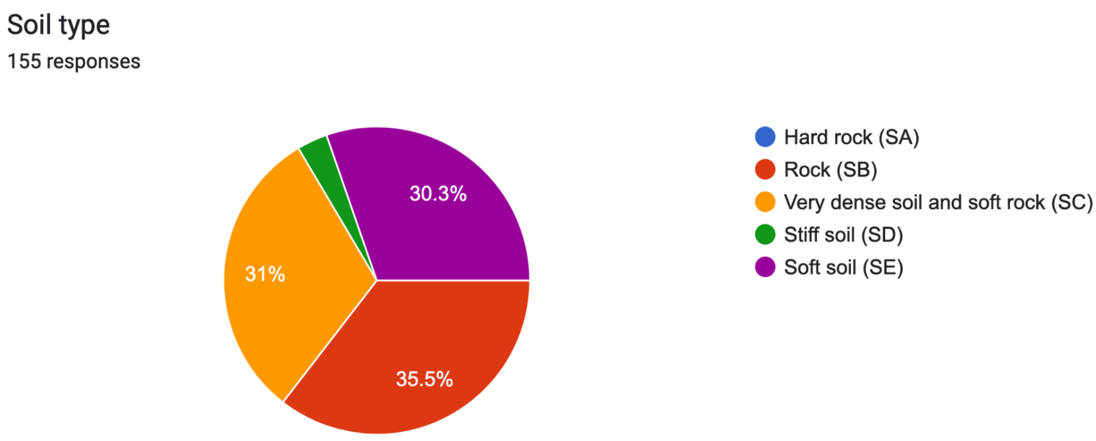
155 responses



Site slope

155 responses





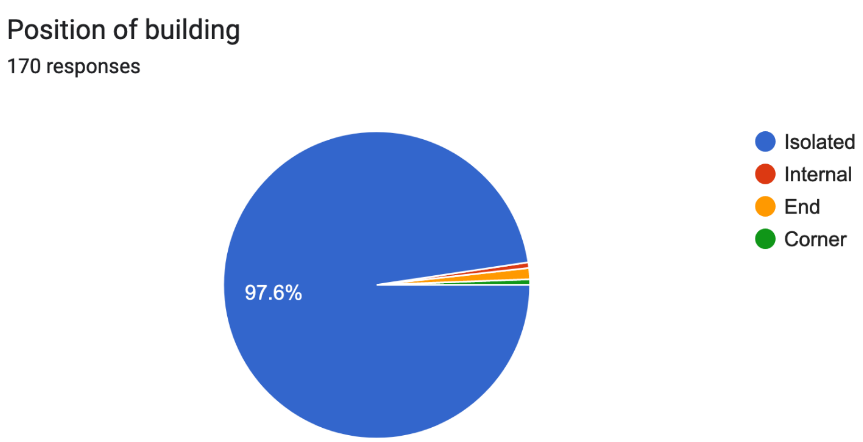
3.4.2 School Buildings

The following sub-sections summarise some of the key statistics for the 170 school buildings that have been inspected. The actual properties for each individual building have been used to develop a seismic risk modifier, as discussed further in Section 4.1.2.

It is noted that during the development of the exposure model for school buildings, a number of differences between the national schools database and the inspected buildings were seen, and this suggests that future efforts to check the data and clean up errors and inconsistencies is required in the future, and is suggested as a future activity (see Section 7.2).

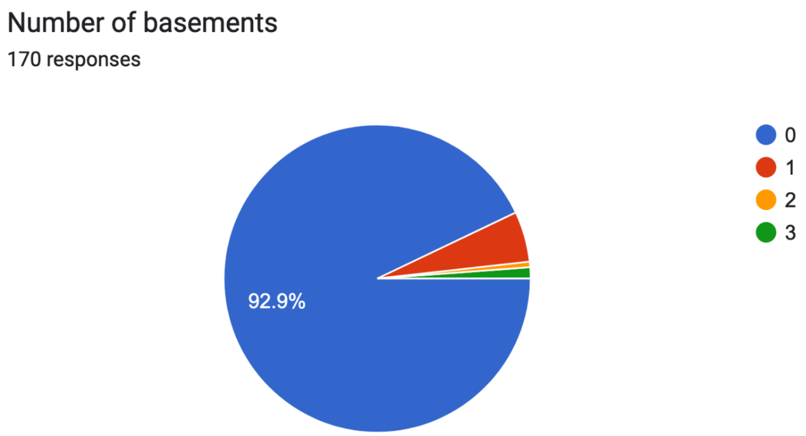
3.4.2.1 General Information

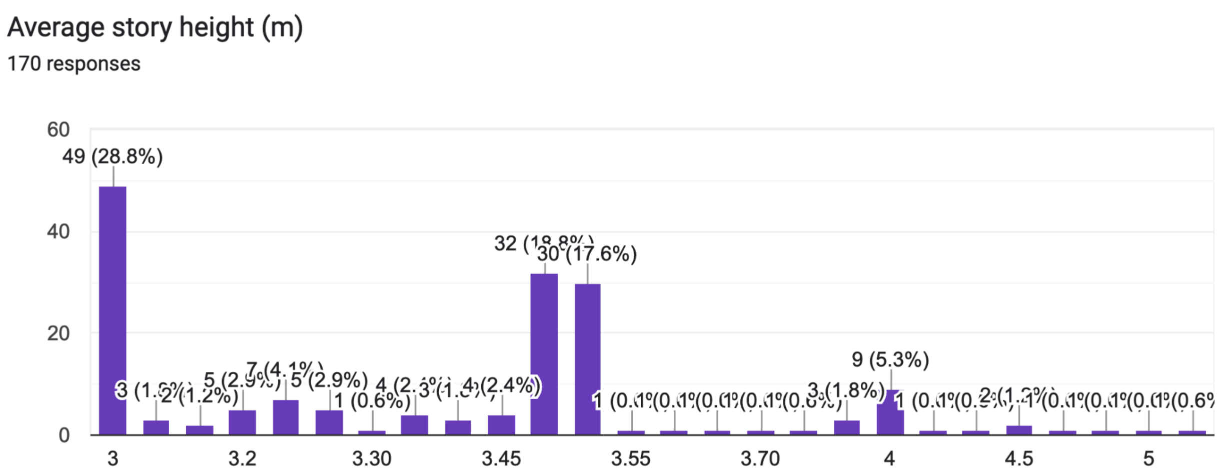
The vast majority of the school buildings (almost 98%) were isolated from other buildings.

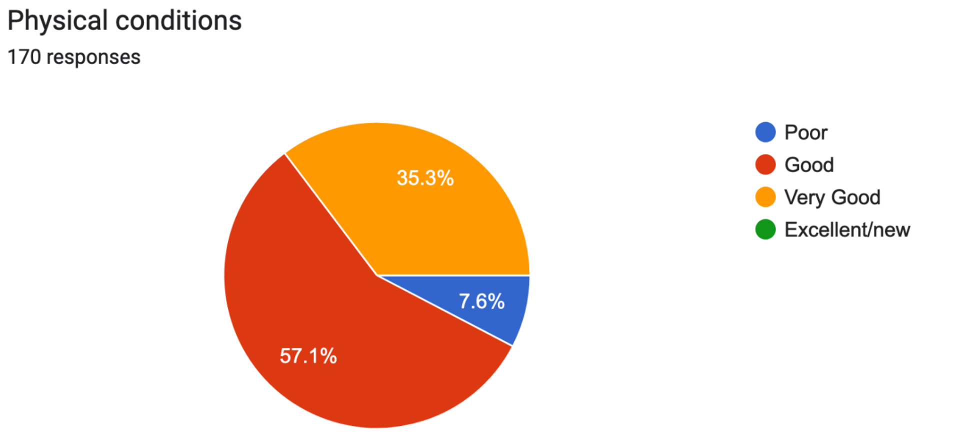


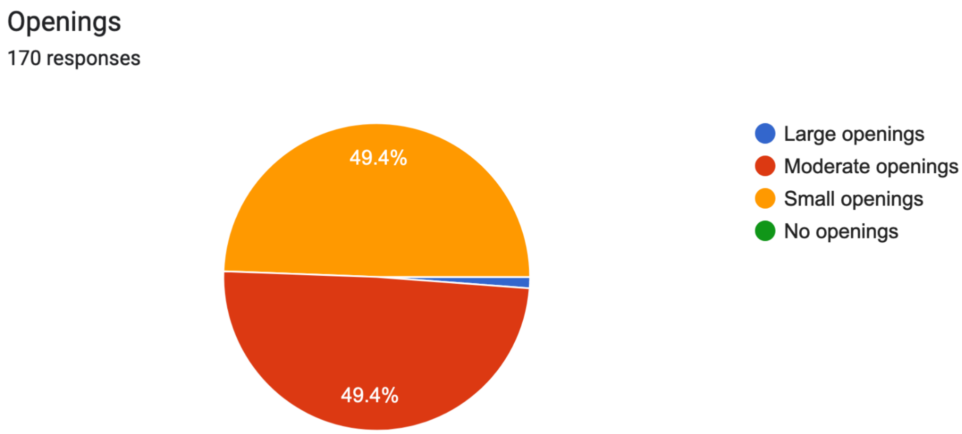
3.4.2.2 Building information

The presence of basements in the school buildings was reported very rarely - in around 7% of the cases. Typically storey heights of between 3 and 3.5 metres were most common. Over 90% of the buildings were in a good or very good condition, though 8% were found to be in poor condition. More moderately sized openings were observed in the school buildings compared with the other inspected buildings.





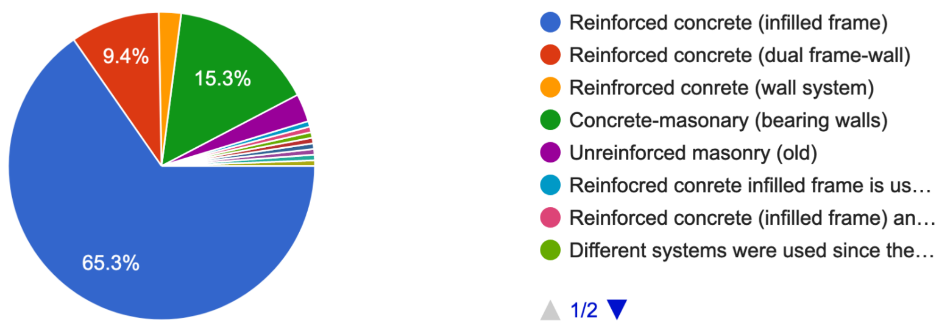




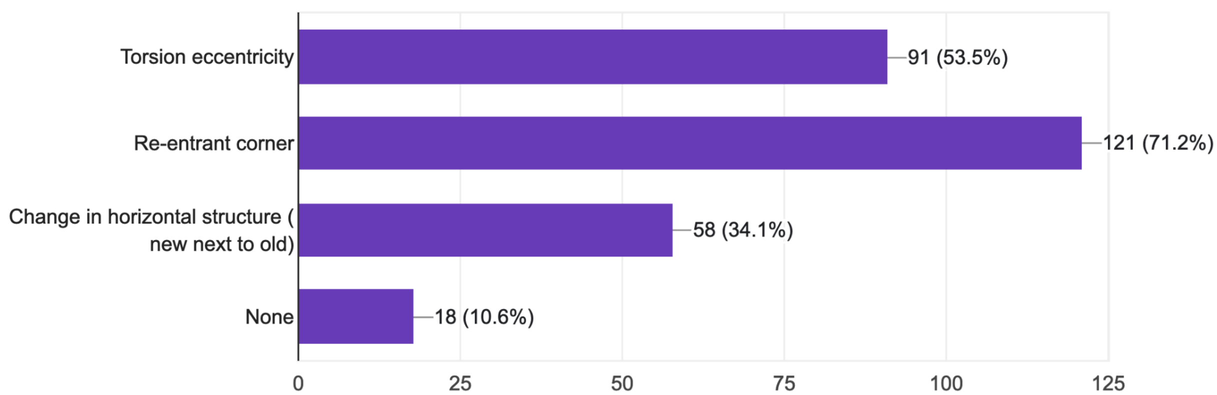
3.4.2.3 Structural information

The predominant material for these buildings was reinforced concrete, with infilled frames being the most common lateral load resisting system, followed by dual frame-wall and wall systems. Around 15% were mixed concrete and unreinforced masonry. Some form of plan irregularity was found in 90% of the buildings, with re-entrant corners being the most common. In terms of vertical irregularity, only around 65% were reported to have such features, with the most predominant being setbacks and changes in the vertical structure (with new construction on top of old). More schools were found to have short columns compared to the other set of inspected buildings. Around a third of buildings had parapets and unsafe entrances, which could be a hazard for people escaping the buildings during earthquakes. Pounding was reported to be an issue in around 20%, which might require further investigation given that the schools were mostly isolated from other buildings. Cantilever systems were present in only around 25% of the inspected buildings, which were mostly on lowland/flat ground or with a moderate slope, and a third of the buildings were on soft soils.

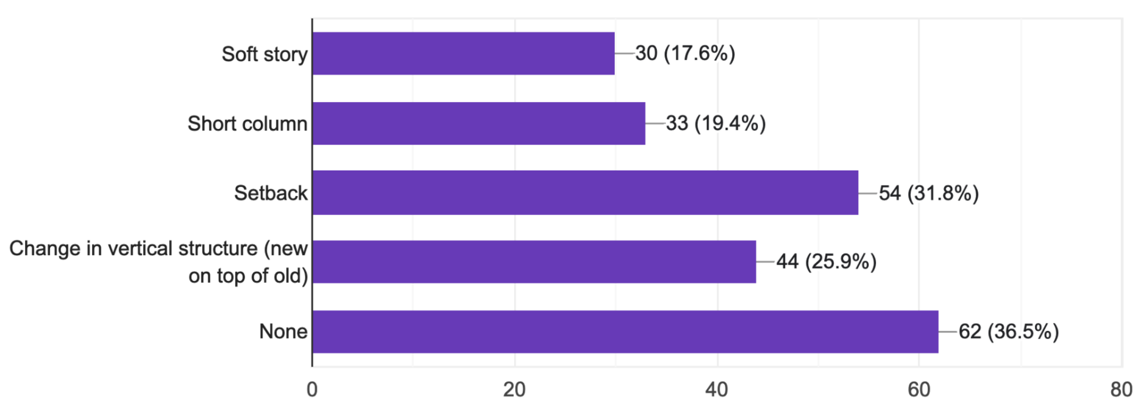
Material of lateral load resisting system
170 responses



Plan irregularity
170 responses



Vertical irregularity
170 responses

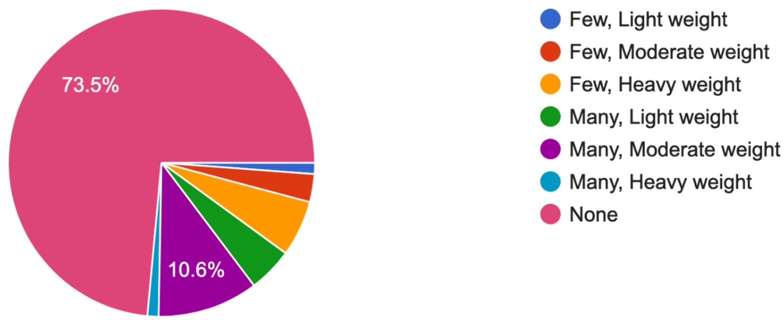


Other vulnerability factors

167 responses

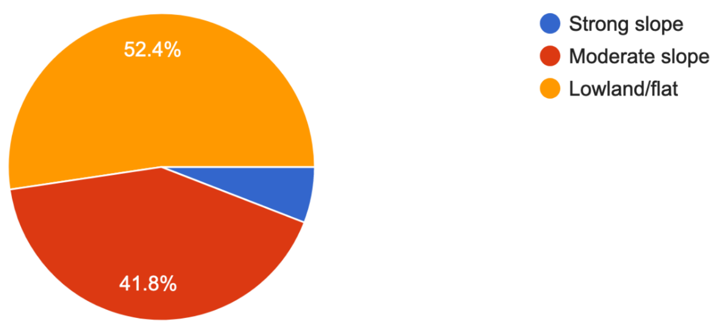
Cantilever system

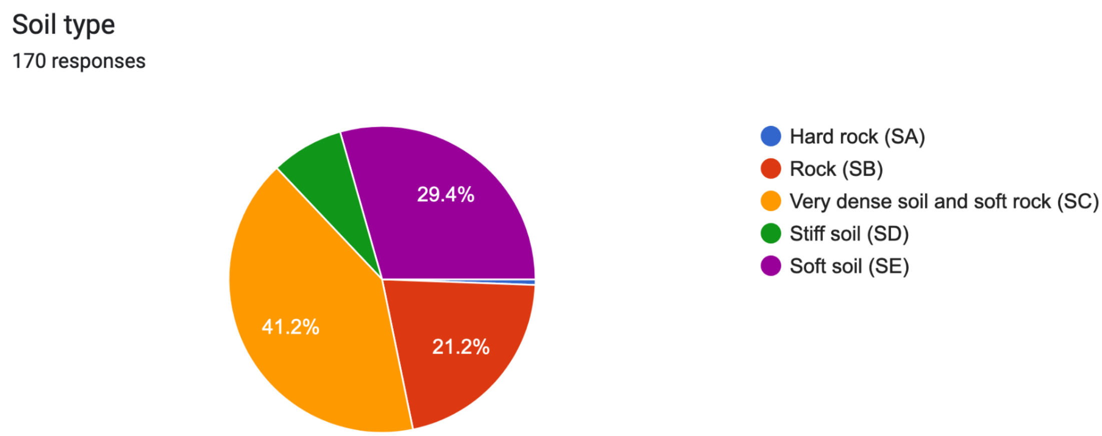
170 responses



Site slope

170 responses





3.5 Agricultural Land

A high resolution map of agricultural land has been developed for West Bank and Gaza by combining the agricultural land data from Geomolg for the West Bank (https://geomolg.ps/) with agricultural lands extract from Gaza land-use map received from the ministry of local governance in Gaza, as shown in Figure 3.11.

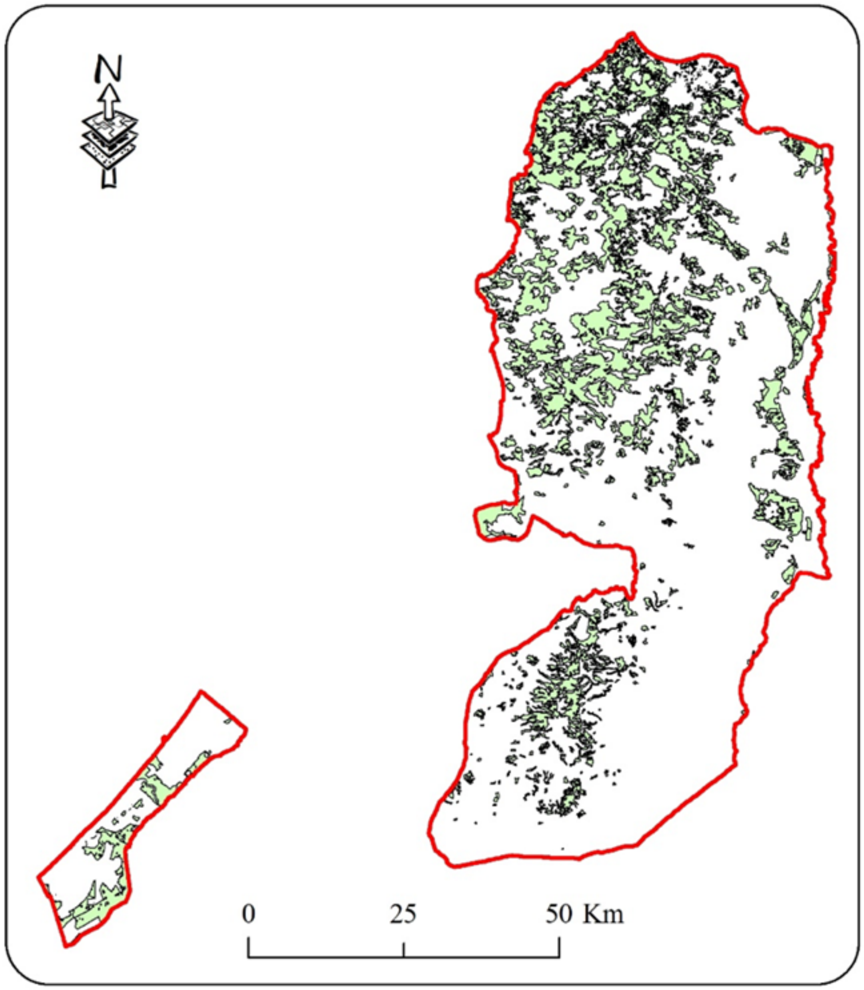


Figure 3.11: Agricultural lands in the West Bank and Gaza

4 Vulnerability Modelling

This Chapter begins by presenting the quantitative (physical) models of vulnerability (probability of loss given a hazard intensity measure level) used for the seismic and flood risk assessment for buildings and (in the case of earthquakes) their occupants. A discussion of climate change vulnerability assessment for the West Bank and Gaza, as undertaken for the National Adaptation Plan, then follows. The Chapter concludes with a discussion of the hazard-agnostic assessment of social vulnerability.

4.1 Seismic Vulnerability Assessment

4.1.1 Fragility and vulnerability functions

In the SASPARM 2.0 project (http://sasparm2.najah.edu/)[15], fragility functions for the following building classes were developed:

- Reinforced concrete frame infilled frame buildings from 1 to 10 storeys,
- Reinforced concrete shear wall buildings from 1 to 10 storeys,
- Masonry buildings from 1 to 4 storeys,

The SP-BELA methodology (Borzi et al., 2008) was used to develop the fragility functions, by combining capacity curves for each typology with a nonlinear static procedure to estimate the response under increasing levels of ground shaking intensity. Displacement thresholds for each damage state (e.g. slight, moderate, near collapse) were defined as a function of global displacement response. The capacity curves for each typology were calculated using typical regular prototype buildings. A study was also undertaken to evaluate the influence of irregularities on the capacity curves (such as those described in Chapter 3), such that modifications (typically an increase) to the fragility could be applied using the data collected during building inspections.

The fragility functions developed in SASPARM 2.0 are representative of typical residential buildings in the city of Nablus (which was the focus of the project). Given that this project also considers schools, many of which have been constructed/retrofitted recently, a method to account for the improved performance of these buildings, compared to typical residential buildings, is required. Also, it is desirable to make use of a methodology based on open data and tools which can be updated in the future, once more buildings in the region are modelled and more capacity curves become available. Hence, rather than use the SASPARM 2.0 fragility functions, a decision has been taken to use the capacity curves and methodology developed by the Global Earthquake Model (GEM) in their Vulnerability Modeller's Toolkit[16] (Martins et al.,

[15] "Support Action for Strengthening PAlestine capabilities for seismic Risk Mitigation" project, funded by the European Union with the European Centre for Training and Research in Earthquake Engineering (EUCENTRE, Pavia, Italy) acting as coordinator, and the Institute for Advanced Study of Pavia (IUSS Pavia, Italy) and An-Najah National University (ANNU) as partners.

[16] https://github.com/GEMScienceTools/VMTK-Vulnerability-Modellers-ToolKit

2021; Martins and Silva, 2020). The capacity curves available in GEM's latest database (v2022.1.0) cover different levels of codes and ductility, thus allowing the different performance of many building classes to be covered.

The capacity curves are used to develop single degree of freedom (SDOF) models, and OpenSeesPy[17] is used to run nonlinear dynamic analysis under a set of records of increasing ground shaking intensity. Nonlinear regression on the displacement response is undertaken to produce structural fragility functions[18] (based on pre-defined displacement thresholds for each structural damage state).

The structural fragility functions are then combined with damage-loss models for both economic losses and fatalities. For economic losses these are based on damage ratios (i.e ratio of cost of repair to cost of replacement) per damage state, whereas for fatalities only the final (complete damage) state is used and the fatality ratios are based on empirical evidence and expert judgement.

For non-structural fragility, the drift-sensitive and acceleration-sensitive components of the buildings have been considered, with proportions for each that depend on the occupancy class.

- For drift-sensitive components, displacement thresholds (for the SDOF models) that represent each non-structural damage state have been defined, and economic loss damage ratios have been assigned for each damage state.
- For acceleration-sensitive components, acceleration thresholds (for the SDOF models) that represent the loss of contents (i.e. damage ratio of 100%) have been defined from a review of the literature. Given that the accelerations transmitted to the components are limited to the maximum shear capacity of the building, this was accounted for in the regression analysis by carrying out a piecewise linear regression with a change in slope at the yield acceleration point of the SDOF. The assumption has been made that damage states of structural components and contents are statistically independent, i.e., if contents are placed outside the building, collapse of the building will not affect the damage state of the contents.

Contents of buildings are assumed to be acceleration-sensitive, and consequently the same method for the vulnerability of acceleration-sensitive non-structural components has been considered.

The structural, non-structural and contents vulnerability models have then been combined into a single total vulnerability model using the replacement value breakdown by component (which varies for residential, commercial and industrial buildings - see Section 3.2).

---

[17] https://openseespydoc.readthedocs.io/en/latest/index.html

[18] Fragility functions provided the probability of reaching or exceeding a given level of damage (e.g. extensive damage), as a function of the level of hazard intensity.

Based on the exposure modelling efforts described in the previous chapter, and the building classes that have been identified in the building stock (classified according to GEM's Building Taxonomy: Silva et al., 2022), the following vulnerability models (for residential, industrial and commercial typologies) have been selected:

- CR/LDUAL+CDL+DUL/H4 (only used for residential buildings)
- CR/LDUAL+CDL+DUL/H5
- CR/LDUAL+CDL+DUL/H6
- CR/LDUAL+CDL+DUM/H5
- CR/LDUAL+CDL+DUM/H6
- CR/LFINF+CDL+DUL/H1
- CR/LFINF+CDL+DUL/H2
- CR/LFINF+CDL+DUL/H3
- CR/LFINF+CDL+DUL/H4
- CR/LFINF+CDL+DUL/H5
- CR/LFINF+CDL+DUL/H6 (only used for residential buildings)
- CR/LFINF+CDL+DUM/H1 (only used for residential buildings)
- CR/LFINF+CDL+DUM/H2
- CR/LFINF+CDL+DUM/H3
- CR/LFINF+CDL+DUM/H4
- CR/LFINF+CDL+DUM/H5
- CR/LFINF+CDL+DUM/H6
- CR/LFINF+DUL/H2/SOS
- CR/LFINF+DUL/H3/SOS
- CR/LFINF+DUL/H4/SOS
- CR/LFINF+DUL/H5/SOS
- CR/LFINF+DUL/H6/SOS
- EU/LWAL+DNO/H1 (only used for residential buildings)
- MUR+STDRE/LWAL+DNO/H1
- MUR+STDRE/LWAL+DNO/H2
- S/LFM+CDL+DUL/H1 (only used for commercial and industrial buildings)
- S/LFM+CDL+DUL/H2 (only used for commercial and industrial buildings)
- S/LFM+CDL+DUM/H1 (only used for commercial and industrial buildings)

The building typologies are described using the GEM Building Taxonomy with the attributes summarised below:

(1) Materials. CR: reinforced concrete, MUR-STDRE: dressed stone masonry, MUR-STRUB: rubble stone masonry, S: steel, EU: earthen material

(2) Lateral load resisting systems. LDUAL: dual frame-wall system, LFINF: infilled frame, LWAL: load bearing wall, LFM: moment frame

(3) Code Level or Ductility. CDN: absence of seismic design, CDL: low code level (designed for lateral resistance using allowable stress design), CDM: moderate code level (designed for

lateral resistance with modern limit state design), CDH: high code level (designed for lateral resistance coupled with target ductility requirements and capacity design), DNO: non-ductile, DUL: low ductility, DUM: moderate ductility, DUH: high ductility

(4) Height. H: number of storeys

(5) Irregularities. SOS: soft storey

Seismic economic vulnerability models for some of the most predominant buildings are shown in Figure 4.1, whereas all plots are provided in Appendix 3.

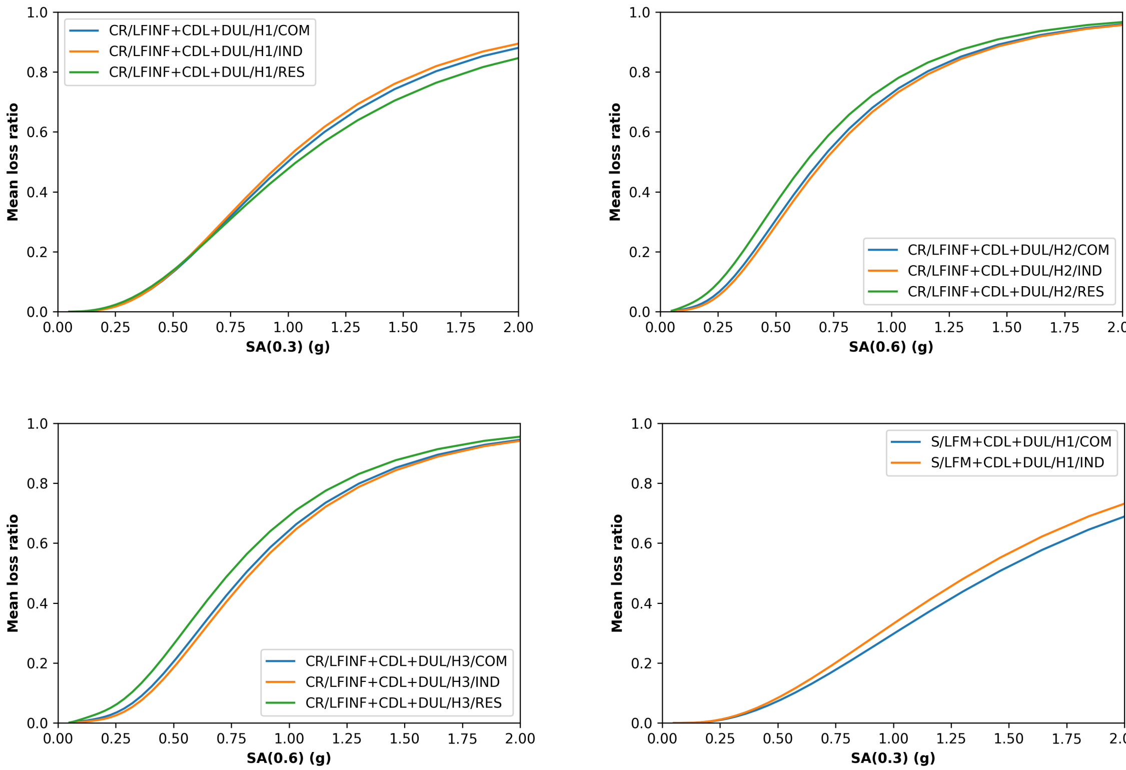


Figure 4.1: Seismic vulnerability models for some of the predominant building classes

4.1.2 Seismic risk modifier

The vulnerability models presented in the previous section describe the mean loss ratio as a function of ground shaking intensity for groups of buildings that are believed to have similar performance if subjected to a strong seismic action due to their similar structural characteristics (e.g. lateral load resisting system, material, design code level, ductility level, number of storeys, soft storey). However, for the schools, hospitals and public buildings, as discussed in Section 3.4.1 and 3.4.2, specific characteristics have been identified at an individual building level that could increase the risk of economic damage or mortality, such as irregularity (in plan and elevation) or the presence of non/structural elements that pose a risk to people outside the building (such as occupants trying to leave the building during the earthquake). These characteristics are considered within the risk assessment methodology adopted in this work through a so/called Seismic Risk Modifier.

To determine this modifier, the procedure proposed by FEMA P-154 (FEMA, 2015), suitably adapted to the West Bank and Gaza building / hazard context. This methodology was used to quickly and economically assess, and with minimal access to buildings, the seismic safety of a large category of properties, allowing the structures that require more attention to be easily identified and prioritised for further inspection and assessment. In this work, some changes were made to the P-154 methodology to take into account the parameters collected during the building inspections described in Section 3.4.1 and 3.4.2.

To derive the final value of this "modifier", we started from a base score (BS) that varies according to (i) the degree of seismicity and (ii) the main construction type of the building. To assign the degree of seismicity, the map of PGA values at the surface with a return period of 475 years (see Deliverable 3.1 were used to assign four categories of seismicity: <0.1g, 0.1-0.2g, 0.2-0.3g, >0.3g. Table 4.1 shows the values of the basic modifier assigned to the hospitals and public buildings based on the material and lateral load resisting system. As can be seen, the values vary from a minimum of one to a maximum of 4.2.

From this "starting value", corrective coefficients that have a negative influence on the final value of the index were subtracted, grouped into vertical irregularities (VI), plan irregularities (PI) and other modifiers (OM), as shown in Table 4.2. For the VI and PI categories, the total modifier for each building must be higher than a minimum value that depends on the type of construction and the degree of seismicity, as indicated in Table 4.2. Once the final score (FS) has been calculated, by subtracting the modifiers from the base score, it cannot be lower than a minimum value that depends on the type of construction and the degree of seismicity, as indicated in Table 4.3.

Table 4.1: Base modifier (adapted from FEMA P-154)

Baseline Score (SB)	**>0.3g**	**0.2g - 0.3g**	**0.1g - 0.2g**	**<0.1g**
Mixed concrete/masonry	1.1	1.3	1.85	3.35
Masonry	1	1.2	1.7	3.2
Reinforced concrete infilled frame	1.2	1.4	2	3.5
Reinforced concrete dual/wall	2	2.1	2.5	4.2

Table 4.2: Values of modifiers per structural characteristic (adapted from FEMA P-154)

Modifiers	**Hazard Level**

Vertical Irregularities (VI)	>0.3g	0.2g - 0.3g	0.1g - 0.2g	<0.1g
Strong slope	-0.3	-0.3	-0.4	-0.4
Soft storey	-0.5	-0.5	-0.6	-0.6
Short column	-0.5	-0.5	-0.5	-0.6
Setback	-0.5	-0.5	-0.6	-0.6
Cantilever (Many, Moderate weight; Many, Heavy weight)	-1	-1	-1.2	-1.3
Cantilever (Few, Moderate weight; Many, Light weight)	-0.5	-0.5	-0.6	-0.6
Change in vertical structure (new on top of old)	-1	-1	-1.2	-1.3
Min VI score	-1.2	-1.3	-1.4	-1.5
Plan Irregularities (PI)				
Torsion eccentricity	-0.7	-0.8	-1	-1.1
Re-entrant corner	-0.4	-0.4	-0.5	-0.6
Change in horizontal structure (new next to old)	-0.7	-0.8	-1	-1.1
Min PI score	-1.1	-1.3	-1.4	-1.6
Other Modifiers (OM)				
Pounding	-1	-1	-1.2	-1.3
Parapet	-0.1	-0.1	-0.2	-0.2
Unsafe entrance	-0.1	-0.1	-0.2	-0.2

Table 4.3: Minimum final score (adapted from FEMA P-154)

	Hazard Level			
Min Final Score (SFmin)	**>0.3g**	**0.2g - 0.3g**	**0.1g - 0.2g**	**<0.1g**
Mixed concrete/masonry	0.25	0.25	0.25	0.45
Masonry	0.2	0.2	0.2	0.4
Reinforced concrete infilled frame	0.3	0.3	0.3	0.5
Reinforced concrete dual/wall	0.3	0.3	0.3	0.6

Once the final score was obtained, this was divided by the base score to obtain the 'seismic risk modifier' (SRM); the lower the risk modifier, the greater the negative influence it has on the total risk of the building. Subsequently, the 'seismic risk modifier' was normalised between 0 and 1 using min-max scaling, as described in Equation (4.1), thus defining a Seismic Risk Modifier Index (I_{SRM}), which gives a highest value of 1 for the lowest risk modifier :

$$I_{SRM} = \frac{SRM - max(SRM)}{min(SRM) - max(SRM)} \tag{4.1}$$

These I_{SRM} values have been calculated for each individual hospital, public building and school (of those that were inspected). They have then been used together with the output of the probabilistic risk assessment in order to prioritise the buildings for further inspection and assessment, described in Sections 5.1.4 and 5.1.5.

4.2 Flood Vulnerability Assessment

No damage or loss data for flood hazards is currently available for the West Bank and Gaza. Thus, a flood vulnerability model was selected from several existing studies for other regions, and then further adapted to better represent the characteristics of the built environment in the region. This work builds upon the efforts reported in Dabbeek et al. (2020) for their probabilistic earthquake and flood loss assessment in the Middle East.

Damage and loss models for floods are typically grouped into empirical (derived from observed post-event data), synthetic (expert-based using what-if analysis), or a mixture of both (Dottori et al., 2016). Other more complex procedures rely on analytical models to simulate force actions on buildings during floods (i.e., hydro-static and hydro-dynamic pressure, debris impacts – e.g., Jalayer et al., 2016). Empirical methods have been found to be the most used in practice (Gerl et al., 2016). However, there are several challenges related to the transferability of these models to other regions. The limitations of using empirical methods can be mitigated by adopting functions developed for the Middle East. Another attribute that has to be considered is the flood type and flood characteristics (i.e., depth, velocity, duration, contamination, and sediments), as they are directly related to building damage. For example, dam-break flooding is known to be abrupt and short, while river flooding can be slower and longer in duration. A review of flood actions on buildings can be found in Kelman and Spence (2004). Given the flood types considered in the Fathom global flood hazard model (see Deliverable 3.1), only fluvial and pluvial vulnerability functions have been selected.

Other considerations that should support the selection of suitable fragility/vulnerability models for flooding are related to building-stock characteristics. For example, the type of occupancy (e.g., residential, commercial, industrial) influences the value of building contents (e.g., furniture, machinery, equipment) and non-structural elements (electrical, HVAC systems, finishes), which are the first to be damaged in case of direct contact with water. Furthermore, the unit of analysis (i.e., building versus geographical area) should be consistent with the exposure characteristics (Merz et al., 2010). Similarly, if the damage scale is absolute (i.e., losses in USD), transferability becomes an issue. In contrast, a standardized damage scale (i.e., % of the building value) offers the possibility to reuse functions regardless of the economic disparities. Finally, it is also relevant to consider the physical characteristics of the buildings under consideration.

In the selection process by Dabbeek et al. (2020), functions that can accurately characterize the vulnerability of the building stock given the construction material, age, number of floors and the presence of basements were considered. The selection process considered a database composed of 47 vulnerability models compiled by Gerl et al. (2016) to which recently released models collected by Dabbeek et al. (2020) were added. The global flood depth-damage functions proposed by the Joint Research Centre (JRC) of the European Commission were finally selected (Huizinga et al. 2017). These functions were developed empirically for different continents (e.g., Europe, Asia, Africa) and considered residential, commercial and industrial occupancies at the building level. The damage functions for the Asian continent were improved by Dabbeek et al. (2020) considering the building stock in the Middle East and the recommendations from the JRC and HAZUS (FEMA, 2019), as described below.

The JRC's vulnerability functions are generic, while the building stock in the Middle East has heterogeneous physical characteristics. For this reason, the following two steps were used by Dabbeek et al. (2020) to adjust the original functions considering the main types of construction material and heights:

A. The adjustment of the vulnerability functions considering different construction materials and content value is done following the JRC recommendations. In particular, a 60% maximum damage is considered for reinforced concrete and masonry buildings. This damage threshold is also in agreement with the HAZUS guidelines. It is important to note that both models (JRC and HAZUS) consider that contents represent 50% of the total building value. However, the value of contents in the Middle East is significantly lower (between 20 and 30%) for residential buildings. The total maximum damage was set to 45% of the total building value, to avoid an overestimation of the losses, which is also consistent with the maximum damage threshold used by the GAR global flood vulnerability model (Maqsood et al., 2014). For non-resilient materials (i. e., mud, adobe and rubble-stone), the maximum damage is set to 100%, as recommended by the JRC guidelines.
B. The vulnerability functions were also adjusted to account for the different building heights. The JRC's database of vulnerability functions does not provide the individual functions used to construct the generic models, nor the contribution of each height category. To adjust the original functions based on the height, the HAZUS vulnerability functions were used, which define damage by height category. In this process, the HAZUS damage ratios for one, two and three stories are averaged, as shown in Equation (4.2). Then, the contribution of each height relative to the average damage is computed, as shown in Equation (4.3). In the last step, this value is multiplied by the JRC function (after adjusting for material and content) to obtain the damage per building height as illustrated in Equation (4.4).

$$D_{i(HAZUS)} = \frac{d_{i,1}+d_{i,2}+d_{i,k}....+d_{i,n}}{n} \quad i\,(depth) = \{0, 6\} \tag{4.2}$$

$$c_{i,k} = \frac{d_{i,k}}{D_{i(HAZUS}} \tag{4.3}$$

$$d_{i,k\,(adapted)} = c_{i,k} \times D_{i(JRC)} \tag{4.4}$$

where $d_{i,k}$ stands for the damage ratio at the hazard intensity i for building feature k (height in this specific case); D_i represents the average damage ratio of all heights; $c_{i,k}$ refers to the ratio between the damage ratio for a single building feature (i.e., height) to the average of all building heights. It should be noted that at a given intensity, when the building height doubles (from one to two stories), the damage does not decrease proportionally. Typically, the distribution of building value is uneven across building floors (i.e., it is common that the central electrical and mechanical units are installed in the basement or ground floor). Figure 4.2 illustrates the average loss ratio given flood-depth, after adjustment, for one- and two-storey reinforced concrete buildings. The final depth-damage functions used for considered buildings are illustrated in Table 4.4.

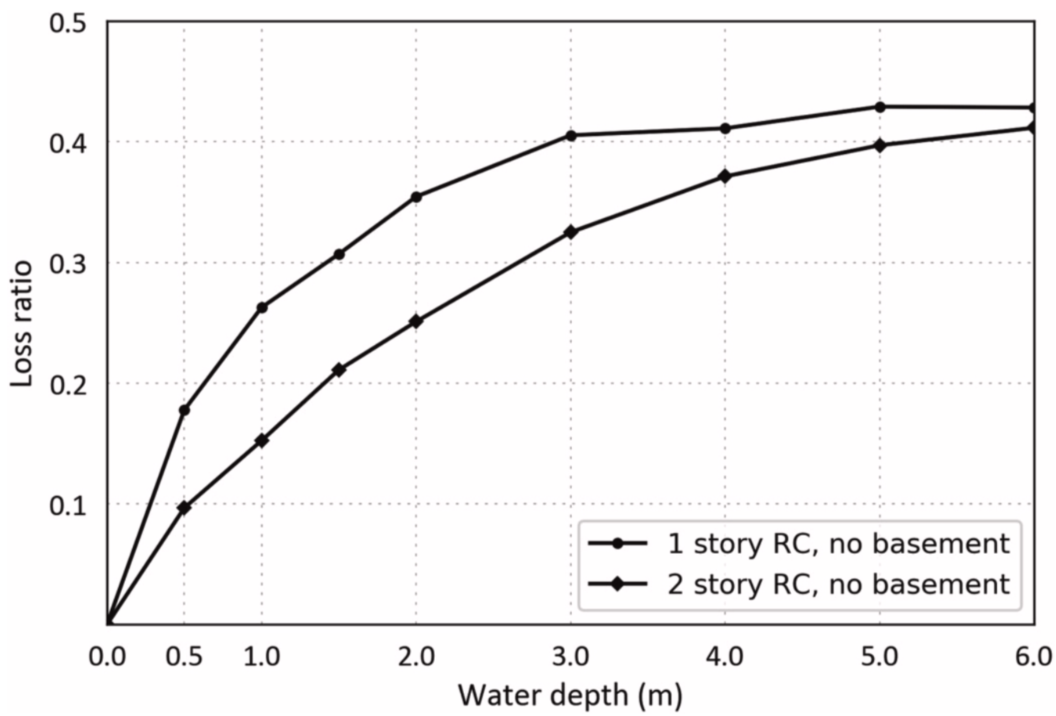


Figure 4.2: Example of the flood vulnerability functions for one and two story reinforced concrete buildings (Dabbeek et al., 2020)

Table 4.4: Depth-damage functions for considered building classes.

Water depth (m)	Reinforced concrete /masonry			Informal construction (adobe)
	1-story	*2-story*	*3-story*	*1-story*
0	0	0	0	0
0.5	0.18	0.10	0.08	0.33
1	0.26	0.15	0.15	0.49
1.5	0.31	0.21	0.20	0.62
2	0.35	0.25	0.23	0.72
3	0.41	0.33	0.29	0.87
4	0.41	0.37	0.33	0.93
5	0.43	0.40	0.37	0.98
6	0.43	0.41	0.39	1

4.3 Climate Change Vulnerability Assessment

4.3.1 Vulnerability Assessment in the National Adaptation Plan (NAP)

The purpose of the National Adaptation Plan (NAP) is the identification, prioritization and implementation of adaptation options according to the analysis of different sectors vulnerable to climate change. The NAP has identified different sectors and themes that were potentially vulnerable to climate change both in the West Bank and Gaza: Agriculture, Coastal and marine, Energy, Food, Gender, Health, Industry, Terrestrial ecosystems, Tourism, Urban and infrastructure, Waste and wastewater and Water.

The following definitions of terms, consistent with the IPCC AR5, were used when assessing the vulnerability of these sectors/themes:

Sensitivity – '*The degree to which a system or species is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea-level rise)*'.

Adaptive capacity – '*The ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences*'.

Vulnerability – '*The propensity or predisposition [tendency] to be adversely affected*'.

The inter-relations between these terms are illustrated in Figure 4.3.

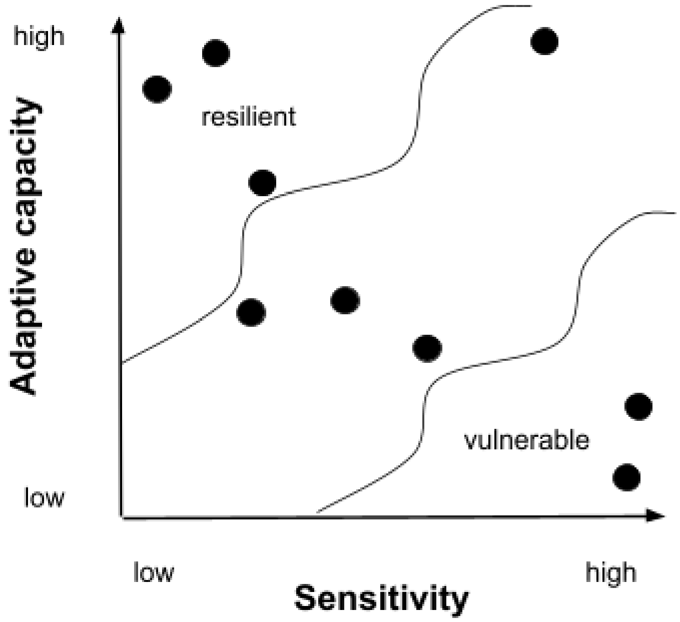


Figure 4.3: Illustration of inter-relations between adaptive capacity, sensitivity, vulnerability and resilience (adapted from the NAP)

An assessment of potential vulnerabilities (biophysical and/or socioeconomic) associated with each of these 12 themes/sectors was initially drafted by a project team of national experts guided by an international expert. Stakeholders met in each thematic/sectoral groups in the West Bank and the Gaza Strip with a member of the project team and they reviewed and amended the relevant list of potential vulnerabilities, the descriptions of climate sensitivities and adaptive capacities. They then rated the climate sensitivities from 1 (will not be adversely affected) to 5 (will become unmanageable) and the adaptive capacities from 1 (unable to adapt without substantially increased support and resources) to 5 (able to adapt without problems). The ratings for climate sensitivity and adaptive capacities in relation to each of the potential vulnerabilities was then inter-related using the matrix in Figure 4.4 to provide a vulnerability rating (with and without Israeli occupation).

Table 4.5 below lists the sectors and themes identified as 'highly vulnerable' for both West Bank and Gaza while Table 4.6 lists the sectors and themes identified as 'vulnerable' for both West Bank and Gaza. The issues rated as 'highly vulnerable' under Israeli occupation were reviewed and agreed at Vulnerability Assessment Workshops, as the focus for identification and prioritization of adaptation options.

Adaptive capacity					
5	1	1	2	2	2
4	1	2	3	3	3
3	2	3	3	4	4
2	2	3	4	4	5
1	2	3	4	5	5
	1	2	3	4	5
	Sensitivity				

Figure 4.4 Matrix used for vulnerability assessment

Table 4.5: Issues ranked as "Highly vulnerable" Source: National Adaptation Plan, EQA

Theme/sector	**Highly vulnerable – West Bank**	**Highly vulnerable – Gaza Strip**
Agriculture	Olive production; Grape production; Stone fruits; Rain-fed vegetables; Field crops; Irrigated vegetables; Grazing area and soil erosion; Irrigation water; Livestock production	Livestock production; Cost of agricultural production; Employment; Vegetable production; Olive production, Citrus; Irrigation water
Coastal and marine	N/A	Fishing/fisheries; Coastal agriculture; Condition of beaches
Energy	Domestic/local energy production; Energy imports; Condition of infrastructure	Domestic energy production; Energy imports; Condition of infrastructure
Food	Domestic food prices; Imported food prices	Domestic food prices; Imported food prices
Gender	Major diseases related to water and sanitation	Employment and gender; Major diseases related to water and sanitation; Food security and gender
Health	Major diseases related to water, sanitation, and food	Major diseases related to water, sanitation, and food
Industry	Value of raw materials imported; Infrastructure; Energy supply; Energy demand	Value of industrial products exported; Value of raw materials exported; Employment; Energy supply; Energy demand

Theme/sector	Highly vulnerable – West Bank	Highly vulnerable – Gaza Strip
Terrestrial ecosystems	Habitat connectivity	Wadi Gaza – Habitat connectivity
Tourism	Condition of cultural heritage	N/A
Urban and infrastructure	Urbanization	Building conditions; Urban drainage
Waste and wastewater	Waste management	Waste management
Water	Groundwater supply; Flood management; Condition of infrastructure	Groundwater supply; Groundwater quality; Flood management

Table 4.6: Issues ranked as "vulnerable" Source: National Adaptation Plan, EQA

Theme/sector	Vulnerable – West Bank	Vulnerable – Gaza Strip
Agriculture		Watermelon production; Greenhouses; Soil erosion; Cut-flower production
Coastal and marine		Coastal agriculture
Energy	Domestic/local energy and prices	Environmental impacts; Social impacts; Imported energy prices; Cost of domestic feedstocks
Food	Food processing sector; Food storage	Exported food prices; Food storage; Food waste
Gender	Employment and gender; Maternal mortality and life	Maternal mortality and life expectancy

Theme/sector	Vulnerable – West Bank	Vulnerable – Gaza Strip
	expectancy; Food security and gender	
Health	Mortality morbidity and life expectancy; Infrastructure; Health costs.	Mortality, morbidity and life expectancy; Infrastructure; Health costs
Industry	Industrial production; Value of industrial products imported and exported; Production of raw materials; Value of raw materials exported; Employment; Waste management	Industrial production; Value of industrial products imported; Production of raw materials; Value of raw materials imported; Infrastructure; Waste management
Terrestrial ecosystems	Biodiversity; Invasive species; Forest shrublands and grasslands; Nature reserves; Birds, mammals, reptile and amphibians; Habitat area; Habitat quality	Biodiversity; Habitat – birds; Wadi Gaza – fauna; Wadi Gaza – flora
Tourism	Infrastructure of the tourism sector; Income from tourism	
Urban and infrastructure	Urban economy; Urban drainage	Urbanization; Urban economy; Urban air pollution;
Waste/wastewater	Management of wastewater	Cost of waste management; Sewerage; Management of wastewater
Water	Surface water supply; Water quality (surface and groundwater water); Water prices; Volume of water imported	Surface water supply; Surface water quality; Condition of infrastructure; Volume of water imported

For the purposes of this study, vulnerability assessment of targeted sectors out of those mentioned in the National Adaptation plan will be carried out in more detail, with an attempt to spatially represent the vulnerability of these sectors across the West Bank and Gaza. These sectors are:

- Agriculture (drought and rainfed agriculture)
- Energy (energy production; energy imports; condition of infrastructure)
- Urban and infrastructure (Building conditions; Urban drainage, urbanization)
- Water (flood management)

These sectors were selected for the following reasons reasons:

- These sectors are those that are mostly related to the work of the group developing this deliverable;
- These sectors are those that have spatial variability in vulnerability that is directly related/correlated with different climatological zones which have been used to deliver the climate susceptibility map (see Deliverable 3.1 and Section 5.3)
- These sectors represent the priority sectors of this work and are related to other parts of the study, especially infrastructure.

In order to explain further the vulnerability of these priority sectors, the following sub-sections summarise the aspects of climate sensitivity and adaptive capacity that were considered by the NAP when assessing the vulnerability.

4.3.1.1 Agriculture (drought and rainfed agriculture)

Climate sensitivity

Different crop production, including olive trees are sensitive to frost, heat waves, drought, wind speed, amount and distribution of rainfall, and hail. Grape production is more climate sensitive than olive production, particularly to frost, hail, drought, and rainfall patterns (amount and distribution). In 2015, frost destroyed production of 170 hectares (3,825 tons), and partially destroyed 300 hectares (3,750 tons) in Hebron and Bethlehem Governorates. The following is a summary of the main climate sensitive issues concerning agriculture:

- Field crops are sensitive to drought, amount and distribution of rainfall, and heat waves. Irrigated vegetables are sensitive to frost, drought, high temperatures, and wind speeds of more than 80 km/h.
- Green houses are sensitive to heavy snow, high wind velocity, and very low temperatures. Heavy snow and high wind speed damage the foundations of greenhouses and their plastic covers.
- In very low temperatures, crops will freeze and losses can result directly from damage or death of plants.
- Planting and harvesting dates of field crops and rain-fed vegetables are sensitive to climate. Low rainfall postpones the planting date, and low temperatures delay maturation.
- The grazing area on the eastern slopes is the most sensitive to climatic conditions.

- Loss of vegetation makes soils sensitive to gully erosion resulting from intense rainfall events and flash floods, which can remove a substantial amount of fertile topsoil.
- Irrigation water is sensitive to rainfall amount and distribution, and shifts in the rainy season. Drought decreases the quantity of water that can be allocated to agriculture yet at the same time increases crops' water requirement, increasing costs of production (inclusive of electricity for pumping).

Adaptive capacity

The adaptive capacity related to agriculture can be summarized in the following facts:

- Olive trees in Palestine comprise 71.6% of trees and 15-19% of total agricultural production. Israeli settlers uproot, burn and destroy olive trees, as well as release wild pigs, which damage olive seedlings. Access to olive groves, which are close to Israeli settlements and military bases, are restricted. Olive oil degrades in quality while awaiting Israeli permission for export to the Arab Gulf and international markets.
- About 8,000 hectares are cultivated for grape production and contribute about 12% of total agricultural production. The MOA distributes seeds of field crops (e.g., wheat and barley) that are drought-tolerant. The Palestinian Government is trying to increase the number of jobs through establishing agro-industrial zones, such as Jericho and Jenin.
- Rangeland cover 2 million dunums, while the area available for grazing is only 621,000 dunums. There is an absence of grazing regulations (those in open and close season). The MOA is undertaking several reforestation projects to protect soils from erosion.
- Irrigation water is supplied by groundwater wells and springs. In 2017, 60 million m^3 of water was available for agriculture. Irrigation infrastructure is old and inefficient, under-developed or undeveloped. Irrigation practices are outdated and there is a need to introduce precision agriculture and drip irrigation.
- Israeli occupation has led to inadequate infrastructure for treating Palestinian wastewater that could be used in irrigation, as: approval of plans for building treatment plants has been delayed (in some cases for more than a decade); Israel has demanded that Palestine should connect settlements to the planned treatment plants (which has been rejected for political reasons); and Israel has forced Palestinians to employ treatment standards more advanced than those generally used in Israel, which has increased the cost of plant construction. Israel also places restrictions on Palestinians building power plants and desalination plants.
- Agricultural extension, awareness-raising and training programs are being implemented by the MOA on farm management and the need to modify practices in order to address the adverse impacts of climate change, including how to cope during drought.

4.3.1.2 Energy (energy production; Energy imports; Condition of infrastructure)

Climate sensitivity

Energy production, imports and the conditions of energy infrastructure are climate sensitive. This climate sensitivity can be summarized in the following:

- Temperature extremes increase energy demands for heating and/or cooling. Currently, 75% of households use solar water heaters. The performance of such systems is climate- sensitive. Changes to climate may increase energy demands for heating and/or cooling. In order to fulfil domestic demand, 93% of electricity is imported currently; 89% from Israel and 4% from Jordan and Egypt. All required petroleum products are imported through Israel.
- Most feedstocks are imported, subject to Israeli permission. Small amounts of biomass from wood and waste, produced locally and used primarily for heating, are affected by the climate. As there are no facilities to store feedstocks, the ability to produce domestic energy from feedstocks is sensitive to climate and is seasonally affected. There is limited ability to import large volumes of feed stocks in order to maintain a continuous energy supply when electricity from Israel is interrupted. In addition, systems for distributing feedstocks are inefficient and are affected by extreme climate events.
- The electricity high-voltage grid is weak and needs rehabilitation, so can be easily damaged during extreme weather conditions, for example, by storms. There are no national fuel pipelines and no power stations in the West Bank. Fuel tankers are affected by weather and road conditions.

Adaptive capacity

Palestine energy strategy was to generate 50% of electricity consumed and two 200MW power stations were planned in the North and South of the West Bank. The strategy also specifically sets a target of 20% from renewables by 2020 which was not materialized. Solar energy has the greatest potential with daily average insolation of 5.4kWh/m2/day for both heat and electricity generation. However, other renewable energy sources, such as wind, geothermal and biomass are expected to play a role. It is estimated that there is potential to generate 20MW from energy-from-waste (e.g., municipality solid waste, agriculture and some industrial waste), with high potential for gasification. There has also been a recent possible discovery of natural gas in West Bank.

Israeli restrictions limit the development of the energy sector in many aspects including:

- Upgrading of Palestine's electricity grid and establishing a national transmission line
- Building power stations in the West Bank
- Palestine ability to extract any natural gas
- The amount of renewable electricity that can be fed into the grid (at medium voltage)
- Import of feedstocks, including only granting import through Israeli agents and companies, and causing delays as a result of security, customs, standards and quality checking, with resultant impact on availability
- Importing of photovoltaics (PV) and other renewable energy systems hampering the rate of installation.

There is no security of electricity supply as Israel can and does cut it off. Palestine’s ability to adapt is limited because the electricity transferred, voltage type, and number of connecting points (feeders) are all determined by Israel. Upgrading of the electrical grid is subject to Israeli approval. Import of fuel from Jordan or other Arab countries is subject to permission from Israel.

Israel also prevents storage of large amounts of petroleum and liquid petroleum gas and development of a distribution system (pipe network) in the West Bank. Despite all of these restrictions, the electricity grid is being connected with Jordan in the Jericho region, so that electricity can be imported from Jordan, and a range of measures are being taken to promote domestic energy production.

4.3.1.3 Urban and infrastructure (Building conditions; Urban drainage, urbanization)

Climate sensitivity

Urban areas are sensitive to floods, heat waves, droughts, and other extreme events. Rapid population growth and urbanisation are contributing to the sensitivity of cities to climate. The average population density in the West Bank is about 500 people per km², which is higher than neighbouring countries. Rapid urbanisation is occurring because of high fertility rates, substantial rural-urban immigration, and the concentration of economic activities in urban areas. The road infrastructure is in a poor condition and heavy rainfall can lead to their erosion, collapse and closure, and to accidents due to the presence of dangerous curves and slopes coupled with a lack of retaining walls, traffic signals and pedestrian bridges.

Adaptive capacity

There are major needs to enhance urban planning due to lack of proper infrastructure at present. These needs include:

- Better policies and administration in relation to urban planning
- Management of the growth of cities, so that they are able to provide basic services and infrastructure to their existing populations. Urban drainage systems are not available in most of the urban areas and when available, they are undersized and in poor conditions.
- Regional planning and connectivity between population centers to be within Palestine's control and not subject to physical disruption from Israeli settlement activity
- Open spaces between rural and urban communities in Palestine to be within the Palestinian Government’s control
- Lifting of restrictions on movement, development and growth of major urban centers; rural communities maintain much of their rural character but have been "urbanized".

4.3.1.4 Water (flood management)

Climate sensitivity

Water resources in the West Bank are limited. The groundwater aquifer is the major source of freshwater supply and is shared between Palestine and Israel. There is excessive pumping or mining of shared aquifers by Israeli occupation. Reduced rainfall results in lower groundwater recharge, as does high- intensity rainfall due to increased run-off. High temperatures increase demand for water and increase the amount of water discharged from aquifers. Drought conditions lead to ever-decreasing amounts of available groundwater.

Urban development increases the amount of water runoff. Storm-water systems in the West Bank are under-designed and poorly managed. Localized flooding occurs in urban areas where there are too few drains, or where their capacity is insufficient to deal with heavy precipitation. Drought allows build-up of solid waste and sediments that can block storm-water drains, impeding the flow of water from the impacted area and polluting a wider area. The overstretched infrastructure is further pressured by increasing urban growth and rural to urban migration.

The condition of urban drainage systems is sensitive to climate for reasons described in relation to flood management. Water losses from open canals, dams and agricultural ponds are considerable due to high evaporation and the presence of cracks and leaks.

Adaptive capacity

Palestine has launched many projects related to use of groundwater, including protection of springs and rehabilitation of wells in different districts. However, Palestine is struggling to attain the most basic level of infrastructure and services of a low-income country. Its agencies are suffering from resource deficiencies and managerial weaknesses. Investment (and investment efficiency) in the West Bank's groundwater supply has dropped to very low levels. The prevailing economic, water resource and institutional constraints mean that the performance of the water utilities is deteriorating. The institutional architecture proposed for the water sector has not been fully implemented. Water harvesting projects are limited and there is an absence of institutional arrangements for shared aquifer systems. There is limited deepening and rehabilitation of wells, protection of springs, and implementation of small-scale desalination units

Since 1967, Israel's policy and practice in Palestine has been to expropriate and assert control over water resources, maintain an unequal and discriminatory allocation of water resources to benefit both Israeli citizens and settlers, and prevent Palestine from developing its resources. The Palestinian Water Authority (PWA) is unable to conduct an integrated water management scheme in the West Bank within the current governance framework. The governance system established by Article 40 of the Oslo Agreement requires the approval by Israeli authorities of any proposed PWA management measure or infrastructure project within the West Bank. This arrangement and its implementation, gives Israeli authorities control over the allocation and management of the West Bank's water resources.

Palestinians have the necessary technology and skills to match urban-drainage systems to the demands made by heavy precipitation. However, adaptive capacity is limited by the scale of required investments in flood management, and the municipalities' and village councils' lack of resources and managerial weaknesses. Palestine faces the challenge of compulsory connection with Israel's infrastructure. Israel has blocked every possible means by which the Palestinians might manage flooding.

Adaptive capacity in relation to the condition of urban drainage systems is as described for flood management. Many of the issues limiting Palestine's adaptive capacity in relation to groundwater supply, described above, are also relevant in relation to the condition of the water infrastructure. Many Palestinian families, especially in rural areas, use cisterns and rainwater harvesting tanks, some of which are centuries old, to gather and store rainwater. Lots of agricultural ponds have been constructed, which are rainwater-fed. Water is conveyed through open channels or pipes. Surface- water harvesting of wadis is still not much developed by the PWA despite significant interest, mainly as a result of Israeli restrictions.

Israeli policy and practice to expropriate and assert control over water resources limits adaptive capacity with regard to the condition of the infrastructure, as does the PWA's inability to conduct integrated water management schemes in the West Bank within the current governance framework. Israel imposes severe restrictions on permits for construction of dam and water harvesting projects.

4.3.2 Vulnerability Assessment of Priority Sectors across Climatological Zones

In order to provide an indication of how the relative vulnerability of the priority sectors (agriculture, energy, urban and infrastructure and water) can vary across the West Bank and Gaza, the information presented above and expert knowledge has been used to provide a relative assessment of the vulnerability (Table 4.7), as a function of the climatological zone. The vulnerability has been evaluated from low to moderate to high: these categories can be represented numerically from 1 to 3 so that they can be combined with the climate change susceptibility map for an assessment of the risk (see Section 5.3).

Agriculture is particularly vulnerable within extremely arid and hyper arid climates where rainfall is lowest (and expected to decrease) and more cases of drought can be expected, whereas the opposite is the case in humid zones where rainfall is abundant. Energy production, imports and the conditions of energy infrastructure are relatively more vulnerable in the less arid and more humid zones, where increases in extreme weather and storms are expected and are more likely to affect the infrastructure. Urban and infrastructure is also most vulnerable in the less arid and more humid zones where rainfall is highest (and expected to increase) and road infrastructure can be negatively impacted through erosion, collapse and closure. Water (flood management) is most vulnerable in the more arid environments where rainfall is lowest, and there is the lowest groundwater recharge.

Table 4.7 Relative vulnerability assessment access West Bank and Gaza climatological zones for priority sectors

Sector	Climatological Zone					
	Extremely arid	**Hyper arid**	**Arid**	**Semi-arid**	**Semi-humid**	**Humid**
Agriculture	High	High	Moderate	Moderate	Low	Low
Energy	Low	Low	Low	Moderate	Moderate	Moderate
Urban and infrastructure	Moderate	Moderate	Moderate	Moderate	High	High

Water	High	High	High	High	Moderate	Moderate

4.4 Social vulnerability assessment

The potential impacts of disasters result from the collective behaviour of the built environment, the earth's biophysical systems and communities' socio-economic characteristics. Social conditions of any community can foster risk and create a differential potential for harm when they occur. While studies of physical vulnerability are well established (such as those presented above for seismic and flood risk assessment), they do not capture spatial patterns of differential capacities of population to reduce disaster risk, to respond to emergencies, and to recover after a damaging event. In this context, resilience can be defined by the ability of the social system to prepare, cope and recover from disasters.

For the West Bank and Gaza in particular, the restrictions and limitations that inhabitants of Palestine face (e.g., restrictions in importing goods, limitation to obtain work permits, limitations to mobility, water resources almost under complete control by Israel), impair their capability to take appropriate risk mitigation and climate change adaptation measures.

Currently, however, social vulnerability indices for West Bank and Gaza are available only at the national level, and were designed to benchmark and cross-compare countries at the global scale. There are no indices at a higher resolution level (i.e., communities) which are instead needed to understand drivers of social vulnerability, plan and develop public policies to reduce disaster risk. This section will therefore assess and map the distribution of social vulnerability within West Bank and Gaza.

The method adopted herein is based on composite indicators. Any observed fact can be an indicator, whereas the aggregation or combination of these individual indicators results in a composite indicator. A group of indicators that are relevant and known to explain the differential capacities of populations to prepare, respond and recover after events were selected based on literature (Rufat et al 2015; Burton at al 2022). A total of 32 indicators were collected for 16 Palestinian governorates from the Palestinian Central Bureau of Statistics (PCBS)[19], Ministry of Health (MoH)[20] and Ministry of Education (MoE)[21]. The variables were collected within categories named herein as sub-components and include population, health, economy, education, infrastructure and political. Table 4.8 illustrates sub-components and variables of social vulnerability with the reference year and source of the information. The variables corresponding to each sub-component are aggregated into sub-indicators, and the sub-indicators are combined to construct the final social vulnerability index.

[19] PCBS. https://www.pcbs.gov.ps/default.aspx
[20] MoH. https://site.moh.ps/
[21] MoHE. https://www.mohe.pna.ps/

Table 4.8: Sub-components of variables of social vulnerability

Sub-component	Variables	Source	Ref year
Education	Percentange of population that obtained higher education	PCBS	2017
	Percentange of illiterate population	PCBS	2017
	Students to teachers ratio	MoE	2020/2021
Population	Population density in built-up areas (population/km^2)	PCBS	2017
	Percentage of female population	PCBS	2017
	Percentage of population with disability	PCBS	2020
	Crude divorce rate	PCBS	2017
	abour force participation rate	PCBS	2020
	Percentage of population under 5 years old	PCBS	2017
	Percentage of population over 65 years old	PCBS	2017
	Percent of population between 5 and 65 years old	PCBS	2017
	Median age at first marriage for females	PCBS	2020
	Percentage of population living in refugee camps	PCBS	2017
Economy	Percentage of unemployed population	PCBS	2020
	Percentage of population under poverty line	PCBS	2017
Health	Hospital beds per 10k population	MoH	2020 (West Bank) 2021 (Gaza)
	General fertility rate	PCBS	2019-2020
	Crude birth rate	PCBS	2020
	Crude death rate	PCBS	2020
	Percentage of population without health insurance	PCBS	2017
	Percentage of population with chronic diseases	PCBS	2017
Political	Ratio of Settlers to Palestinian population	PCBS	2019

Sub-component	Variables	Source	Ref year
	Criminal offences per 100k of population	PCBS	2020
Infrastructure	Housing density	PCBS	2017
	Percentange of households without access piped water	PCBS	2017
	Percentage house hold not connectedto electricity network	PCBS	2017
	Percentage of households without access to public sewage network	PCBS	2017
	Percentage of households living in apartments	PCBS	2017

Each of the variables has been standardised using either percentages, density or rate per specific count i.e. population, then the variables were normalized on a scale from 0 to 1 using min-max transformation which ensures that all variables utilize the same scale. To ensure the quality of the final index, variables that showed strong correlation with other variables (correlation factor above 0.7) were removed, resulting in 26 variables. The variables were finally averaged per sub-component to form sub-indicators and then the six sub-indicators were simply summed to form the final vulnerability index. This aggregation method assumes each and every variable has the same weight or importance. Weights can be assigned by correlating the variables with existing loss data, which in this context is not available, or the weights could be assigned using a participatory approach of community stakeholders. Figure 4.5 illustrates the spatial distribution of the final social vulnerability index (SVI) for 16 governorates in West Bank and Gaza. The dark red colours indicate that social vulnerability in the respective communities are relatively higher than others. The index suggests the Gaza strip is overall more socially vulnerable than the West Bank. While in the latter, vulnerability is highest in Jericho, Salfit, Jerusalem and Tubas. Drivers of social vulnerabilities could be explained by the sub-indicators for each component, as presented in the following sections. The variables per governorate can be found in Appendix 4 for further reference.

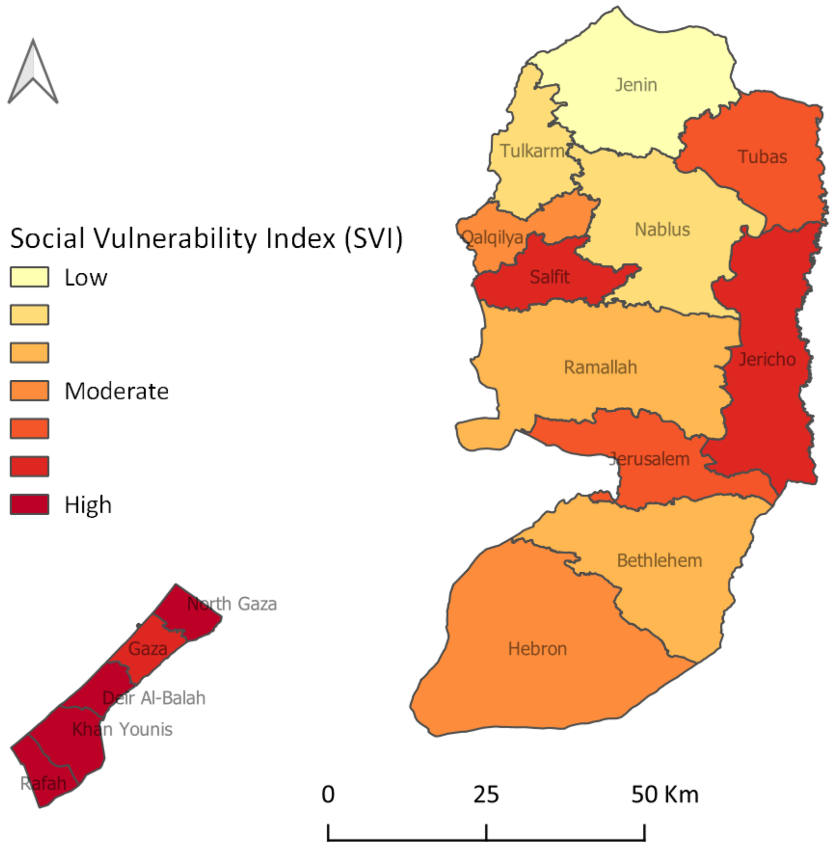


Figure 4.5: Spatial distribution of social vulnerability index (SVI) in West Bank and Gaza.

4.4.1 Education

Education can positively impact different aspects of community vulnerability. This includes preparedness, reaction to early warning, evacuation and relocation decisions, adaptation to environment and ability to cope with disaster consequences (Hoffmann and Blecha 2020). Education sub-indicator in Figure 4.6 reflects distribution of social vulnerability influenced by teachers to students rate, illiteracy rates and percentage of the population with a higher degree of education[22]. In Gaza, the illiteracy ratio and percentage of population with a second degree is higher than in the West Bank. Nonetheless, the variable teachers to students rate is generally higher in Gaza. Compared to the global literacy rates, Palestine has one of the lowest illiteracy rates at 2.6%. The highest illiteracy rate can be found in Jericho governorate at 4.7%. Illiteracy is disproportionately higher among women at 6.7% compared to men at 2.6%.

[22] Completed associate diploma or above

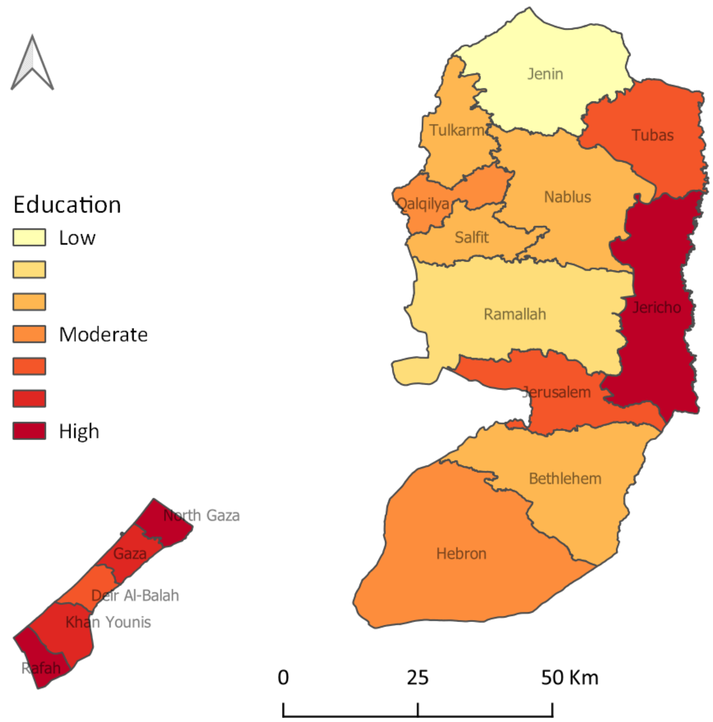


Figure 4.6: Spatial distribution of education sub-indicator in West Bank and Gaza

4.4.2 Population

The population indicator reflects the vulnerable groups inside communities. Age is considered the leading demographic driver of social vulnerability. Extreme age groups (i.e. very young or old) face mobility difficulties and increased care burden after major events caused by disruption of basic services need for recovery. In general, age distribution among Palestinians is quite similar with a small variation between Gaza and West Bank. In the former, the average percentage of population below 5 years old is 18% and above 65 is 2.76%, while in the latter it is 15.3% and 3.6%, respectively. The population in Gaza is slightly younger than in the West Bank. Younger population can be a factor contributing to resilience, as shown in some studies.

Gender can also be linked to social vulnerability. The inequality between men and women is attributed to the uneven resources, opportunities and income. The gender distribution in Palesinian communities is almost homogenous. Other studies have reported that women are a factor of resilience when compared to men, mainly due to their commitment to knowledge of risk (risk behaviour) and social connections. As such gender alone can not be considered a factor of vulnerability, however, poor socio-economic conditions can interact with gender and increase inequality which can increase social vulnerability.

Among the vulnerable groups are persons with disabilities, including but not limited to seeing , hearing, communication, moving, remembering and concentration disabilities, in addition to learning and mental disabilities. Based on PCBS estimates, the prelevance of disability is about 2.7%, however this only includes persons with major diffculties, when minor difficulties are considered the prelevance of disability raises to 7%.. In Palestine, mobility is the most common disability, at 49.5%, and is highly correlated with age. Disability in Gaza is slightly higher than in West Bank, with 2.6% compared to 1.7%. Exclusion of disability can impede response operations e.g., evacuation, search and rescue and first aid and post-disaster need assessments. Similarly, the disruption in the essential services can slow down the recovery process for this group of population. The disabled individual survey (PCBS and MoSD 2011) found that one third of disabled persons above 18 years old have never been to school and have a 53.1% illiteracy rate. The majority of the disabled of working age do not work, with unemployment rates of 87.3% which is close to the highest rates on the spectrum for developing countries of 80-90%, according to UN estimates. As shown in survey during COVID emergency 99.1% of households could access health services, while only 73.2% could access treatments or care for the disabled. Disability, in addition to gender, poverty, education and poor access makes disabled groups the most vulnerable populations.

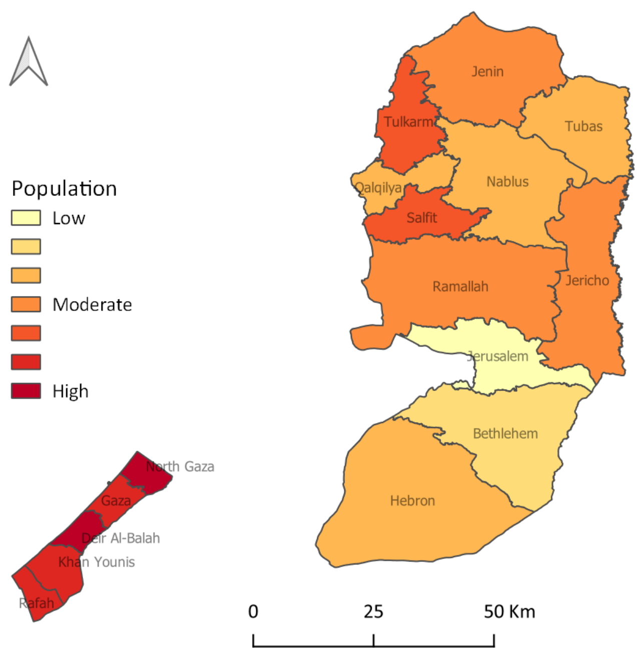


Figure 4.7: Spatial distribution of population sub-indicator in West Bank and Gaza

4.4.3 Economy

On average, poverty rates in Gaza are higher than in the West Bank. All Gaza governorate's poverty rates exceed 50 percent. In the West Bank, Jerusalem, Hebron and Qalqilya are the poorest. According to PCBS Multidimensional Poverty Index (MPI), monetary poverty is the largest contributor to poverty levels in West Bank and Gaza. Poverty within governorates is more severe in refugee camps, 39% as compared to 24% in urban areas and 14% in rural areas. This explains the dark red colours in Gaza, which is mostly urban and with a large percentage of refugees living in refugee camps. Monetary poverty lines[23] measure the actual spending patterns of population, the normal poverty line is calculated to reflect budget for food, clothing, housing, health care, education, transportation, personal care and housekeeping supplies. Poverty determines access to resources, coping behaviour and stress. Poverty is considered a key driver of social vulnerability and is coupled with other indicators that define social vulnerability including access to education, health, household overcrowding (Rufat et al. 2015).

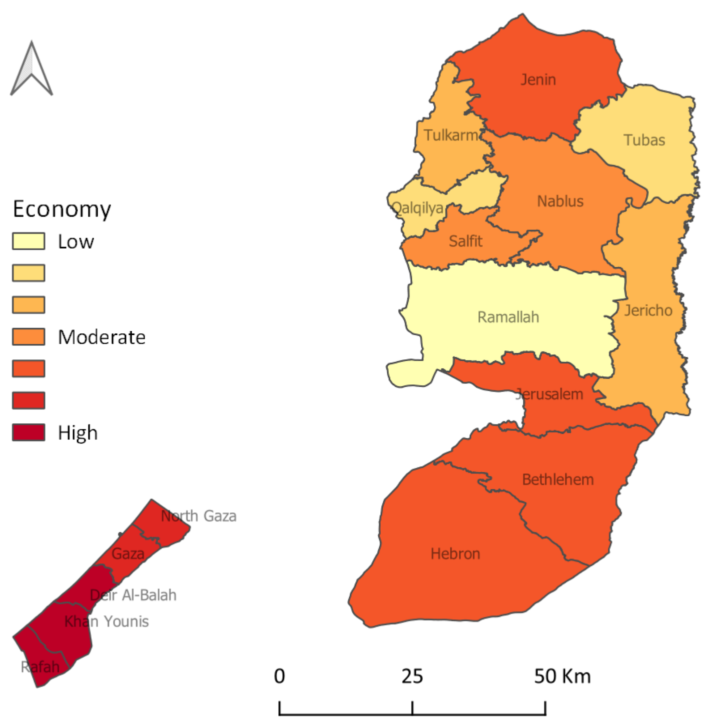


Figure 4.8: Spatial distribution of economy sub-indicator in West Bank and Gaza

4.4.4 Health

The health indicators measure mainly population characteristics related to their physical conditions, e.g, chronic diseases, crude birth and death rates. The indicator also combines access to health services and facilities, e.g., number of hospital beds per 10k population and percentage of population insured. In general, access to health facilities and services, i.e.

[23] Accroding to PCBS in 2017, the poverty line and deep poverty line for a reference household of five individuals (2 adults and 3 children) were, respectively, 2,470 NIS (New Israeli Shekels) and 1,974 NIS.

number of beds or health insurance, is higher in Gaza than in the West Bank. Hospital beds are mainly concentrated in specific regions: Gaza, Khan Younis, Bethlehem, Ramallah, Jerusalem. Unlike Gaza, West Bank communities are separated by larger distances and reaching hospitals can be challenging considering the movement restrictions. Section 3.4 provides an overview of type hospitals and their distribution. The high concentration of red colours in the West Bank is related to a relatively low percentage with health insurance compared to Gaza. In West Bank on average 35% have no health insurance while in Gaza, the percentage is 3.8%. A recent study by Shadeed and Alawna (2021) has shown that availability of hospitals and population with chronic diseases among other factors were correlated with the spread of COVID-19 in the West Bank governorates.

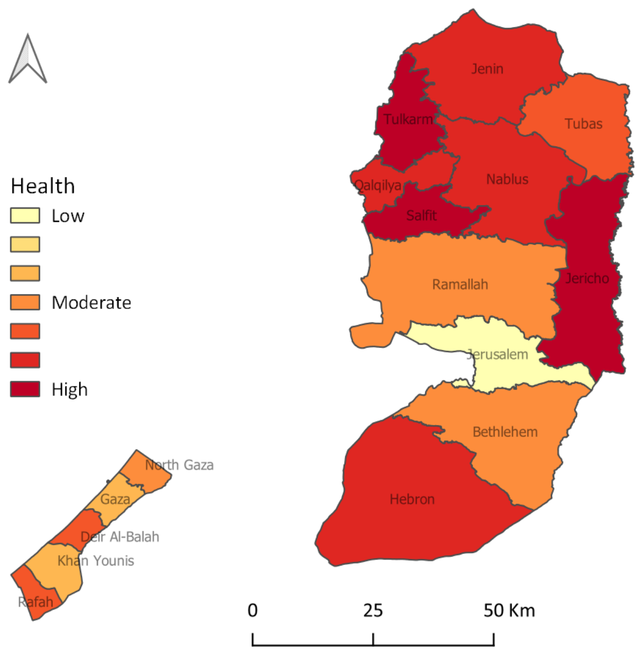


Figure 4.9: Spatial distribution of health sub-indicator in West Bank and Gaza

4.4.5 Political

West Bank has a very fragmented landscape. Following Oslo Accords in 1993, the land was divided into three areas A, B, C (see Figure 4.10). Each area has specific rules for control, most Palestinian cities are located in areas A and the PA has civil and security control over it. In areas B, PA has only civil control. Areas C are not controlled in any way by the PA. Communities in Area A are isolated from each other because of the permanent and temporary checkpoints and illegal settlements that surround them. Checkpoints limit freedom of movement and economic activity between communities. They can be closed for hours or days which put extra burden and difficulties on the economy, security and well-being of the people. Gaza, on the other hand, remains isolated from the West Bank; although there is no settlers presence, it is land-locked and movement out and in of goods and people is very restricted. The aim of this sub-indicator is to have a measure of security and stability using ratio of settlers per Palestinian population and number of criminal offences per 100k of population. The rate of criminal offenses in Gaza is 2570 which is higher ithan in the West Bank with 1300 recorded offenses. and in West Bank 1300. Within the West, there are variations between regions with the highest rates in Salfit (2934) and Jericho (2803) and the lowest in Jerusalem (575) and Hebron (587). This variable could coincide with poverty and level of law enforcement.

The Presence of settlements in general imposes many difficulties on Palestinian communities. First settlements usually obstruct further development and expansion of cities and villages causing over density of population. This also implies control of the natural resources such as water, and fertile agricultural lands, limiting farmers to cultivate or use their lands. In addition, settlements are always surrounded by checkpoints which cut-off roads, causing mobility issues. Often in the vicinity of settlements, Palestinian communities are exposed to settlers violence which often blocks roads, harms villagers and burns olive trees. As of 2019, the number of settlers in the West Bank reached about 688 thousand distributed across the region. Settlers density compared to the Palestinian population is highest in Jerusalem at 69.2%, Salfit 59.6%, Bethlehem 39.2%, and Qalqiliya 33.9%. In Gaza there are no settlers, yet to reflect the effect of the siege and keep the variable consistent in both regions, it was assumed that each governorate in Gaza has settlers equivalent to the governorate with the highest ratio of settlers in the West Bank. Gaza suffers the most due to the siege and almost periodic wars. Occupation affects all aspects of life, regions that are mostly affected by occupation will be more vulnerable in all stages of disasters.

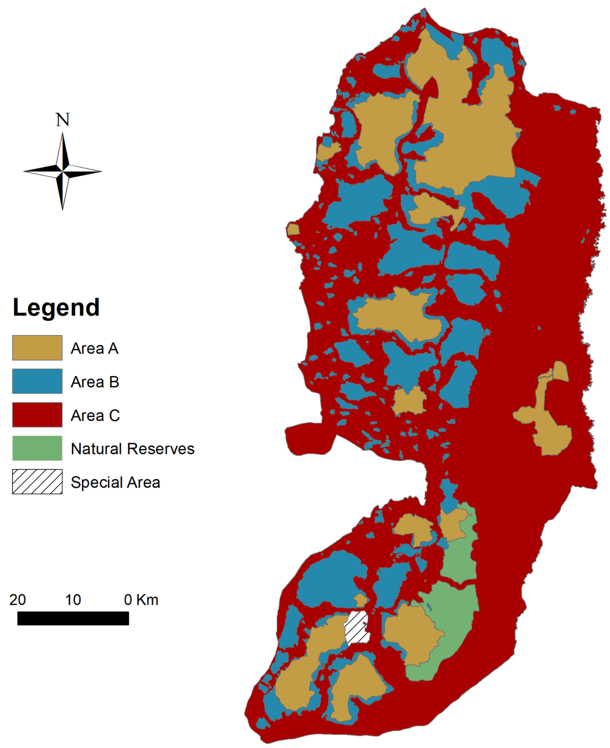


Figure 4.10: Land classification according to the Oslo agreement.

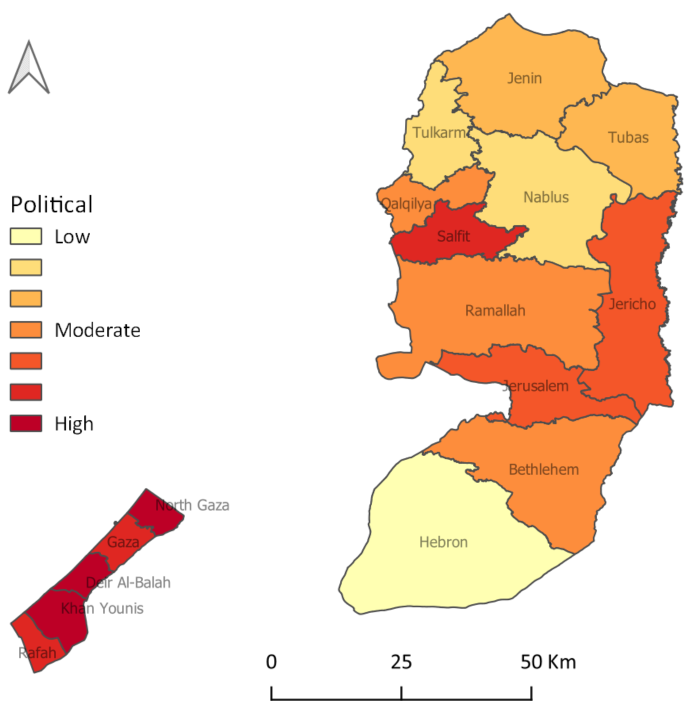


Figure 4.11: Spatial distribution of political sub-indicator in West Bank and Gaza

4.4.6 Infrastructure

The infrastructure sub-indicator measures in general housing access to basic infrastructure i.e. public water network, electricity grid and drainage. The indicator also includes percent of population living in apartments and housing density (person per room). Population living in apartments are represented mostly by the lower-income class, typically these multi-story buildings are poorly constructed and have no dedicated service areas, e.g., evacuation and emergency exits. Apartments buildings are often rented, and precautionary measures, structural mitigation were higher among homeowners than renters (Steinführer and Christian 2007). Moreover, post-disaster housing assistance favoured property owners over renters (Kamel 2012). Limited access to public infrastructure means a limited alternative to cope, for example, households relying on tankers to fulfil their daily needs of water could suffer more than others due to that lack of alternatives in case a destructive event disrupts these services. Population with higher access to public infrastructure have more alternatives and are likely to be reached first after an event.

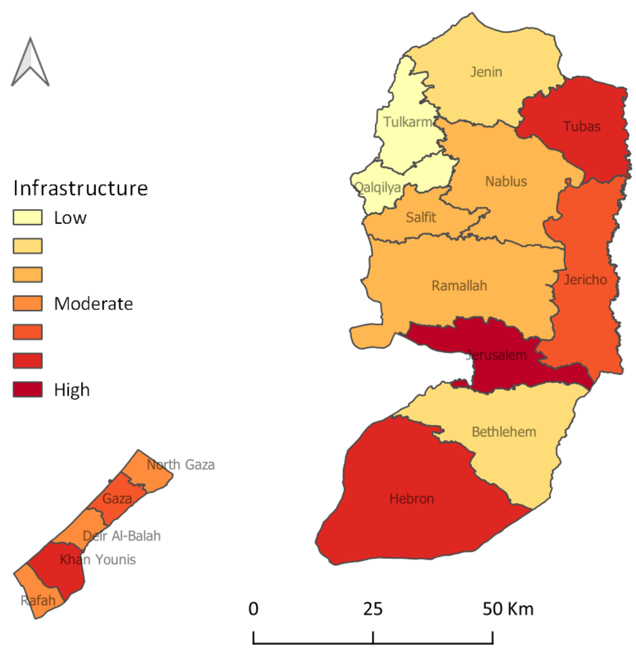


Figure 4.12: Spatial distribution of infrastructure sub-indicator in West Bank and Gaza

5 Multi-hazard Risk Assessment

5.1 Seismic Risk Assessment

5.1.1 Regional Probabilistic Seismic Risk Assessment

A regional probabilistic seismic risk assessment has been undertaken with the OpenQuake-engine (Pagani et al., 2014; Silva et al., 2014) to evaluate the earthquake impacts on human lives and the built infrastructure (i.e. economic loss and fatalities) due to strong ground shaking. The seismic hazard model (see Deliverable D3.1) has been used to develop stochastic catalogues (each of 10,000 years) for each branch of the logic tree and ground motion fields for each event in these catalogues. For each ground motion field, the ground shaking to the buildings in the exposure models (see Chapter 3) is obtained and combined with seismic vulnerability models (see Section 4.1.1) to calculate the losses (economic losses and fatalities). The losses for all events in the catalogues can be used to calculate the average annual losses as well as loss curves (i.e. loss versus return period), at the national level, and at varying spatial resolutions.

The average annual losses at the national scale are provided Table 5.1.

Table 5.1: National average annual loss and loss ratio for economic loss (AAEL, AALR) and average annual loss of life (AALL) due to earthquake ground shaking for each category of exposure (residential, commercial, industrial), and for all the building stock (total)

	Residential	Commercial	Industrial	Total	(Total AAEL / GDP) %	(Total AALL / population) %
AAEL (M USD)	62.81	3.71	0.71	67.2	0.48 %	-
AALR (%)	0.046	0.024	0.027	0.043	-	-
AALL (number of people)	13.48	0.19	0.02	13.69	-	0.0003 %

The national loss curves (i.e. loss versus return period) for economic loss and fatalities are plotted in Figure 5.1 and 5.2, respectively.

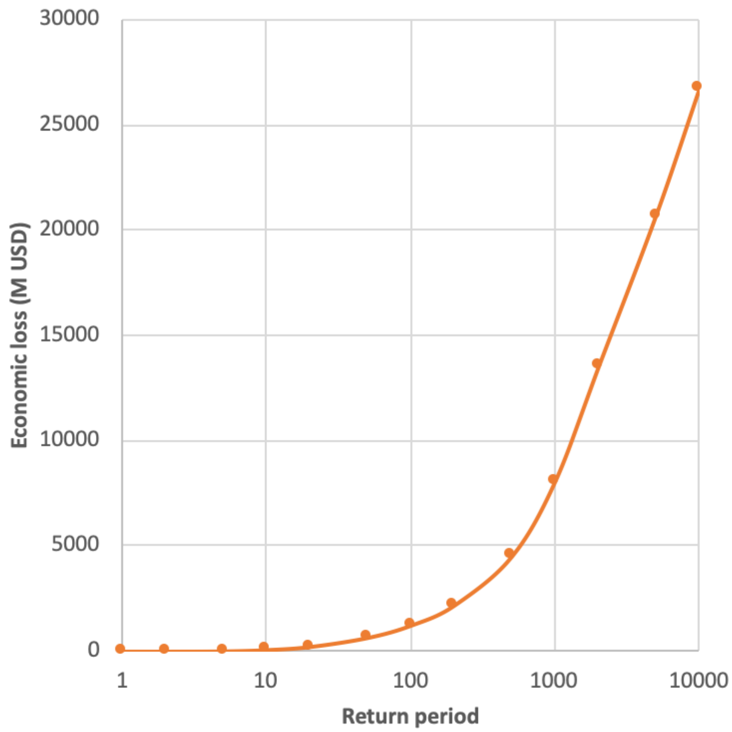


Figure 5.1: National loss curve in terms of economic loss (M USD)

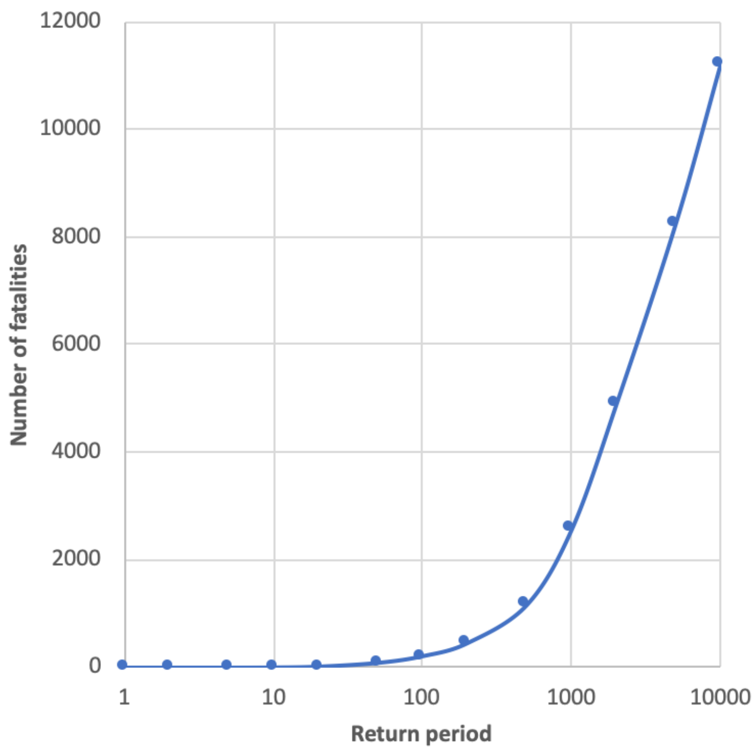


Figure 5.2: National loss curve in terms of fatalities

The maps of average annual losses (economic: AAEL and fatalities: AALL) and average annual economic loss ratio (AALR) at the community level are presented below, and are provided in the web-based mapping platform (see Chapter 6).

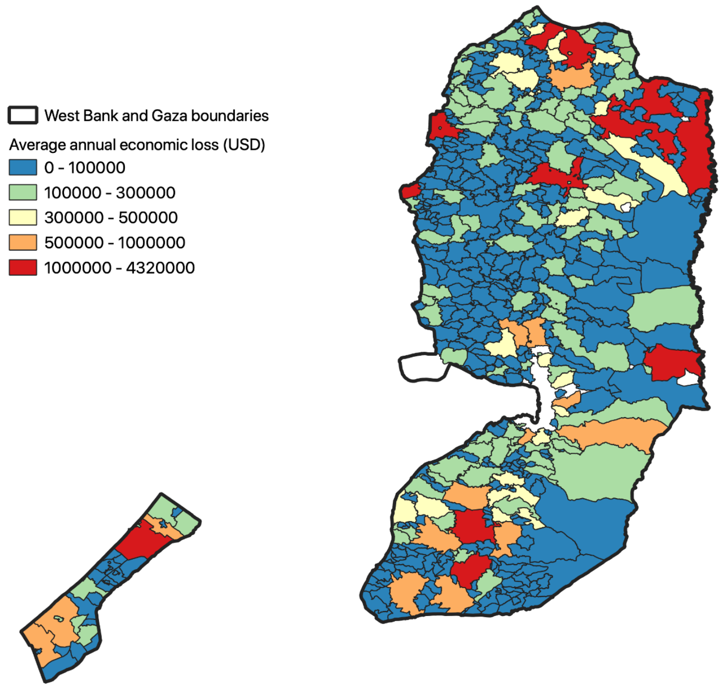


Figure 5.3: Map of average annual economic loss (AAEL) due to earthquake ground shaking at the community level

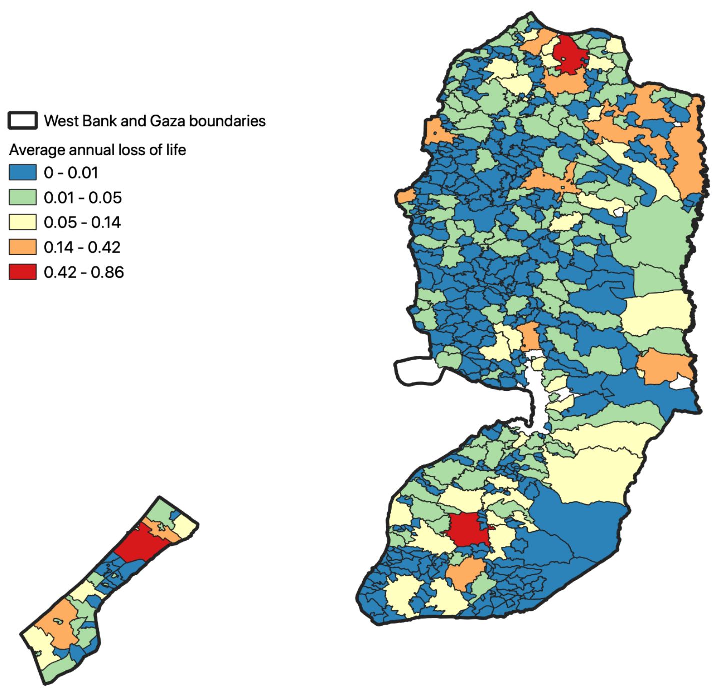


Figure 5.4: Map of average annual economic loss (AAEL) due to earthquake ground shaking at the community level

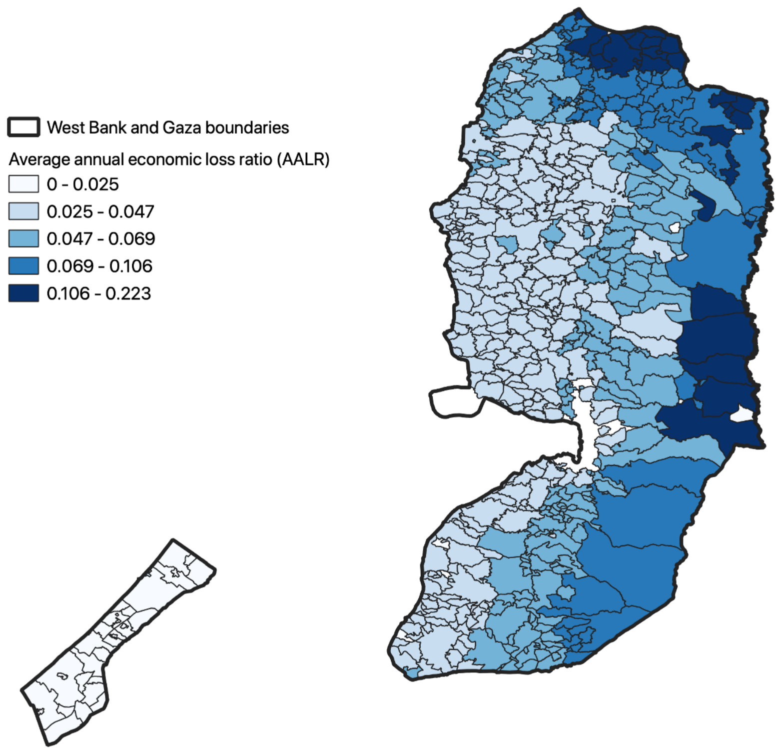


Figure 5.5: Map of average annual economic loss ratio (AALR) due to earthquake ground shaking at the community level

5.1.2 Integrated Regional Seismic Risk Assessment

The total or integrated seismic risk of communities can be expressed by combining the physical risk metrics described in the previous section with the social vulnerability index (SVI) presented in Section 4.2 through the so-called Moncho's equation (e.g. Carreno et al., 2012):

$$R_T = R_F(1 + F) \tag{5.1}$$

where R_T is the total risk index, R_F is the physical risk index and F is the aggravating coefficient (i.e. social vulnerability index). For the physical seismic risk index (R_F), this has been calculated herein for each community as the sum of an economic loss index and a loss of life index, each of which is obtained from the average annual losses, normalised through min-max scaling:

$$R_F = \frac{AAEL - min(AAEL)}{max(AAEL) - min(AAEL)} + \frac{AALL - min(AALL)}{max(AALL) - min(AALL)} \tag{5.2}$$

The map of the integrated (total) seismic risk index at the community level is provided below.

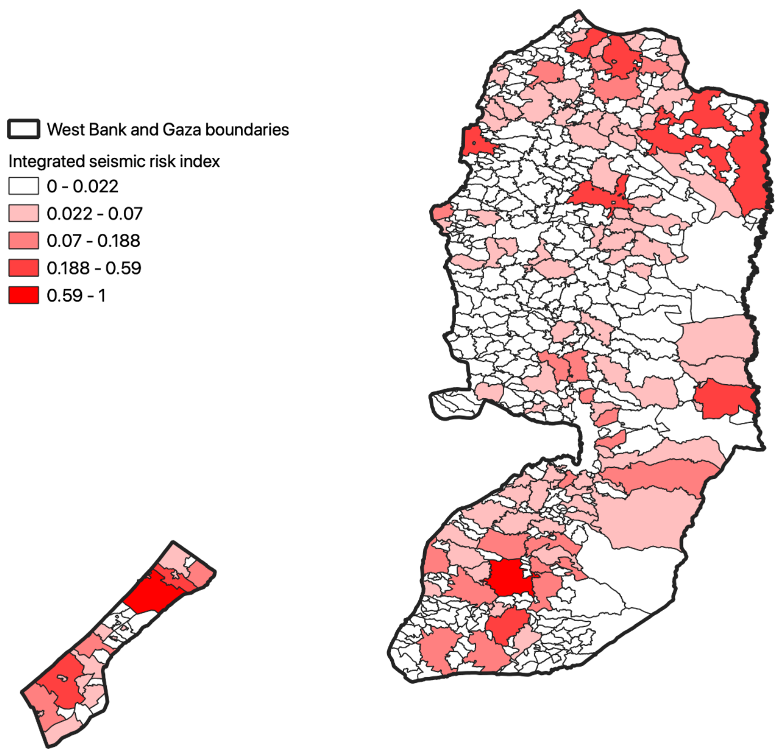


Figure 5.6: Map of integrated (total) seismic risk index due to earthquake ground shaking at the community level

5.1.3 Seismic Risk Assessment for Scenario Events

The stochastic catalogue that led to loss curves closest to the mean loss curve shown in Figure 5.1 was investigated to identify ruptures to model as specific scenario events (Figure 5.7). A scenario in the central area of the West Bank which would be a repetition of the 1927 Jericho earthquake was first selected. A scenario event in the south which could be representative of a 1 in 2000-5000 year loss and which impacts both West Bank and Gaza was then selected. Unlike the other scenarios, this event does not correspond with any known/mapped faults, but is possible (though very rare) as the maximum magnitude of the background seismicity in the seismic hazard model (see Deliverable D3.1) in that area is 8.15. Finally, an event in the north that was representative of a 1 in 200-500 year loss was selected. The characteristics of the four scenarios are presented in Table 5.2. It is noted that for the 1927 scenario the USGS ShakeMap for this event has been directly used[24], whereas for the other three events a rupture model has been developed.

[24] https://earthquake.usgs.gov/earthquakes/eventpage/iscgem909378/shakemap/intensity

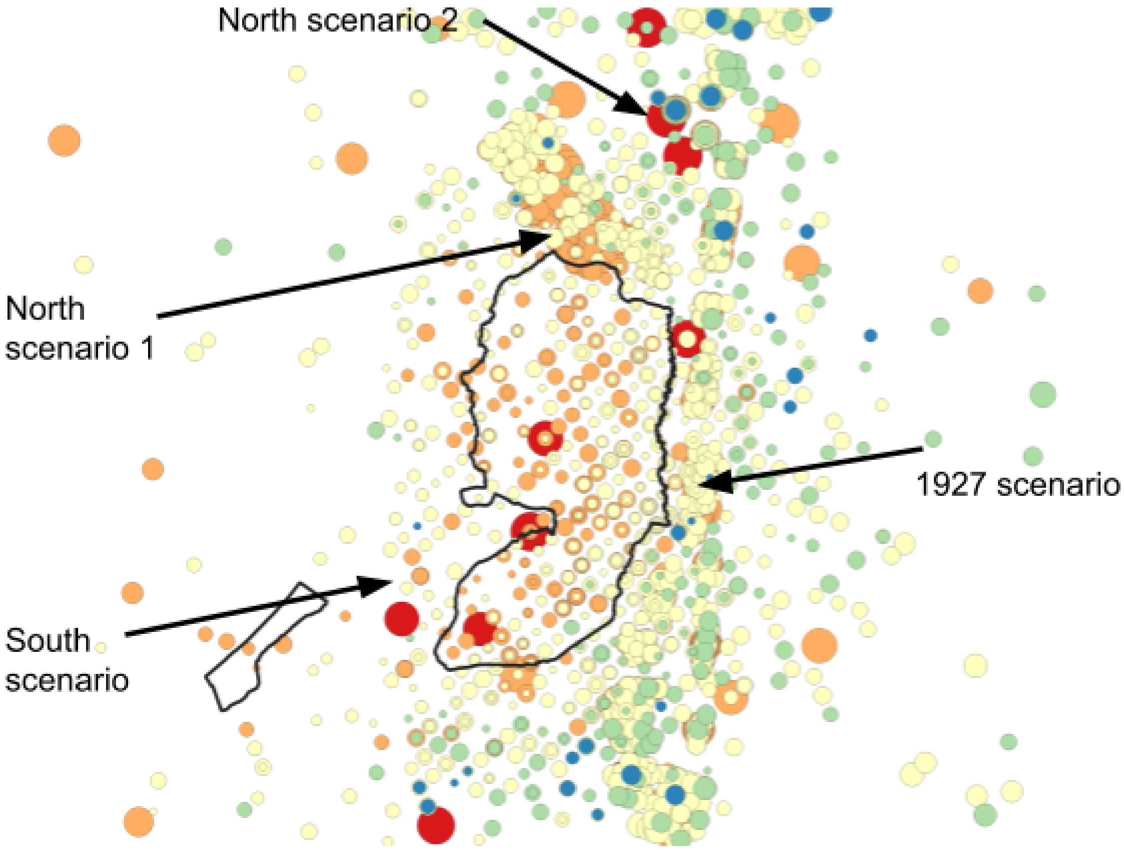


Figure 5.7: Map of events in "mean" stochastic catalogue: the colours of the circles from green to red represent increasing economic losses and the size represents increasing magnitude. The approximate location of the four scenarios is illustrated on the map.

Table 5.2: Characteristics of the four scenario events

Scenario	**Mag**	**Depth (km)**	**Lat, Lon**	**Strike (°)**	**Dip (°)**	**Rake (°)**	**Comments**
1927 ShakeMap	6.3	15.0	31.922, 35.633	N/A	N/A	N/A	Similar location and magnitude to 1927 earthquake. Analyses use the USGS ShakeMap.
South	6.5	25	31.614, 34.839	19.96	90	0	Approx. 1 in 200-500 year loss in the south
North 1	6.5	15.42	32.621, 35.270	322.56	57.41	6.71	Approx. 1 in 200-500 year loss in the north
North 2	7.5	20	32.938, 35.549	19.8	90	0	Similar location and magnitude to 1202 earthquake (north of Tiberius lake)

Table 5.3: Summary statistics of damage and loss for the four scenario events

Scenario	Mean loss (B USD)	Mean fatalities	Mean number of completely damaged buildings
1927 ShakeMap	4.0	1000	5475
South	5.9	2110	9000
North 1	3.6	1005	6180
North 2	13.2	4560	24,840

The fatalities and completely damaged buildings in the 1927 scenario, can be compared with the reported damage and losses for that event where in the city of Nablus 69 people were killed, more than 100 injured and about 300 houses collapsed (Amiran, 1950). The larger impact of the repetition of such a scenario today is expected given the significant increase in urbanisation in the West Bank since the 1920's. It is also worth noting that there is a large uncertainty in the values presented in Table 5.3 (which just present the mean risk metrics), given both by the uncertainty in the levels of ground shaking and from the response of the buildings, which is currently represented by global vulnerability models and has not been calibrated to the local characteristics of the buildings. Maps of the distribution of completely damaged buildings for each scenario are presented in the following figures. Similar maps can be produced for the economic losses and fatalities.

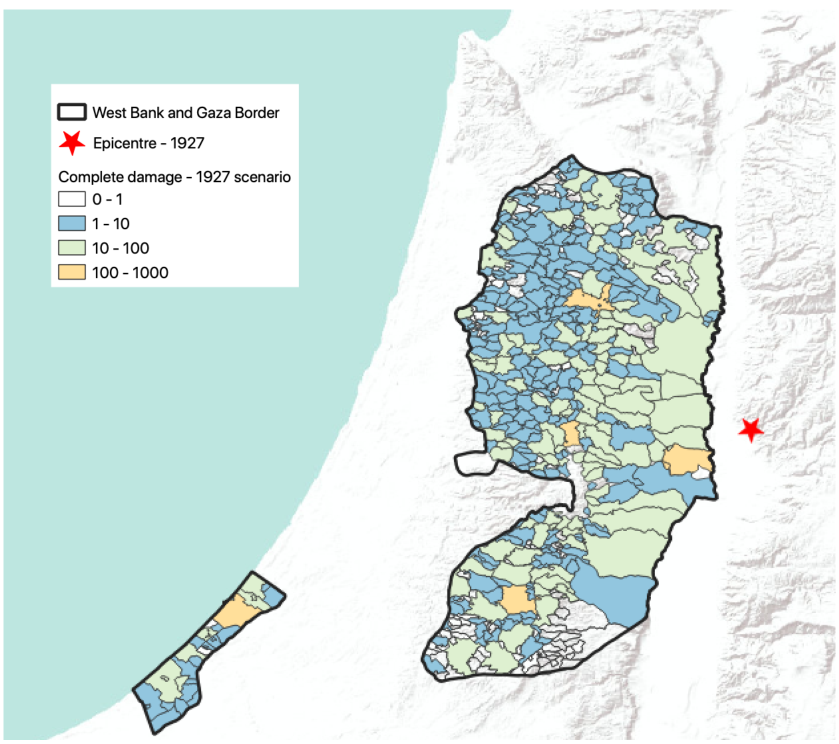


Figure 5.8: Map of the distribution of completely damaged buildings for the 1927 scenario

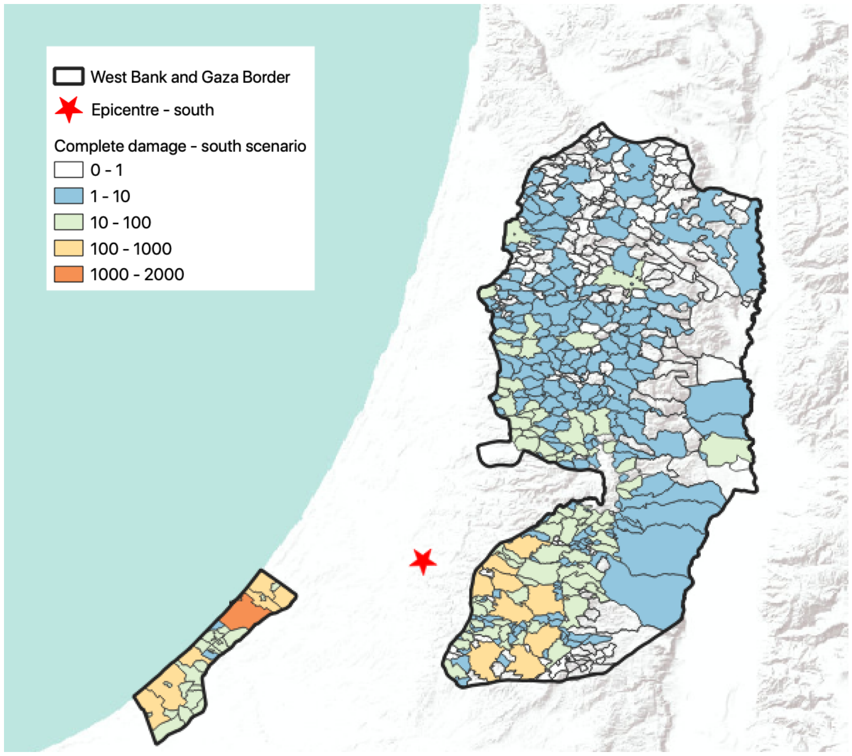


Figure 5.9: Map of the distribution of completely damaged buildings for the South scenario

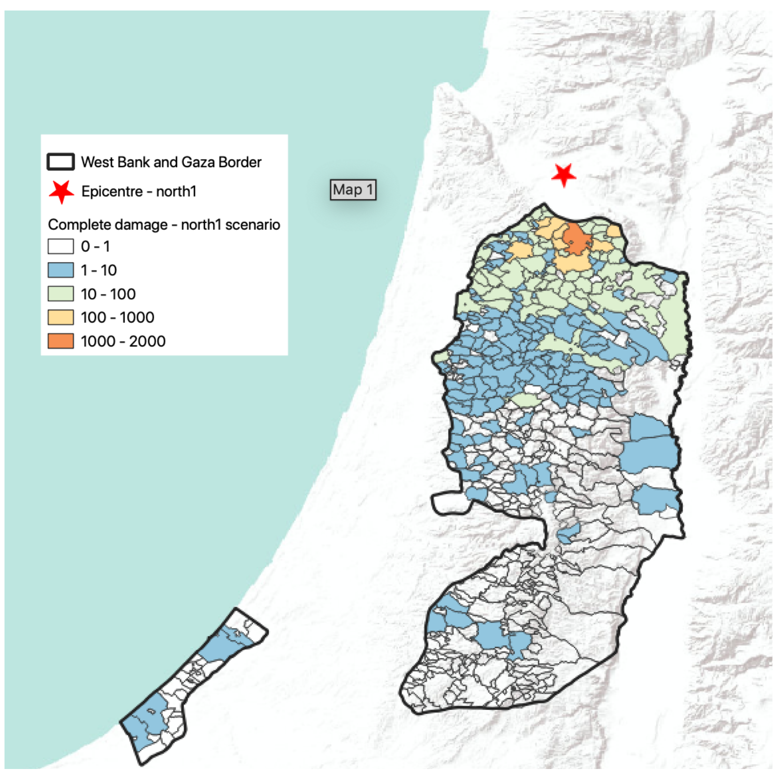


Figure 5.10: Map of the distribution of completely damaged buildings for the North 1 scenario

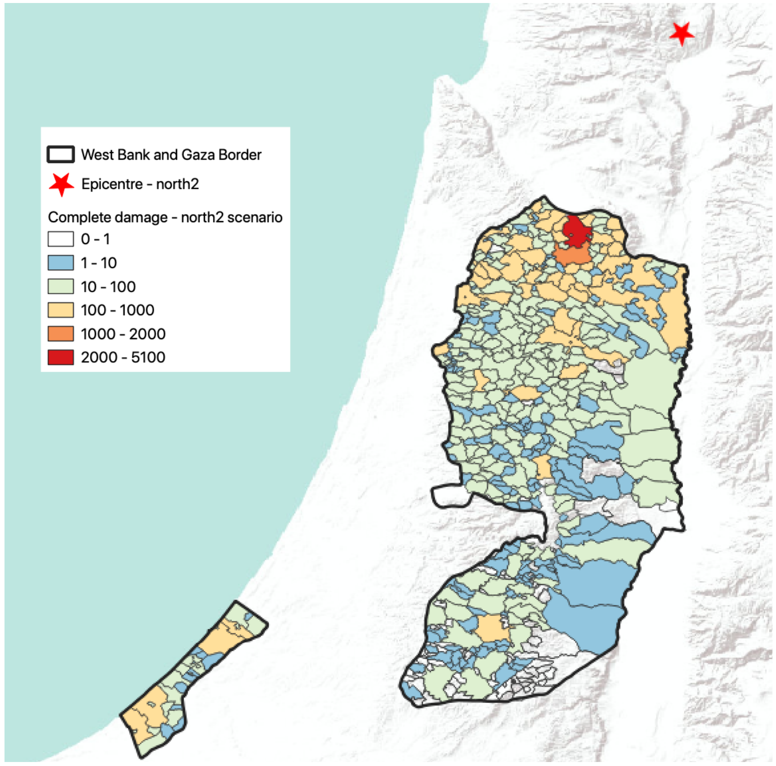


Figure 5.11: Map of the distribution of completely damaged buildings for the North 2 scenario

5.1.4 Seismic Risk-Based Ranking of Priority Buildings

In order to rank the hospital and civil protection buildings in terms of priority for seismic retrofitting activities, a seismic risk index has been calculated that combines the physical risk index for each building (Equation 5.2) with the seismic risk modifiers computed in Section 4.1.1.2. Equation (5.1) has been used again here, with F in this case equal to the Seismic Risk Modifier Index (I_{SRM}) (see Equation 4.1). For these buildings, only the annual economic loss is used as the physical risk index, as the fatality risk of these buildings is less important and the focus is instead on limiting the damage to these buildings, which should remain functional during an earthquake.

The full results and ranking of all hospital and civil protection buildings (across all communities in the West Bank and Gaza except Jerusalem 1, for which data is not available and access could not be obtained for the inspections) are available for all buildings here:

https://docs.google.com/spreadsheets/d/1HTYKWYbEj9cZTiWZzVwPKUQMzH0AiJ1ptWzoev1Ae88/edit#gid=1733790066

It is important to consider that the ranking presented in the link above is highly dependent on the quality of the inspected building data. It cannot thus be used to immediately identify buildings which should be retrofitted, but instead to prioritise the buildings that should be further investigated and checked, to ensure all of the assumptions taken herein are correct. An iterative procedure can thus be applied, whereby after each set of additional checks and inspections, the risk analyses can be re-run and the ranking adjusted accordingly.

5.1.5 Seismic Risk of School Buildings

As not all school buildings have been inspected in this project, it is not yet possible to fully apply the methodology from the previous section to all the schools, but this is something that could be undertaken in the future, should it be possible to collect the risk modifier parameters for all schools across West Bank and Gaza. Instead, for the analyses undertaken here, an average seismic risk modifier index based on the number of storeys has been used (as this parameter is available for all schools in the West Bank and Gaza and was seen to correlate well with the seismic risk modifier), as shown in Table 5.4. Taller buildings are more likely to have structural deficiencies related to plan and vertical irregularity, as well as other falling hazards.

Table 5.4 Average seismic risk modifier index for school buildings for each number of storeys

Number of storeys	Average seismic risk modifier index (I_{SRM})
1	0.65
2	0.84
3	0.84
4	0.87

The exposure data collected on all the schools in West Bank and Gaza has been used to assign the building class, for which the appropriate vulnerability models have been adopted in a physical probabilistic seismic risk assessment using the OpenQuake-engine. A seismic risk index for all schools has then been calculated that combines the physical risk index for each building (Equation 5.2) with the seismic risk modifiers from Table 5.4. Equation (5.1) has been used again here, with F in this case equal to the Seismic Risk Modifier Index (I_{SRM}) (see Equation 4.1).

The full results and ranking of school buildings are available for all buildings here:

https://docs.google.com/spreadsheets/d/12psh-RnspZzm6NWIHAkIjM-p_XjyMhZ_jjSN8SGvuoE/edit#gid=813643373

As mentioned previously, it is important to consider that the ranking is highly dependent on the quality of both the exposure model and the inspected building data. It cannot thus be used to immediately identify buildings which should be retrofitted, but instead to prioritise the buildings that should be further investigated and checked, to ensure all of the assumptions taken herein are correct. An iterative procedure can thus be applied, whereby after each set of additional checks and inspections, the risk analyses can be re-run and the ranking adjusted accordingly.

5.2 Flood Risk Assessment

5.2.1 Regional Probabilistic Flood Risk Assessment

A regional probabilistic flood risk assessment to evaluate the impact of floods (combined pluvial and fluvial) on the built environment (in terms of loss of building function and resulting economic loss) has been undertaken by integrating the global flood hazard maps (Sampson et al., 2015) for different return periods with the residential model (see Section 3.5), and the flood vulnerability functions (see Section 4.1.2). The average annual losses for economic loss (AAEL) at the national scale is 8.5 million USD which represents 0.06 ‰ of the residential building stock value. The national loss curve (economic loss) is plotted in Figure 5.12.

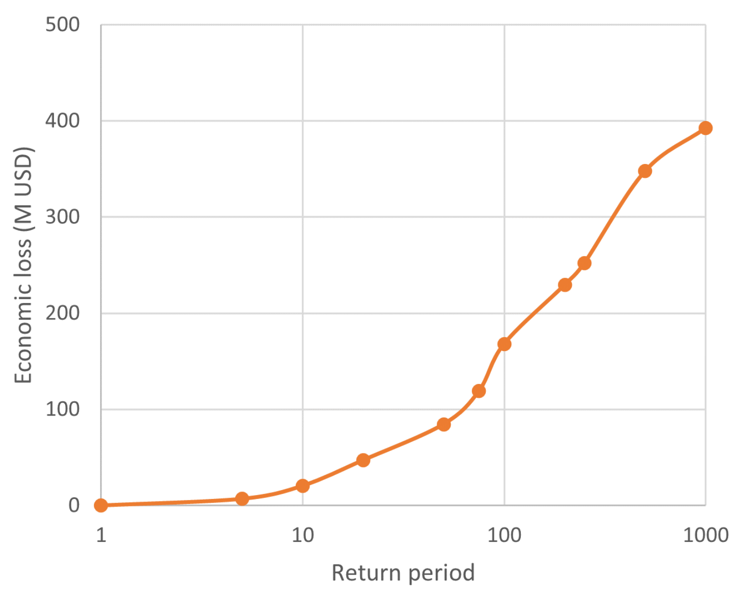


Figure 5.12: National loss curve in terms of economic loss (M USD)

The maps of average annual losses (economic: AAEL), average annual economic loss ratio (AALR) and 200-years return period loss at the community level are presented below, and are provided in the web-based mapping platform.

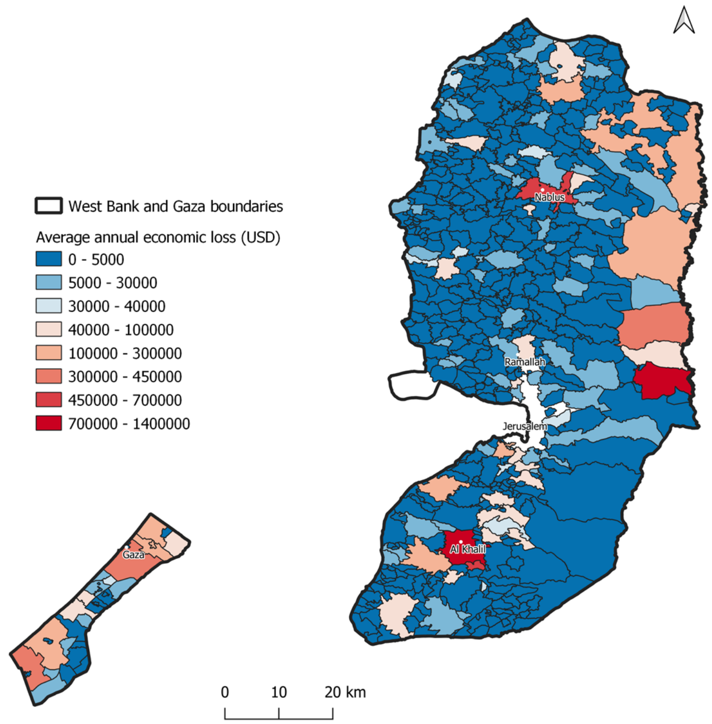


Figure 5.13: Map of average annual economic loss (AAEL) due to flood inundation at the community level

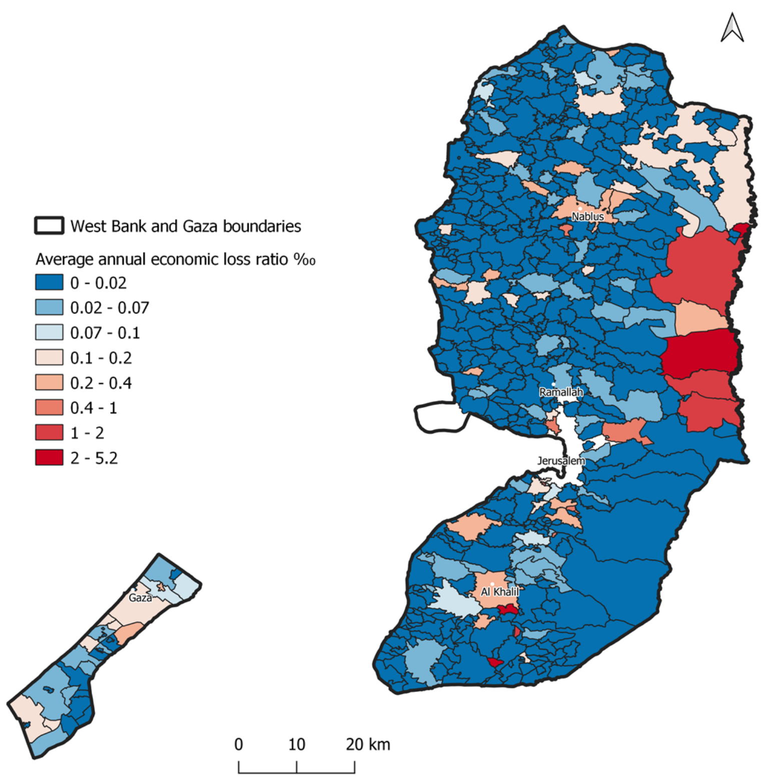


Figure 5.14: Map of average annual economic loss ratio (AAELR) due to flood inundation at the community level

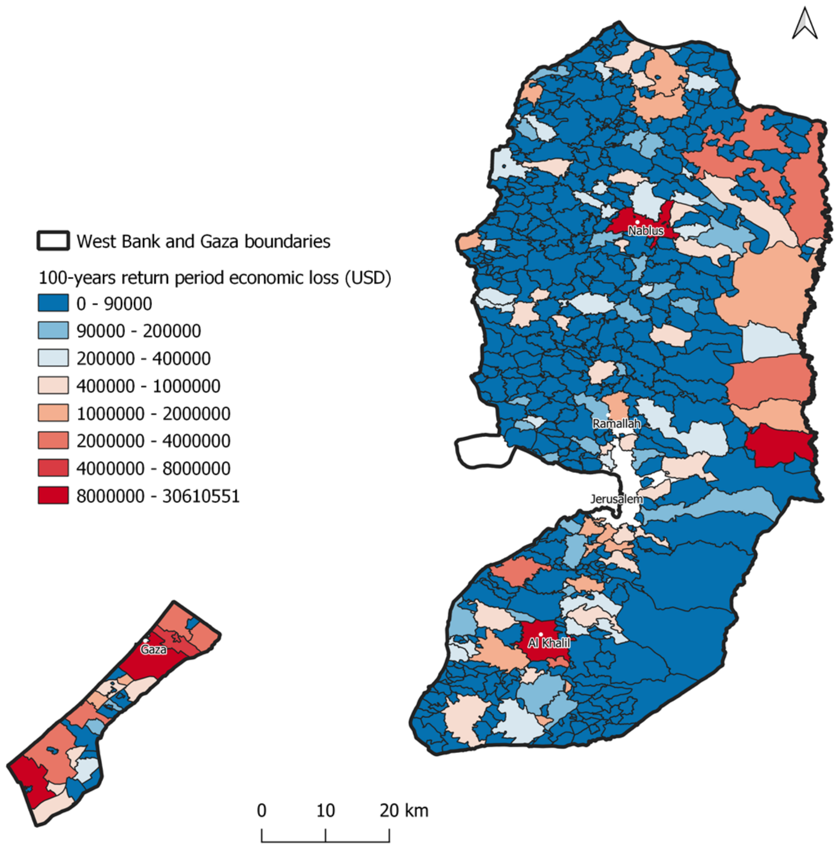


Figure 5.15: Map of 200-years return period loss due to flood inundation at the community level

5.2.2 Integrated Regional Flood Risk Assessment

The total or integrated flood risk of communities can be expressed by combining the physical risk metrics described in the previous section with the social vulnerability index (SVI) presented in Section 4.2 through the so-called Moncho's equation (e.g. Carreno et al., 2012) (Equation 5.1). For the physical flood risk index (R_F), this has been calculated herein for each community as the sum of an economic loss index, obtained from the average annual losses, normalised through min-max scaling:

$$R_F = \frac{AAEL - min(AAEL)}{max(AAEL) - min(AAEL)} \quad (5.3)$$

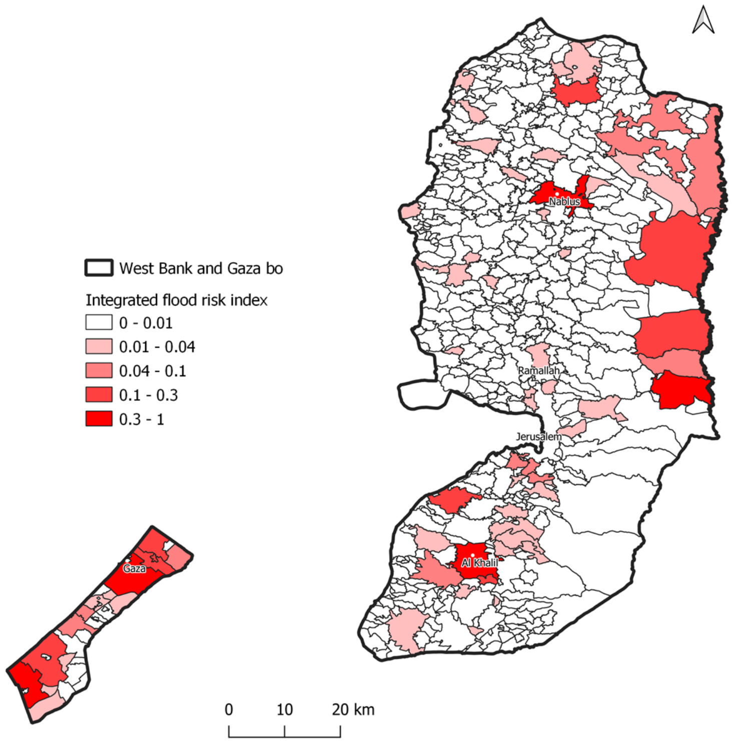


Figure 5.16: Map of integrated (total) flood risk index at the community level

5.2.3 Flood Risk-Based Ranking of Priority Buildings

The hospital, civil protection and school buildings have been ranked in terms of priority for flood risk retrofitting activities through the average annual economic loss which has been obtained by integrating the global flood hazard maps (Sampson et al., 2015) for different return periods with the appropriate exposure models (see Section 3.2), and the flood vulnerability functions (see Section 4.1.2). Based on the results of the analysis, none of the inspected hospitals or civil defence buildings have flood risk mainly because their locations are not exposed to flood hazard. 64 schools (about 2% of the considered buildings) had flood risk with variable levels of risk ranging from minor to major monetary loss due to building damages. The link below presents school buildings exposed to flood risk across all communities in the West Bank and Gaza in terms of prioritisation for further inspection and analysis for flood retrofitting.

[https://docs.google.com/spreadsheets/d/199zIcoB82JnLcuuJZg-UGG54BRWL9UYwF7tDuQ78OZE/edit#gid=552648109]

It is important to consider that the ranking presented in the link above is highly dependent on the quality of the input data i.e. location accuracy of the school buildings and quality of flood hazard and depth-damage functions. It cannot thus be used to immediately identify buildings which should be retrofitted, but instead to prioritise the buildings that should be further investigated and checked.

5.2.4 Agricultural Land Flood Risk Maps

Worldwide, agriculture is one of the most vulnerable sectors to the consequences of climate change (Burke and Emerick, 2016; Thornton et al., 2018). Extreme weather conditions (e.g., floods and droughts) accompanied by changing rainfall and temperature patterns negatively impact crop productivity in several countries in the world (IPCC, 2014; European Environment Agency, 2019). Agricultural lands are experiencing severe environmental impacts due to frequent flooding that might potentially undermine food security in numerous countries (Vahedifard et al., 2016; Oskorouchi and Sousa‐ Poza, 2021). Globally, flooding is considered the second key factor in crop production losses between 2008 and 2018 (FAO, 2021).

This section aims to assess the flood potential risk at the agricultural lands in the West Bank and Gaza. To do so, the available global flood depth maps (Sampson et al., 2015) together with the available land use map (MoA, 2016) are used. The used approach (GIS-based) can be summarized as follows:

1. Flood depth maps were clipped for the West Bank and Gaza for 10 different return periods (5, 10, 20, 50, 75, 100, 200, 250, 500, and 1000 years).
2. From the land-use map, the agricultural lands were identified (see Section 3.6 and Figure 3.11) and intersected with potential flooded areas of different return periods to estimate potential flooded agricultural areas (Figure 1).
3. The estimated potential agricultural flooded (AF) areas were aggregated for each governorate in the West Bank and Gaza and for the 10 different return periods (Figure 5.17 as a sample).
4. Average annual flooded areas (AAFA- Figure 5.18) of potential AF areas were estimated for each governorate by averaging the estimated AF areas based on the probability of exceedance (P =1/Tr) of the 10 different flood return periods (see Figure 5.19 as samples).
5. The relative average annual flooded areas (RAAFA - Figure 5.20) were estimated by dividing the AAFA (Figure 5.18) by the agricultural areas within each governorate.
6. Finally, all calculations are summarised in Table 5.5.

The figures and tables presented below indicate that agricultural areas in the West Bank are affected by floods disproportionately; mostly concentrated in the northern and central regions of the West Bank. Similarly, the northern and central regions of the Gaza strip are relatively more exposed than southern Gaza. Agricultural lands with the highest exposure to frequent flood events (return period 5 years) are located in Jenin, Jericho, Nablus and Ramallah.The events with moderate return periods (20 to 100 years) increase the exposure of the agricultural areas with the highest flooded areas in Jenin governorate. The rare events with return periods larger than 250 years seem to have the highest influence on agriculture in terms of the total flooded area in Jericho governorate.

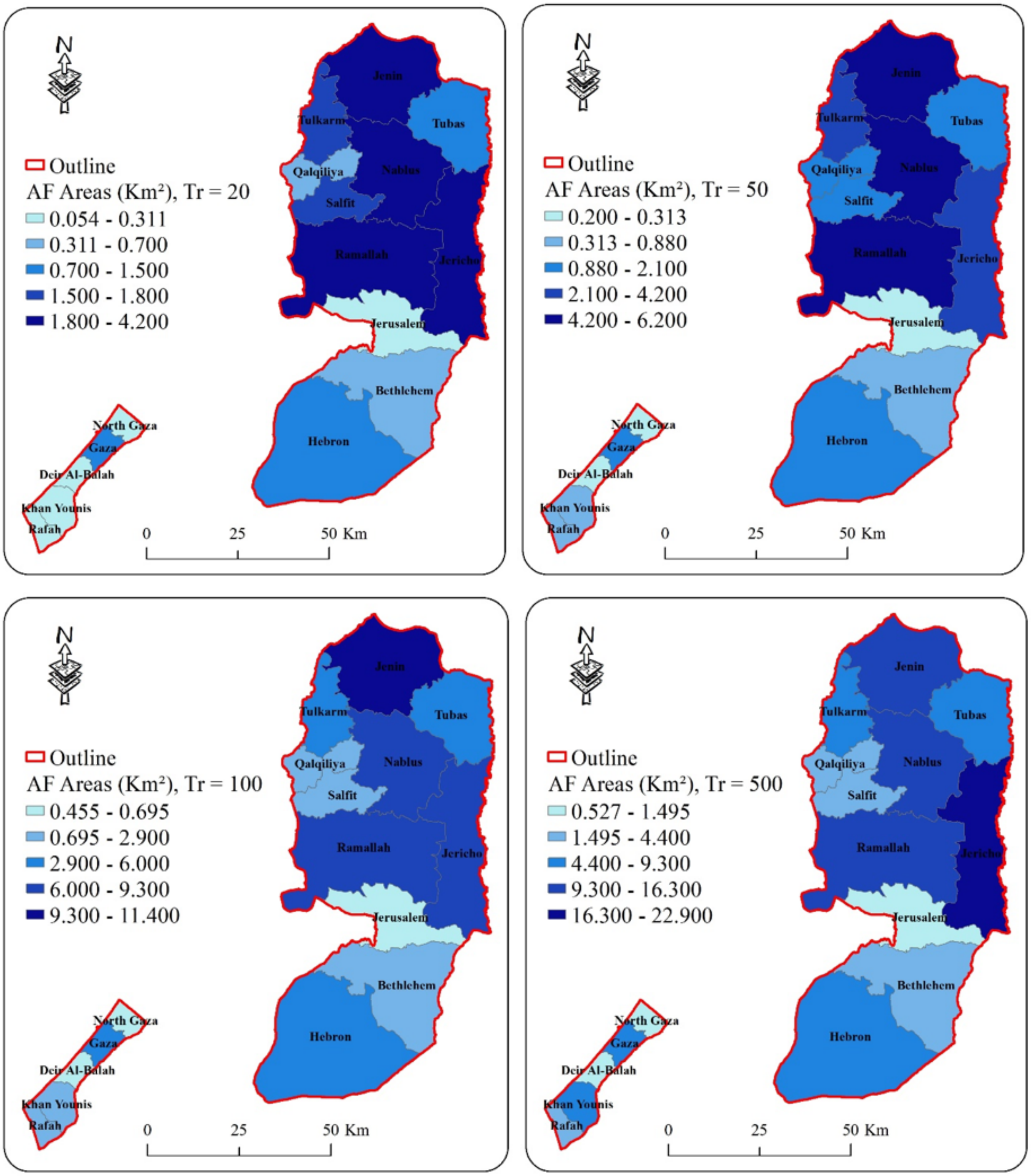


Figure 5.17: Agricultural flooded (AF) areas at the different governorates in the West Bank and Gaza for selected return periods.

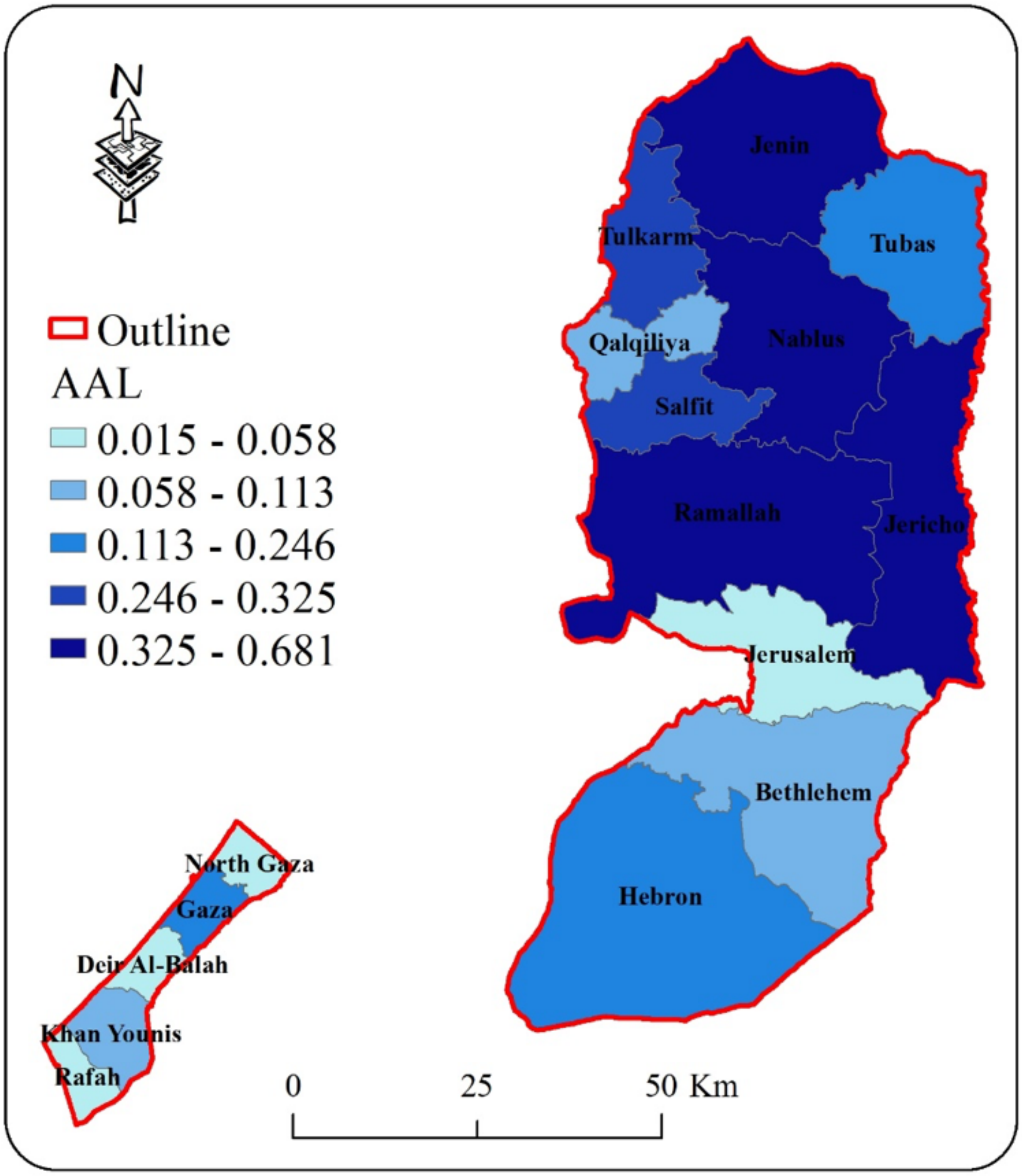


Figure 5.18: Average annual flooded areas (AAFA) of agricultural areas in the West Bank and Gaza governorates

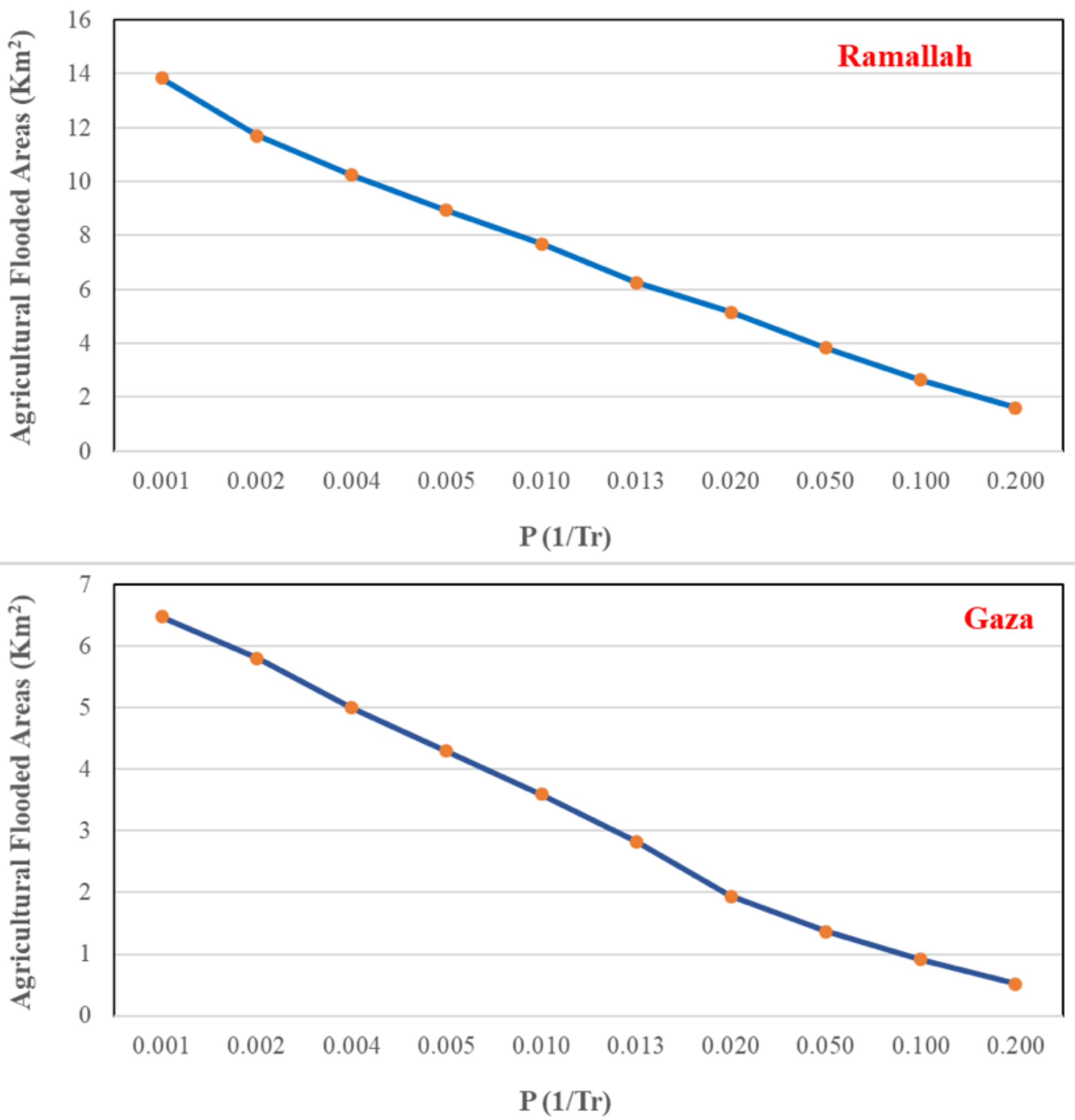


Figure 5.19: Agricultural flooded (AF) areas versus probability of exceedance (P =1/Tr) for Ramallah and Gaza governorates

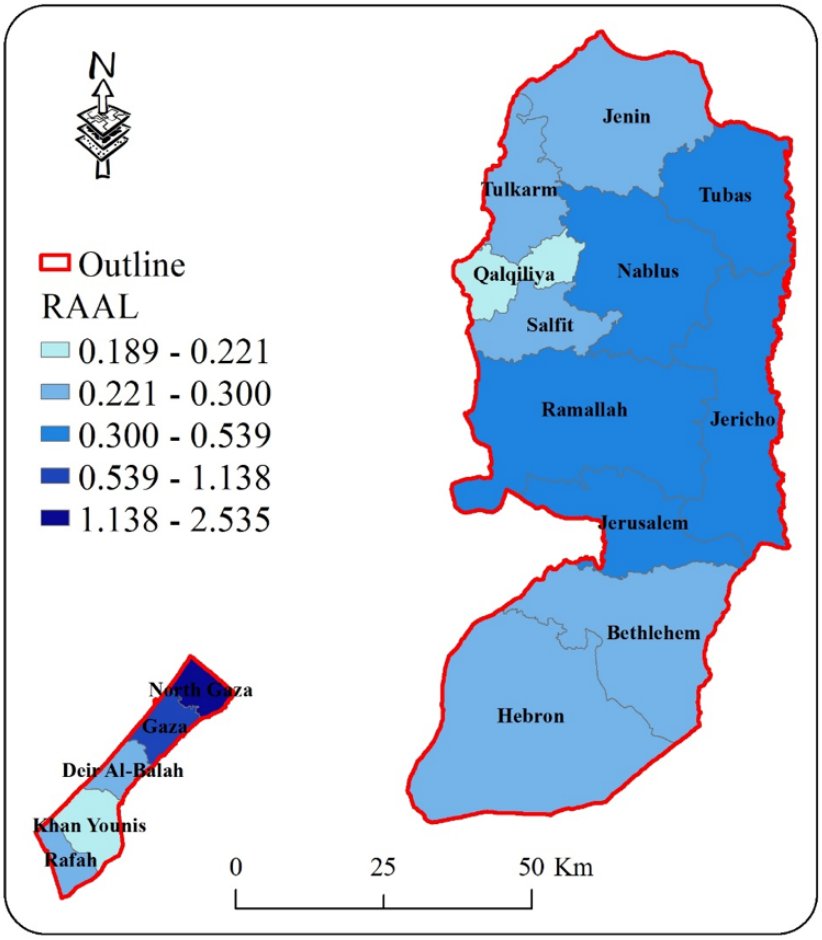


Figure 5.20: Relative average annual flooded areas(RAAFA) (%) of agricultural areas in the West Bank and Gaza governorates

Table 5.5: Agricultural flooded (AF) areas calculation summary at the different governorates in the West Bank and Gaza for the 10 flood return periods

	Governorate	Area (Km^2)	Agricultural Areas (Km^2)	Agricultural Flooded Areas (Km^2)										AAL	RAAL
				Tr = 5	Tr = 10	Tr = 20	Tr = 50	Tr = 75	Tr = 100	Tr = 200	Tr = 250	Tr = 500	Tr = 1000		
West Bank	Bethlehem	633.7	32.8	0.2	0.3	0.5	0.7	1.0	1.5	1.7	2.1	2.4	2.8	0.086	0.262
	Hebron	1007.3	95.4	0.2	0.6	1.5	2.1	3.3	4.6	5.3	6.4	7.2	8.6	0.231	0.243
	Jenin	589.2	251.1	0.9	1.8	4.2	6.2	9.0	11.4	13.0	15.1	16.3	19.9	0.649	0.258
	Jericho	613.6	115.9	1.5	2.2	3.2	4.2	6.3	9.3	11.5	15.5	22.9	25.2	0.625	0.539
	Jerusalem	344.2	6.6	0.0	0.1	0.2	0.2	0.4	0.6	0.7	0.8	0.9	0.9	0.025	0.381
	Nablus	563.8	194.7	1.6	2.7	3.9	5.4	6.9	8.5	9.8	11.4	13.2	15.4	0.681	0.350
	Qalqiliya	163.4	60.0	0.0	0.3	0.7	1.4	1.9	2.4	2.7	3.0	3.6	4.2	0.113	0.189
	Ramallah	859.4	170.7	1.6	2.6	3.8	5.2	6.3	7.7	8.9	10.3	11.7	13.8	0.656	0.385
	Salfit	204.4	91.4	0.5	1.2	1.6	2.1	2.6	2.9	3.2	3.4	4.4	5.4	0.274	0.300
	Tubas	412.2	48.3	0.5	0.6	1.3	1.7	2.6	3.9	4.3	5.8	6.8	8.1	0.216	0.448
	Tulkarm	248.0	109.4	0.3	0.8	1.8	4.0	5.2	6.0	7.0	7.8	9.3	10.6	0.325	0.297
Gaza	Deir Al-Balah	58.39	11.56	0.006	0.061	0.139	0.230	0.455	0.695	0.914	1.167	1.495	1.933	0.028	0.238
	Gaza	74.14	21.64	0.516	0.917	1.370	1.939	2.824	3.593	4.295	4.996	5.802	6.474	0.246	1.138
	Khan Younis	107.63	36.63	0.000	0.145	0.311	0.818	1.468	1.897	2.838	4.152	6.179	6.943	0.081	0.221
	North Gaza	61.15	0.60	0.000	0.000	0.054	0.313	0.407	0.455	0.487	0.502	0.527	0.532	0.015	2.535
	Rafah	63.67	19.59	0.000	0.075	0.286	0.880	1.103	1.438	1.778	2.027	2.630	2.813	0.058	0.298

5.3 Climate Change Risk Assessment

5.3.2 Regional Relative Climate Change Risk Assessment for Priority Sectors

Climate change effects in Palestine are already being noticed. The International Union for Conservation of Nation (IUCN) has reported that residents of the West Bank consider floods and droughts as the main climate-related risks affecting their region. Agricultural production in Palestine has already been affected by recent droughts which are projected to become more pronounced over time. Continuing population growth and projections of regional climate change will intensify water stress for Palestinians. The challenge will be to increase food security (by domestic production and/or imports) in a context of increased water stress and with water allocation patterns determined by Israel.

An attempt has been undertaken in this project to better model the spatial variability of climate change susceptibility within the West Bank and Gaza, which has led to the map shown in Figure 5.21.From zone 1, being the least susceptible to climate change hazard to zone 4, being the most susceptible to climate change hazard.

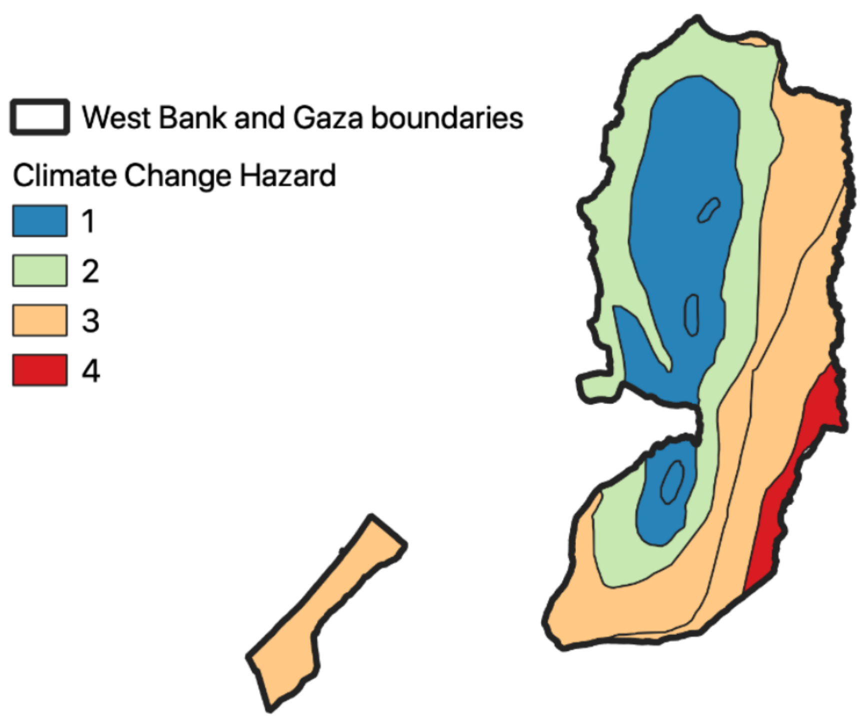


Figure 5.21: Climate change susceptibility map for West Bank and Gaza

For each category shown in Figure 5.21, a score of 1 (for humid) to 4 (for extremely arid) can be assigned and these numbers can then be multiplied by the vulnerability scores for each priority sector (see Table 4.7), and summed to obtain a final risk score. This final score indicates the relative average risk of these sectors across the West Bank and Gaza, and can be mapped to a qualitative risk ranking, from low to medium to high, as shown in Figure 5.22.

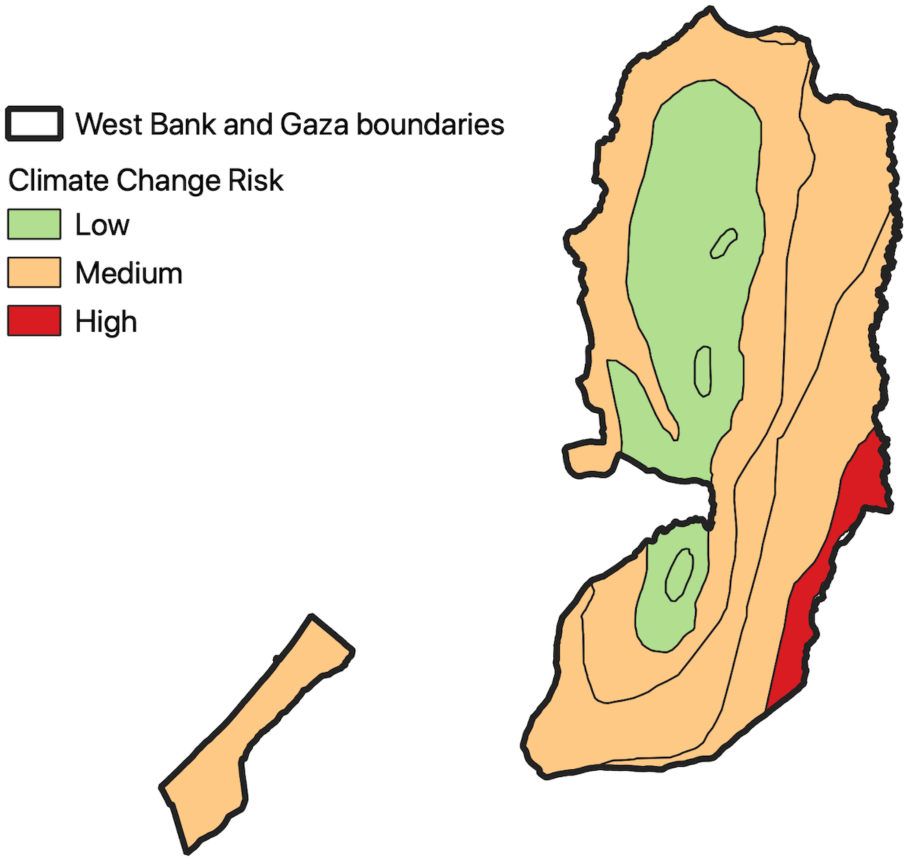


Figure 5.22: Map of relative climate change risk for West Bank and Gaza, averaged across the sectors of agriculture, energy, urban and infrastructure and water

5.3.2 Future Studies for Climate Change Risk in West Bank and Gaza

The issues/assets within 12 different sectors that are vulnerable to climate change have been presented in Section 4.3, based on the analyses and stakeholder workshops undertaken for the NAP. A number of adaptation actions have been proposed in the NAP to reduce the vulnerability of these sectors, comprising management and operational strategies, infrastructural changes, policy adjustments or capacity-building. Some actions involve adjusting (climate-proofing) current activities, while others are new, or require major transformations in operations. Some are ecosystem-based, i.e., helping people adapt to the impacts of climate change through the conservation, sustainable management, and restoration of ecosystems. The NAP also provides a multi-criteria analysis and ranking of the various adaptation options at the national scale.

In order to identify the locations where climate change risk might be highest for each specific sector within the West Bank and Gaza, and to provide more insight into where such adaptation actions should be prioritised, a more detailed analysis than the one that has been presented so far herein (i.e. Section 4.3.2 and 5.3.1) is required. This analysis would require data and studies on the exposure of vulnerable assets (i.e where they are located, their value, their level of vulnerability) for each of the sectors. To demonstrate how such an assessment might be undertaken in the future, a preliminary analysis of the spatial variation of climate change risk in West Bank and Gaza (based on currently available data) has been undertaken herein for urban infrastructure.

To demonstrate where the climate change risk for urban infrastructure could be highest in the West Bank and Gaza, the climate change susceptibility map has been combined with an exposure map for built-up areas (from Geomolg) and the infrastructure social vulnerability index (see Section 4.4.6). The urban and infrastructure assets that have been identified as vulnerable to climate change hazard in the West Bank and Gaza in the NAP include: urbanisation, building conditions, urban drainage, urban economy and urban air pollution. The infrastructure social vulnerability index takes into account similar aspects through indicators that include housing density and percent without drainage, and other aspects that are correlated with building conditions and urban economy (e.g. percent without piped water, percent without electricity network, percent living in apartments). A bi-variate map showing the climate change susceptibility and social vulnerability index for each built-up area grid cell is shown in Figure 5.23. The dark green, purple and blue areas on map have both moderate to high climate change hazard and moderate to high infrastructure social vulnerability (e.g. the urban areas in Tubas, Jerusalem, and Jericho and Al Aghwar).

Such a map can help identify the areas of West Bank and Gaza where adaptation actions to reduce the climate change vulnerability of urban infrastructure could be prioritised. Similar maps could be produced for other sectors, following the collection of the necessary exposure data and further investigation into the spatial variability of the vulnerability of these sectors.

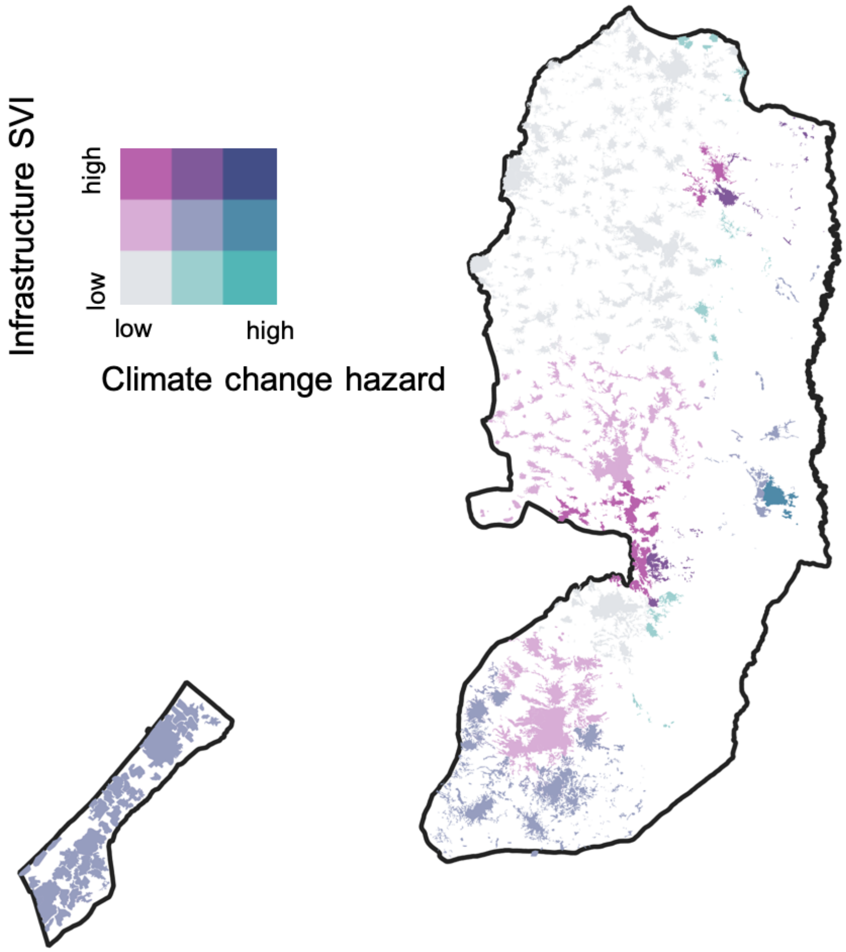


Figure 5.23: Proposed climate change risk map for urban infrastructure in West Bank and Gaza

In addition to such analyses, a dynamic assessment of the climate change risk could be undertaken by assessing how cities are expected to expand in the future (e.g. Calderon and Silva., 2021), and this could be combined with flood hazard models accounting for future climate change scenarios (see Deliverable 3.1 for the scenarios considered in the NAP). Analyses in this direction have recently been undertaken by the World Bank, where the changes in built-up area from 1985 to 2015 in 7 cities in West Bank and Gaza were considered (see Figure 5.24), and it was found that across the cities, built-up areas have grown by 64% in this period, while built-up areas exposed to pluvial flood hazard have grown by 55% and those exposed to fluvial flood hazard have grown by 15% (World Bank, 2022). They state that urban expansion will push more built-up areas into flood zones in the remainder of the 21st century, especially under one of the three climate projection scenarios (from the Climate Change Knowledge Portal, CCKP) that they considered.

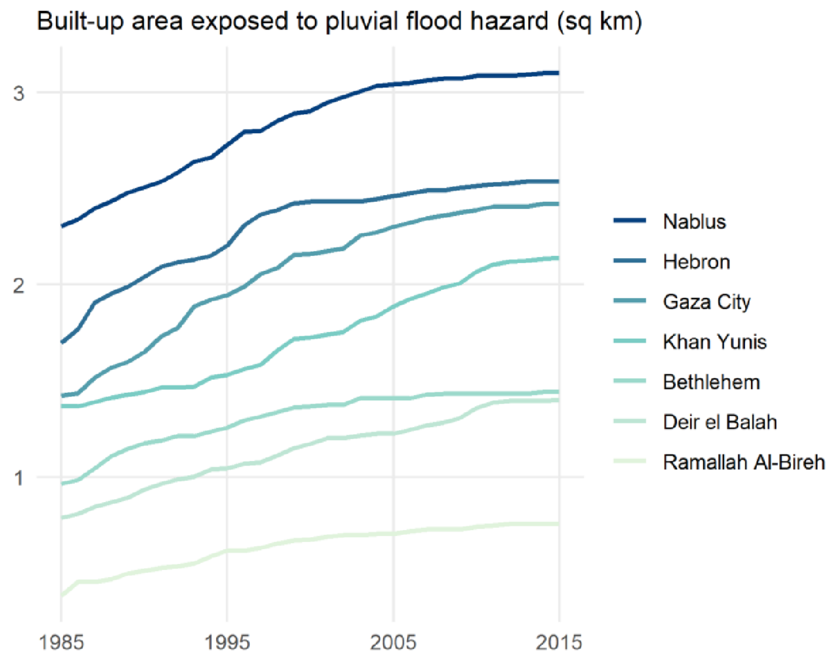


Figure 5.24: Change in built-up area exposed to pluvial flood hazards in 7 cities in West Bank and Gaza (World Bank, 2022)

6 Web-based mapping platform

This Chapter describes the web-based platform that has been developed in order to share the hazard, exposure, vulnerability and risk data from the project in the form of maps.

6.1 Open source technologies

The IT team of the GEM Foundation has developed, in collaboration with OPENGIS.ch (www.opengis.ch), an interactive web-based mapping and data visualisation platform that is based on the following open source technologies:

- QGIS (A Free and Open Source Geographic Information System): https://www.qgis.org/en/site/
- Leaflet (an open-source JavaScript library for mobile-friendly interactive maps): https://leafletjs.com/
- MapProxy (an open source proxy for geospatial data): https://mapproxy.org/
- Django (high-level Python web framework): https://www.djangoproject.com/
- Docker (a set of platform as a service products that use OS-level virtualization to deliver software in packages called containers): https://www.docker.com/
- Nginx (a web server that can also be used as a reverse proxy, load balancer, mail proxy and HTTP cache): https://www.nginx.com/
- Fedora (an innovative, free, and open source platform for hardware, clouds, and containers): https://getfedora.org/

The resulting platform, or 'GeoViewer', is a website that collects together a number of different maps, each of which can be interactively accessed via a dedicated web-based viewer.

Some improvements and new functionalities to the standard platform have been added by the GEM IT team for greater flexibility in the privacy settings of the maps. Prior to these improvements, the platform offered the possibility to keep a map "unpublished", i.e. invisible to unauthenticated or standard users, until the website administrator decided that such map was ready to be made available to the general public. Meanwhile, nobody else was allowed to either visualize or edit the map. However, for the purposes of this project, it was deemed necessary to make specific maps visible only to a restricted set of users, without having to grant those users full administrator permissions. Hence, there are now two different types of users of the platform: “editors” and “viewers”.

- Editors have access to a restricted set of administrative functionalities, sufficient only to modify the properties of those maps for which the group has been granted permission. Furthermore, for the same maps, they also have the possibility to visualize them even before they have been published. This is useful during the map review process, allowing reviewers not only to approve the proposed map, but also to contribute directly to its refinement.
- Viewers are not allowed to change the map in any way, but are able to see its thumbnail in the website homepage and to visualize the map itself.

At this stage, a “viewer” user profile has been set up to allow the maps of the platform to be internally reviewed before they are made available to the general public.

An empty version of this platform has been set up by the GEM IT team for the project, and the UPDRRC has added a landing page to describe the project, as well as a number of maps from D3.1 and this deliverable, as will be described in the following sections through a number of screenshots of the current version of the platform. It is noted, however, that the features of the landing page (including logos, disclaimers and appearance) still need to be agreed upon together with the NDRMC. The UPDRRC will host the platform during the project. After the project ends, the platform will be migrated to the NDRMC servers and the UPDRRC will provide free maintenance for 2 years. The UPDRRC will train the NDRMC on how to use the platform, update the existing maps and metadata, and add new viewers.

6.2 Landing Page

A draft landing page has been set up for the project, with a brief description of the objectives and hyperlinks to the different categories of maps: Hazard, Exposure, Vulnerability and Risk. A screenshot of the landing page is shown in Figure 6.1.

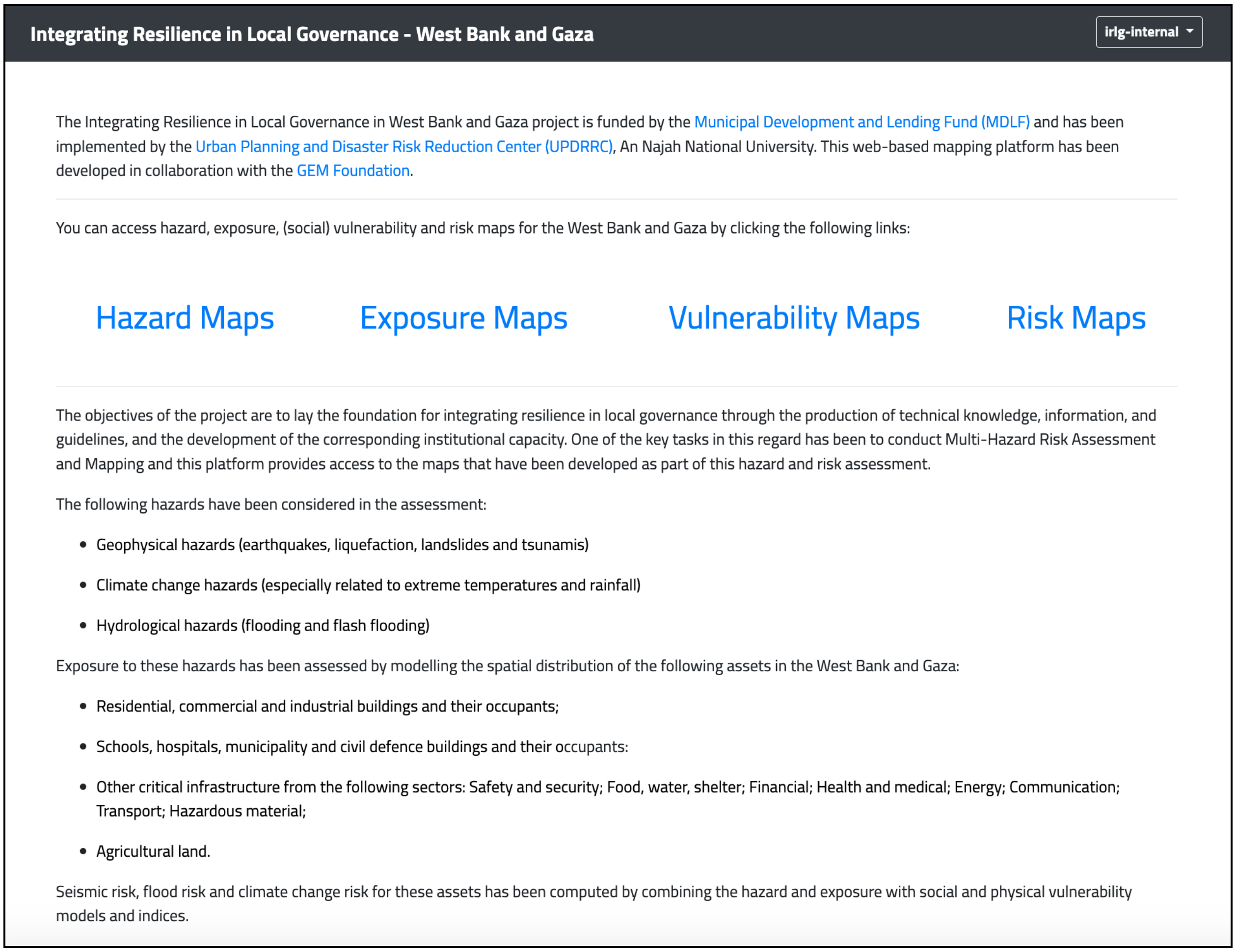


Figure 6.1: Screenshot of landing page

6.3 Maps

Once a user clicks a specific category of maps on the landing page (e.g. Hazard), they are presented with all the available maps of that category, together with a brief description of each. Each available map can be interactively accessed via a dedicated web-based viewer. Figure 6.2 shows an example of the exposure mweb-based viewer for the residential exposure map.

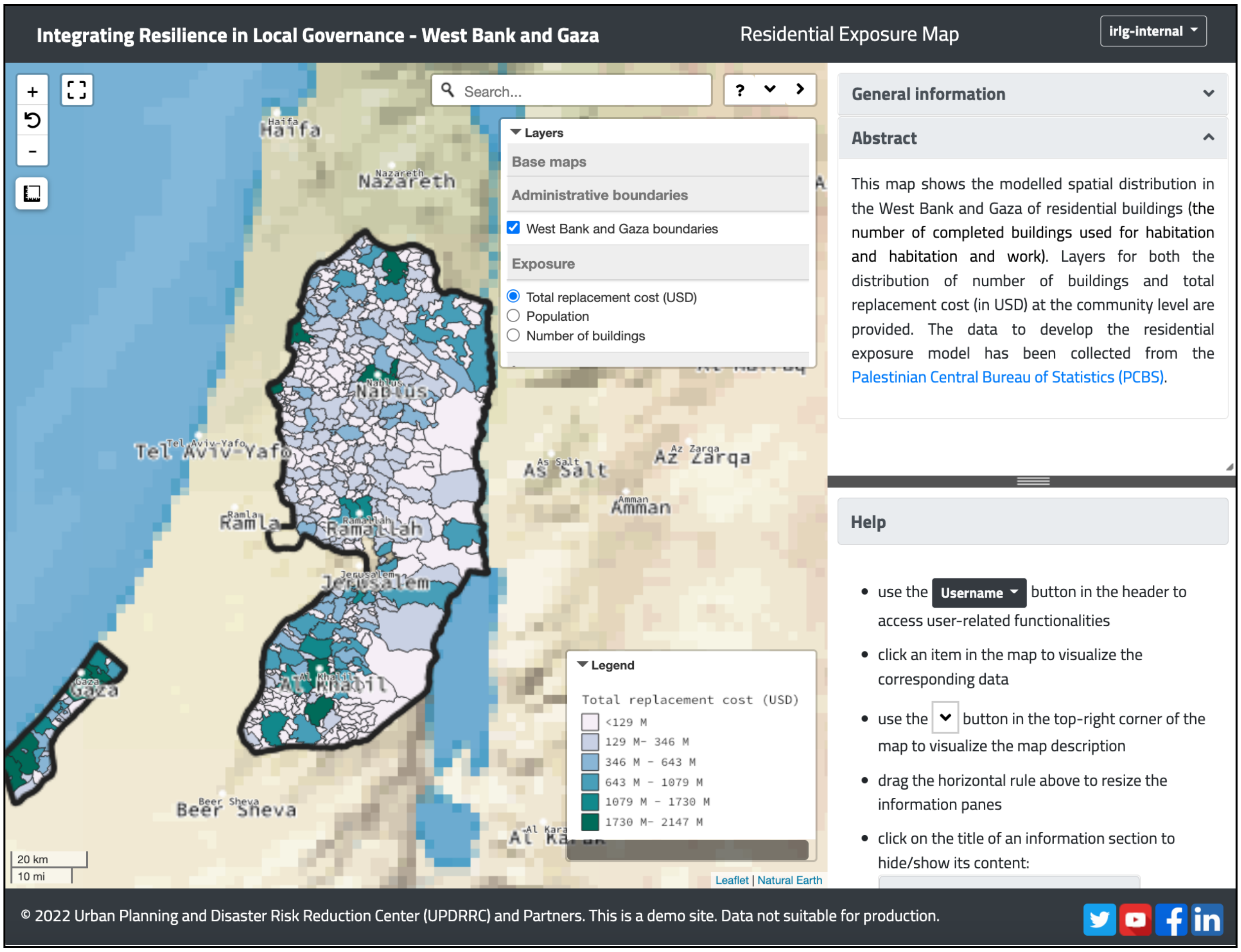


Figure 6.2: Screenshot of one of the GeoViewer Maps

From this web-based viewer, the user can:

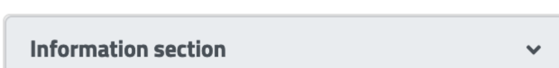
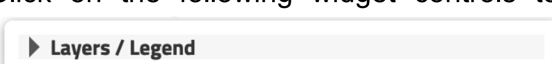
- use the  button in the header to access user-related functionalities (such as 'edit map', if the user has such permissions - see Section 6.1)
- click an item on the map to visualize the corresponding data;
- use the  button in the top-right corner of the map to visualize the map description and access the web services (see Section 6.3);
- click on the title of an information section to hide/show its content: 
- Click on the following widget controls to show/hide the map Layers and Legend: 
- Search for place names using the Search box

Table 6.1 lists the maps that have been added to the platform for each category.

Table 6.1: List of maps currently available from the GeoViewer

Hazard	Exposure	Vulnerability	Risk
- Flood hazard - Seismic ground shaking hazard - Landslide susceptibility - Liquefaction susceptibility - Climate change susceptibility	- Residential exposure - Industrial exposure - Commercial exposure - Safety and Security - Health and Medical - Energy -Transport - Food, Water and Shelter - Hazardous material	- Social Vulnerability	- Seismic risk - Flood risk - Agricultural flood risk - Climate change risk

6.3 Geospatial Web Services

WMS geospatial web services for all maps have been made available through the interactive map viewers. The URL for each web service can be found from the interactive viewer by clicking on the  button in the top right of the web browser, and then clicking the 'web services' drop down menu (see image below). The URL can then be copied and used in other applications, for example QGIS, as shown in this tutorial: https://youtu.be/w1GEgvbTygM.

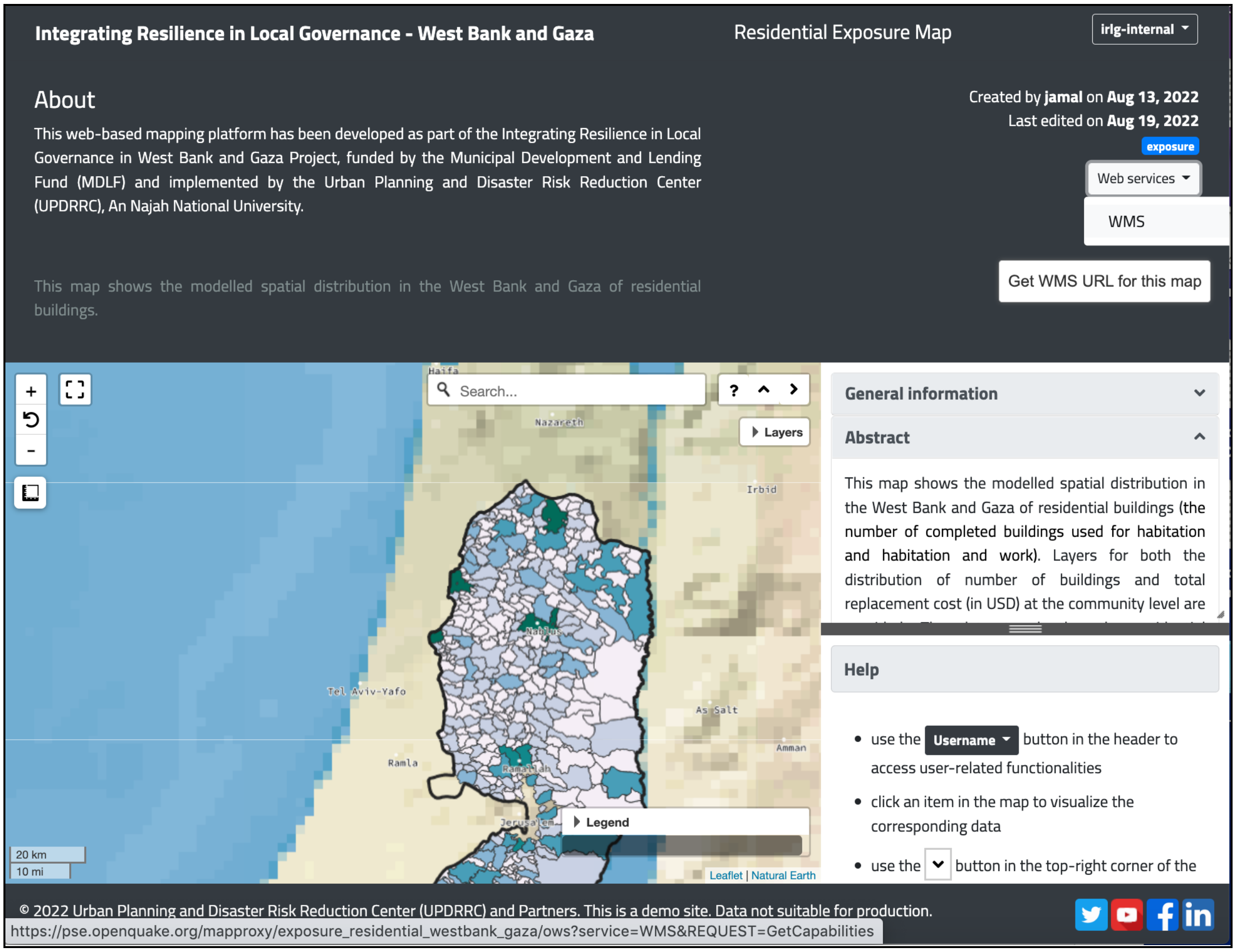


Figure 6.3: Screenshot showing access to WMS web services URL for a given GeoViewer Map

7. Conclusions

7.1 Summary

This deliverable has described the activities related to exposure, vulnerability and risk modelling for multiple hazards that are of particular concern to the West Bank and Gaza (see Deliverable D3.1), namely earthquake hazards, flood hazards and climate change hazards. Hazard models and maps were explored and developed in Deliverable D3.1, and have been summarised herein. The hazard models have been transformed into a number of maps which have been made available through the web-based mapping platform (set up specifically for the project): https://map-irlg.najah.edu/tags/hazard/.

A large number of datasets have been collected and compiled to model the exposure of residential, industrial and commercial buildings, critical infrastructure and priority buildings comprising hospital, civil protection, municipality and school buildings. An extensive campaign to inspect 326 individual buildings, filling in a dedicated form that was set up for the project (Appendix 2), was undertaken over a period of 12 weeks, successfully overcoming a number of external factors which interrupted and delayed the process. The exposure data has also been transformed into a number of maps, https://map-irlg.najah.edu/tags/exposure/, as well as input models for the estimation of seismic and flood risk.

For the quantitative assessment of seismic risk and flood risk for the physical assets in the exposure model, a number of appropriate vulnerability models have been identified and mapped to the building classes present in the West Bank and Gaza. The sectors that are particularly vulnerable to climate change have been extensively evaluated through the National Adaptation Plan, and this work has been reported herein. An attempt to map the relative vulnerability of four sectors that are particularly vulnerable has been included, based on expert judgement. In order to capture spatial patterns of the differential capacities of the population in West Bank and Gaza to reduce disaster risk, to respond to emergencies and to recover after a damaging event, a study of the social vulnerability has been undertaken by collecting and combining indicators for a number of sub-indicators related to education, population, economy, health, politics and infrastructure, leading to a Social Vulnerability Index for each governorate. The maps related to the social vulnerability indices are available on the web-based mapping platform: https://map-irlg.najah.edu/tags/vulnerability/.

The hazard, exposure, physical vulnerability and social vulnerability models have been combined in quantitative regional (integrated) risk assessments for earthquakes and floods, accounting for the residential, industrial and commercial buildings. More detailed building-by-building analyses to rank the priority buildings (hospitals, civil protection and schools buildings) in terms of an integrated risk index that accounts for their specific characteristics/deficiencies has also been undertaken, thus identifying the buildings for which further, more detailed inspections and analyses are required. A quantitative risk assessment of the flood hazard to agricultural land in each governorate has also been presented, by combining the exposure of agricultural land with the flood hazard model. For what concerns climate change, an expert-judgement based analysis that identifies the zones where multiple sectors are most at risk to climate change hazard has been presented. Finally, an initial proposal towards a higher resolution climate change risk assessment for the West Bank and Gaza has been investigated for the urban and infrastructural sector. A number of maps with the results of these risk analyses have been made available: https://map-irlg.najah.edu/tags/risk/.

The studies presented in both D3.1 and this deliverable require maintenance and there are a number of areas where improvements can be made in the future, in particular to replace the global datasets/models with local data and knowledge. These aspects are covered in the next section.

7.2 Capacities for maintaining and updating the multi-hazard risk assessments

This section provides an assessment of the capacities (of both central and local institutions, including academia and technical institutions) to maintain and advance the multi-hazard and risk studies that have been presented in Deliverables D3.1 and D3.2. In order to do this, for each component of risk (hazard, exposure, vulnerability assessment), a summary of the primary needs for maintaining and/or updating the analyses is provided in Table 7.1 below, followed by the institutions that would be required for any associated data curation, those that would support the technical developments, and any supporting institutions at the local or central level. The summary is preliminary and needs further discussion with relevant stakeholders to better identify roles and responsibilities and gaps in existing capacities.

Table 7.1: Summary of capacities for maintaining/updating the multi-hazard risk assessments

Component	Summary of needs for sustaining/ updating analyses	Data collection and curation	Technical expertise	Supporting institutions
Climatological hazards	- Increase weather stations to cover all of the distinct climatological zones in West Bank and Gaza - Develop local high resolution local climate models and future scenarios.	Palestinian Weather Department (PWD)	Water and Environmental Studies Institute (WESI) at An Najah National University and -Other universities or research centres	Water Quality Authority (WQA)

Component	Summary of needs for sustaining/ updating analyses	Data collection and curation	Technical expertise	Supporting institutions
Geophysical hazards	- Compilation of local datasets (with the means for frequent updating) for both West Bank and Gaza: water table depth, mean annual precipitation, distance to rivers, land cover, monthly rainfall data, database of strong motion records, Vs30 data, high resolution Digital Terrain Mode, seismic faults database - Development of a database with georeferenced data on earthquake ground shaking and ground failure (liquefaction and landslides), including associated damage and losses	Earth sciences and seismic engineering unit – An-Najah National university	Earth sciences and Seismic engineering unit – An-Najah National university	-Environmental Quality Authority (EQA)
Flood hazard	- Installation of more rainfall and streamflow gauges - Frequent updating of soil maps and land use/cover maps for both West Bank and Gaza - Development of a database with georeferenced data on flooding (pluvial and fluvial), including associated damage and losses	Palestinian Weather Department (PWD)	Water and Environmental Studies Institute (WESI) at An Najah National University and - Other universities or research centres	-Palestinian Weather Department (PWD) -Minister of Local Government
Exposure modelling	- Continued building inspections (of priority buildings) - Database of historical/heritage buildings and monuments - Expand critical infrastructure data e.g. water and electricity supply networks, telecommunications - Expand agricultural exposure data e.g. subdivide agriculture by crop type and land productivity. Include a database of green houses - Review and checking of collected data and national databases - Compilation of local datasets	Palestinian Central Bereau of Statistics (PCBS) and relevant ministries Local Government Units (LGUs)	Urban Planning and Disaster Risk Reduction Center – An-Najah National University	-Ministry of Local Government -Ministry of agriculture

Component	Summary of needs for sustaining/ updating analyses	Data collection and curation	Technical expertise	Supporting institutions
	for the sectors highly vulnerable to climate change			
Social Vulnerability	- Stakeholder workshops to review variables and weights applied in composite indicators	Palestinian Central Bereau of Statistics (PCBS)	Urban Planning and Disaster Risk Reduction Center – An-Najah National University	-Minister of Social Development -Local Government Units (LGUs)
Physical vulnerability (earthquake ground shaking and flood hazards)	- Development of structural models of typical building classes and priority buildings by local engineers, and subsequent updating of vulnerability models - Calibration of empirical flood vulnerability functions using local data - Account for effects of war in Gaza on the quality of buildings - Develop flood vulnerability functions for different types of agriculture	Earth sciences and seismic engineering unit at An-najah National University	Earth sciences and seismic engineering unit – An-najah National University	- Minister of Public Works and Housing -Minister of National Economy -Water Quality Authority

الملخص

كخطوة أولى باتجاه زيادة وتعزيز قدرة الحكومات المحلية على الصمود و مواجهة الكوارث ، تم تقييم أهم المخاطر التي يتعرض لها السكان و المباني والبنية التحتية الحيوية في الضفة الغربية وقطاع غزة و نشر النتائج الرئيسية لتقييم المخاطر المتعددة في عدة تقارير تحليلية و مجموعة من الخرائط التي تم توفيرها من خلال منصة وطنية لخرائط مخاطر الكوارث.

تقييم الخطر

تم تقييم أخطار الزلازل، تميؤ التربة،الانزلاقات الأرضية، أمواج تسونامي، ومخاطر تغير المناخ، مثل درجات الحرارة و الأمطار، والمخاطر الهيدرولوجية مثل الفيضانات في الضفة الغربية وقطاع غزة. لكل خطر تم إنتاج خرائط تظهر المناطق التي من المتوقع أن يكون فيها الخطر أعلى أو أقل مع زمن تكرارها.

https://map-irlg.najah.edu/tags/hazard/

تقييم التعرض

تم عمل خرائط لمواقع البنية التحتية الحيوية في الضفة الغربية وقطاع غزة لاكثر من 22 نوع من منشآت البنية التحتية مرتبطة بقطاع الطوارئ والأمن و قطاع الغذاء والماء و المأوى و قطاع الصحة و قطاع الطاقة و قطاع المواصلات .تم عمل تحليل أكثر تفصيلاً لمباني المستشفيات والبلديات والدفاع المدني و المدارس من خلال تقييم ميداني سريع. بالاضافة للبنية التحتية، تم عمل خرائط للقطاع السكني و التجاري و الصناعي على مستوى التجمعات الفلسطينية توضح توزيع المباني وخصائصها و توزيع السكان و القوى العاملة.

https://map-irlg.najah.edu/tags/exposure/

تقييم قابلية التضرر

تم تقييم أنواع مختلفة من قابلية التضرر، على النحو التالي: تم تقييم قابلية التضرر المادي للمباني الفلسطينية، و قابلية التضرر القطاعي؛ مثل الطاقة و الزارعة و الماء و البنية التحتية الحيوية المرجح تاثرها بمخاطر التغيرات المناخية. تم أيضا تقييم قابلية التضرر/ الضعف المجتمعي، المرتبط بقدرة السكان على الحد من مخاطر الكوارث ، والاستجابة لحالات الطوارئ ، والتعافي بعد وقوع أي حدث كارثي، وذلك من خلال اخذ عوامل مرتبطة بضعف المجتمع مثل مستويات الفقر و التعليم و الصحة للسكان و الاوضاع السياسية مثل الاحتلال و الاستيطان.

https://map-irlg.najah.edu/tags/vulnerability/

تقييم المخاطر

تم الجمع بين نماذج المخاطر والتعرض و قابلية التضرر لحساب الخسائر السنوية المتوقعة للمباني السكنية والتجارية والصناعية الناجمة عن الزلازل والفيضانات مع الاخذ بعين الاعتبارتاثير الضعف المجتمعي على مستوى التجمعات السكانية الفلسطينية. تم أيضا تقييم الأضرار والخسائر لأربعة سيناريوهات زلزالية محتملة وعرض الخسائر البشرية و المادية الناجمة عنها في جميع التجمعات السكانية الفلسطينية. كما تم حساب مساحة الأراضي الزراعية السنوية المتوقعة غمرها بسبب الفيضانات. تم أيضًا حساب متوسط الخسائر السنوية المادية المتوقعة لمباني المستشفيات والدفاع المدني و المدارس بعد ذلك تم إجراء تصنيف للمباني من الأعلى إلى الأقل خطورة، وبالتالي تحديد المباني التي بحاجة لدراسات تفصيلية. فيما يتعلق بتغير المناخ ، قسمت فلسطين لمناطق جغرافية حسب مستويات مخاطر التغير المناخي و القطاعات الأكثر عرضة وأهميةً.

https://map-irlg.najah.edu/tags/risk/

التحسينات المستقبلية لدراسات المخاطر والمخاطر

تم إجراء تقييم للقدرات الوطنية والمحلية، بما في ذلك الجهات الأكاديمية والتقنية من اجل استكمال دراسات تقييم المخاط و تطويرها. بحيث تم تقديم ملخص للاحتياجات الأساسية لكل مكون من مكونات المخاطر (الخطر ، والتعرض ، وقابلية التضرر) اللازمة للحفاظ على التحليلات و / أو تحديثها في المستقبل، وتحديد الجهات القادرة على جمع و معالجة البيانات، وأي مؤسسات داعمة على المستوى المحلي أو المركزي.إن توفر خرائط لمخاطر الكوارث و التصنيف الأولي للبنية التحتية الحيوية المقدم يشكل ثروة من المعلومات يمكن استخدامها لتصنيف هيآت الحكم المحلي حسب مستوى الخطر لغرض توجيه السياسات و إعطاء الأولوية لتمويل أنشطة التخفيف و الحد و من مخاطر الكوارث في انحاء الوطن.

References

Aliqtisadi (2020) www.aliqtisadi.ps: https://www.aliqtisadi.ps/article/54539/. Accessed 30 Aug 2020

Amiran D.H.K. (1950) “A Revised Earthquake-Catalogue of Palestine” Israel Exploration Journal, 2(1), pp. 48-65

Borzi B., Crowley H. and Pinho R. (2008) “Simplified pushover-based vulnerability analysis for large-scale assessment of RC buildings,” Engineering Structures, 30, pp. 804-820.

Burke, M. and Emerick, K. (2016) “Adaptation to Climate Change: Evidence from US Agriculture,” Am. Econ. J-Econ. Polic., 8(3): 520 106–40, https://www.aeaweb.org/articles?id=10.1257/pol.20130025

Burton CG, Toquica M, Asad KM Bin, Musori M (2022) Validation and development of composite indices for measuring vulnerability to earthquakes using a socio-economic perspective. Nat Hazards 111:1301–1334. https://doi.org/10.1007/S11069-021-05095-9/FIGURES/4

Calderon A., Silva V. (2021) Exposure forecasting for seismic risk estimation: Application to Costa Rica, Earthquake Spectra, DOI: https://doi.org/10.1177/8755293021989333

Carreno M.L., Cardona O.D., Barbat A.H. (2012) “New methodology for urban seismic risk assessment from a holistic perspective,” Bulletin of Earthquake Engineering, DOI: 10.1007/s10518-011-9302-2

Crowley H, Despotaki V, Rodrigues D, Silva V, Toma-Danila D, Riga E, Karatzetzou A, Fotopoulou S, et al (2020) Exposure model for European seismic risk assessment: https://doi.org/101177/8755293020919429 36:252–273.

Dabbeek J, Silva V (2020) Modeling the residential building stock in the Middle East for multi-hazard risk assessment. Nat Hazards 100:. https://doi.org/10.1007/s11069-019-03842-7

Dabbeek J., Silva V., Galasso C., Smith A. (2020)” Probabilistic earthquake and flood loss assessment in the Middle East,” International Journal of Disaster Risk Reduction, https://doi.org/10.1016/j.ijdrr.2020.101662

De Bono A, Chatenoux B (2014) A Global Exposure Model for GAR 2015. https://www.unisdr.org/we/inform/publications/49763. Accessed 24 Apr 2019

Dottori F., R. Figueiredo, M.L.V. Martina, D. Molinari, A.R. Scorzini, INSYDE: a synthetic, probabilistic flood damage model based on explicit cost analysis, Nat. Hazards Earth Syst. Sci. 16 (2016) 2577–2591, https://doi.org/10.5194/nhess-16-2577-2016.

European Environment Agency (2019) Climate change adaptation in the agriculture sector in Europe, EEA Report, https://www.eea.europa.eu/publications/cc-adaptation-agriculture (last access 14 December 2020), 108 pp..

FAO. (2021). The impact of disasters and crises on agriculture and food security: 2021. Rome. https://doi.org/10.4060/cb3673en

FEMA (2015) Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook, Third Edition, Federal Emergency Management Agency, Washington D.C.

FEMA (2020) Community Lifelines, Federal Emergency Management Agency (FEMA), USA. https://www.fema.gov/emergency-managers/practitioners/lifelines. Accessed 1 Aug 2020.

FEMA, HAZUS-MH MR3 Technical Manual, Multi-Hazard Loss Estimation Methodology, Flood Model, 2019 (Washington, D.C).

Gamba P, Cavalca D, Jaiswal KS, Huyck C, Crowley H (2012) The GED4GEM project: development of a Global Exposure Database for the Global Earthquake Model Initiative. Proc 15th World Conf Earthq Eng 1–13

Gerl T., H. Kreibich, G. Franco, D. Marechal, K. Schroeter, A review of flood loss models as basis for harmonization and benchmarking, PloS One 11 (2016), e0159791, https://doi.org/10.1371/journal.pone.0159791.

Grigoratos I, Dabeek J, Faravelli M, Di Meo A, Cerchiello V, Borzi B, Monteiro R, Ceresa P (2016) Development of A Fragility and Exposure Model for Palestine – Application to The City of Nablus. Procedia Eng 161:2023–2029. https://doi.org/10.1016/j.proeng.2016.08.797

Hoffmann R, Blecha D (2020) Education and Disaster Vulnerability in Southeast Asia: Evidence and Policy Implications. Sustain 2020, Vol 12, Page 1401 12:1401. https://doi.org/10.3390/SU12041401

Huizinga J., H. de Moel, W. Szewczyk, Global flood depth-damage functions: methodology and the database with guidelines, EUR 28552 EN (2017), https://doi. org/10.2760/16510. https://ec.europa.eu/jrc/en/publication/global-flood-depth-damage-functions-methodology-and-database-guidelines

IPCC: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, edited by: Field, C. B., Barros, V. R., Dokken, D. J., Mach, K. J., Mastrandrea, M. D., Bilir, T. E., Chatterjee, M., Ebi, K. L., Estrada, Y.O., Genova, R. C., Girma, B., Kissel, E. S., Levy, A. N., MacCracken, S., Mastrandrea, P. R. and White, L. L., Cambridge University.

Jaiswal K. and Wald D. (2010) “Development of a semi-empirical loss model within the USGS Prompt Assessment of Global Earthquakes for Response (PAGER) System,” Proceedings of the 9th US and 10th Canadian Conference on Earthquake Engineering: Reaching Beyond Borders, Toronto, Canada.

Jalayer F, Carozza S, De Risi R, Manfredi G, Mbuya E (2016) Performance-based flood safety-checking for non-engineered masonry structures. Eng Struct 106:109–123. https://doi.org/10.1016/J.ENGSTRUCT.2015.10.007

Kamel N (2012) Social marginalisation, federal assistance and repopulation patterns in the New Orleans metropolitan area following Hurricane Katrina. Urban Studies 49 (14):3211-3231

Kelman I., R. Spence, An overview of flood actions on buildings, Eng. Geol. 73 (2004) 297–309, https://doi.org/10.1016/J.ENGGEO.2004.01.010

Maqsood T., M. Wehner, H. Ryu, M. Edwards, K. Dale, V. Miller, GAR15 Regional Vulnerability Functions: Reporting on the UNISDR/GA SE Asian Regional Workshop on Structural Vulnerability Models for the GAR Global Risk Assessment, 11-14November,2013,GeoscienceAustralia,Canberra,Australia,2014.https://doi.org/10.11636/Record.2014.038

Martins L. and Silva V. (2020) “Development of a fragility and vulnerability model for global seismic risk analyses,” Bulletin of Earthquake Engineering, https://doi.org/10.1007/s10518-020-00885-1

Martins L., Silva V., Crowley H. and Cavalieri F. (2021) “Vulnerability Modeller’s Toolkit, an Open-Source Platform for Vulnerability Analysis,” Bulletin of Earthquake Engineering, https://doi.org/10.21203/rs.3.rs-458348/v1

Merz B., H. Kreibich, R. Schwarze, A. Thieken, Review article "Assessment of economic flood damage", Nat. Hazards Earth Syst. Sci. 10 (2010) 1697–1724, https://doi.org/10.5194/nhess-10-1697-2010.

MoA, (2016) Ministry of Agriculture land use map. Available via GeoMolg https://geomolg.ps/L5/index.html?viewer=A3.V1

Monteiro R, Ceresa P, Cerchiello V, Dabeek J, Di Meo A, Borzi B (2016) Towards integrated seismic risk assesment in Palestine - application to the city of Nablus. In: Proceedings of the VII European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS Congress 2016). Athens, pp 5987–5998

Oskorouchi, H. R., & Sousa-Poza, A. (2021) “Floods, food security, and coping strategies: Evidence from Afghanistan,” Agricultural Economics, 52(1), pp. 123-140.

Pagani, M., Monelli, D., Weatherill, G., Danciu, L., Crowley, H., Silva, V., Henshaw, P., Butler, L., Nastasi, M., Panzeri, L., Simionato, M. and Vigano, D., (2014) “OpenQuake Engine: An open hazard (and risk) software for the Global Earthquake Model,” Seismological Research Letters, Vol. 85, No. 3, pp 692-702.

PCBS (2017) Population, Housing and Establishments Census 2017. Palestinian Central Bureau of Statistics (PCBS). http://www.pcbs.gov.ps/default.aspx. Accessed 1 Aug 2022

PCBS and MoSD (2011). Disabled Individuals Survey, 2011, Main Findings Report. Ramallah Palestine. Palestinian Central Bureau of Statistics and Ministry of Social Affairs

Pesaresi M, Ehrilch D, Florczyk AJ, Freire S, Julea A, Kemper T, Soille P, Syrris V (2015) GHS built-up grid, derived from Landsat, multitemporal (1975, 1990, 2000, 2014). In: Eur. Comm. Jt. Res. Cent. (JRC), [Dataset]. http://data.europa.eu/89h/jrc-ghsl-ghs_built_ldsmt_globe_r2015b. Accessed 24 Apr 2019

Rufat S, Tate E, Burton CG, Maroof AS (2015) Social vulnerability to floods: Review of case studies and implications for measurement. Int J Disaster Risk Reduct 14:470–486. https://doi.org/10.1016/J.IJDRR.2015.09.013

Sampson, C. C., A. M. Smith, P. D. Bates, J. C. Neal, L. Alfieri, and J. E. Freer (2015) “A high-resolution global flood hazard model”, Water Resour. Res., 51, pp. 7358–7381, doi:10.1002/ 2015WR016954.

Sampson, C. C., Smith, A. M., Bates, P. D., Neal, J. C., Alfieri, L. and Freer, J. E. (2015) ‘A high-resolution global flood hazard model’, Water Resources Research. Blackwell Publishing Ltd, Vol. 51, No. 9, pp. 7358–7381. doi: 10.1002/2015WR016954.

Shadeed S, Alawna S (2021) GIS-based COVID-19 vulnerability mapping in the West Bank, Palestine. Int J Disaster Risk Reduct 64:102483. https://doi.org/10.1016/J.IJDRR.2021.102483

Silva V., Brzev S., Scawthorn C., Yepes-Estrada C., Dabbeek J. and Crowley H. (2021) “A Building Classification System for Multi-Hazard Risk Assessment,” International Journal of Disaster Risk Science, https://doi.org/10.1007/s13753-022-00400-x

Silva V., Crowley H., Pagani M., Monelli D. and Pinho R. (2014) “Development of the OpenQuake engine, the Global Earthquake Model’s open-source software for seismic risk assessment," Natural Hazards, 72(3), pp. 1409–1427, DOI: https://doi.org/10.1007/s11069-013-0618-x

Steinführer A, Kuhlicke C (2007) Social vulnerability and the 2002 flood: country report Germany (Mulde River). FLOODsite Report T11-07-08

Thornton, P., Dinesh, D., Cramer, L., Loboguerrero, A. M. and Campbell, B. (2018) "Agriculture in a changing climate: Keeping 645 our cool in the face of the hothouse," Outlook Agr., 47(4), pp. 283–290, https://doi.org/10.1177/0030727018815332

Vahedifard, F., AghaKouchak, A., & Jafari, N. H. (2016) "Compound hazards yield Louisiana flood" Science, 353(6306), pp. 1374-1374.

Wafa (2020) http://info.wafa.ps: http://info.wafa.ps/index.aspx. Accessed 30 Aug 2020

World Bank (2022) West Bank and Gaza - Urban Climate Risk Analysis (English). Washington, D.C. : World Bank Group http://documents.worldbank.org/curated/en/099605006232219639/P17827105ebc570c30884204dd4870f2d97

Appendix 1: Exposure Models

Click the link to view the exposure models data and methods
https://drive.google.com/drive/folders/1Ii2jLUgvSaUKVxQaLzuGcw-urTfQ6jMM?usp=share_link

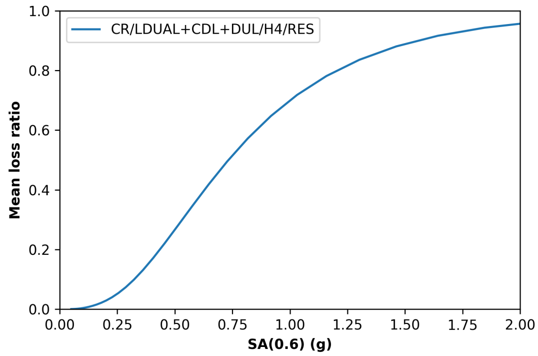
Appendix 2: Template of Building Inspection Form

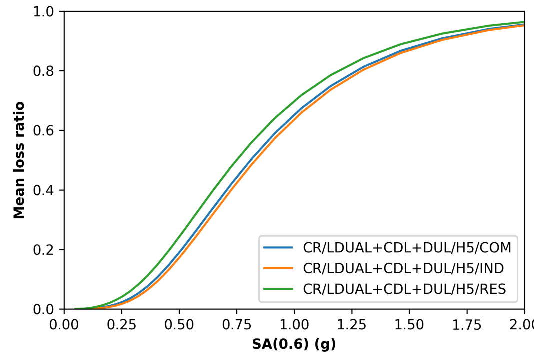
Click the link to view the form (google forms version)
https://drive.google.com/file/d/1eASUPm9ybDGLV1Ru5l5eKNsQpVrIXeTo/view?usp=sharing

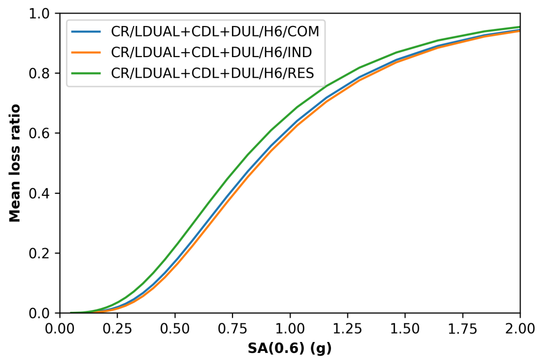
Click the link to view the annex of the building inspection form
https://drive.google.com/file/d/1o8edoaOk7GSyc5clPP9XfHkLk3u4WjI0/view?usp=share_link

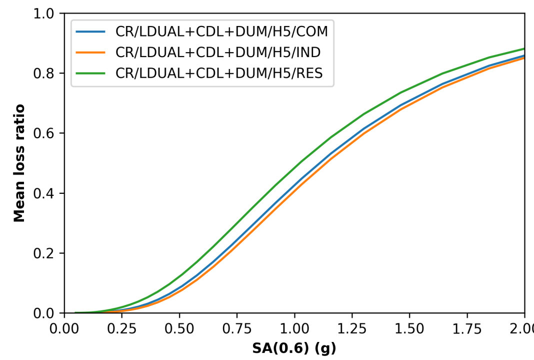
Appendix 3: Seismic Vulnerability Model Plots

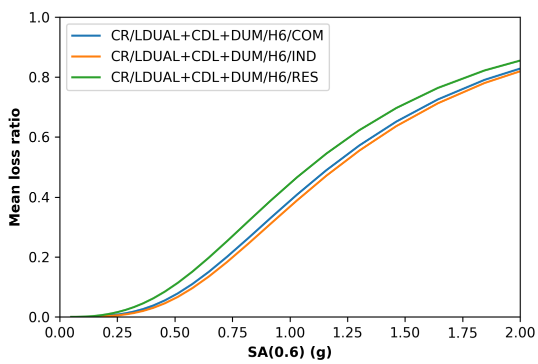
The seismic economic vulnerability models for all building classes, developed using the capacity curves and methodology developed by the Global Earthquake Model (GEM) in their Vulnerability Modeller's Toolkit[25] (Martins et al., 2021; Martins and Silva, 2020) as described further in Section 4.1.1, are shown in the following plots:

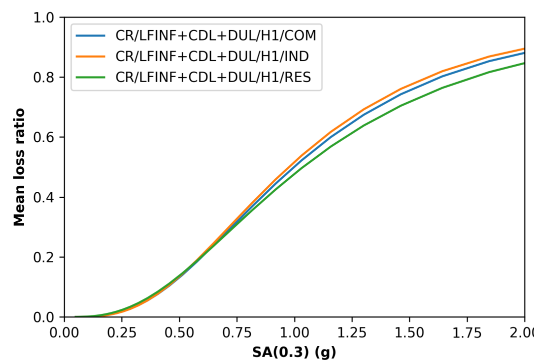




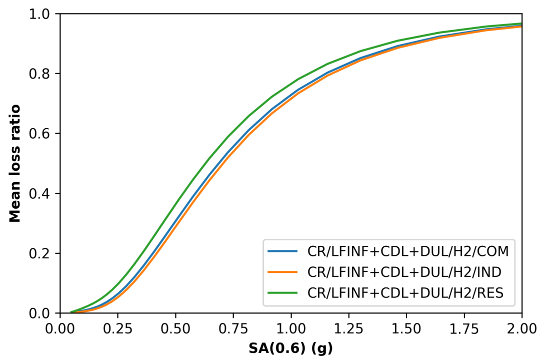


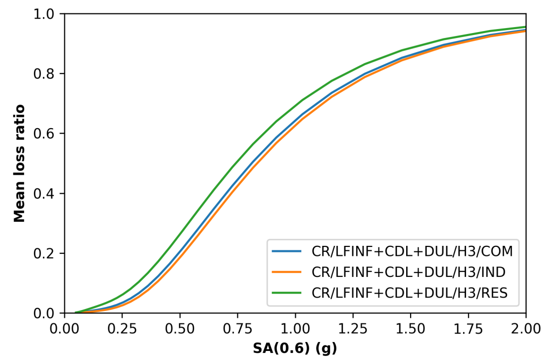


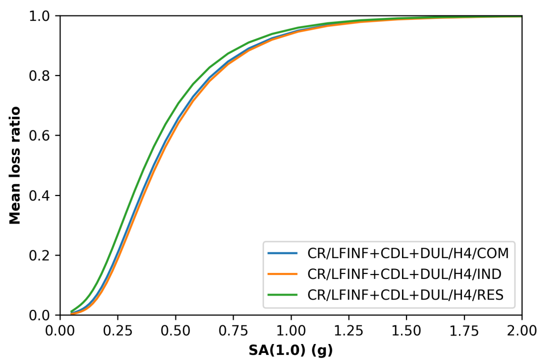


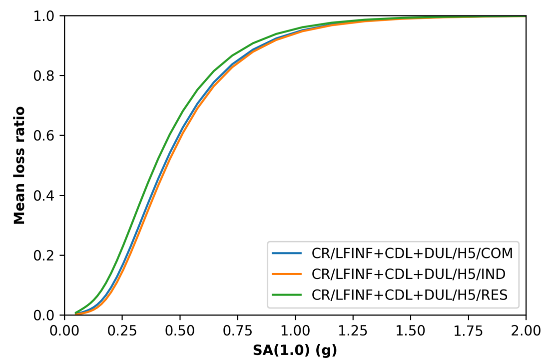


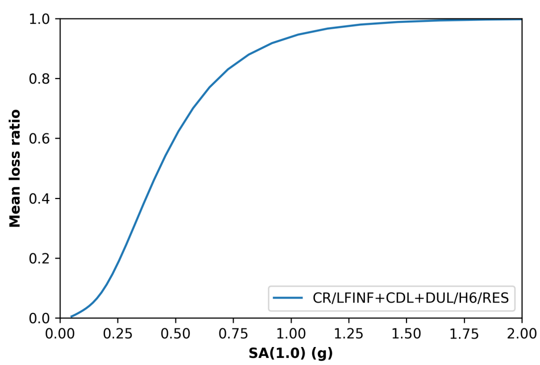
[25] https://github.com/GEMScienceTools/VMTK-Vulnerability-Modellers-ToolKit

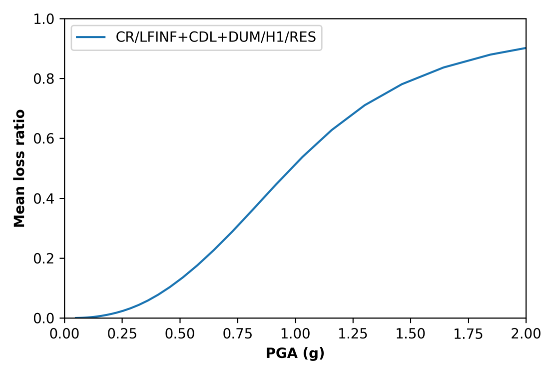

Mean loss ratio
SA(0.6) (g)
CR/LFINF+CDL+DUL/H2/COM
CR/LFINF+CDL+DUL/H2/IND
CR/LFINF+CDL+DUL/H2/RES

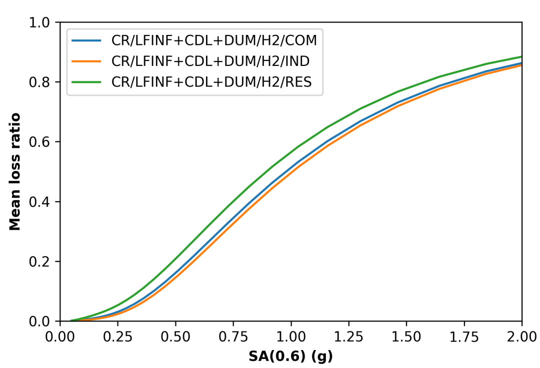

Mean loss ratio
SA(0.6) (g)
CR/LFINF+CDL+DUL/H3/COM
CR/LFINF+CDL+DUL/H3/IND
CR/LFINF+CDL+DUL/H3/RES

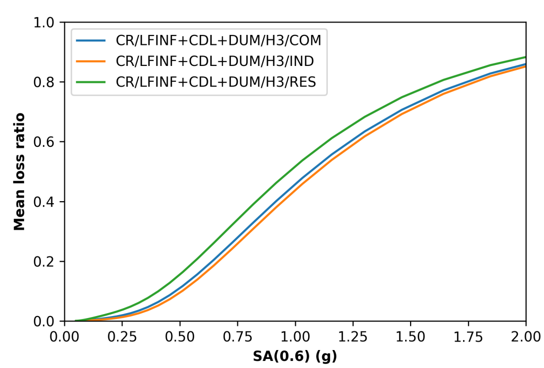

Mean loss ratio
SA(1.0) (g)
CR/LFINF+CDL+DUL/H4/COM
CR/LFINF+CDL+DUL/H4/IND
CR/LFINF+CDL+DUL/H4/RES

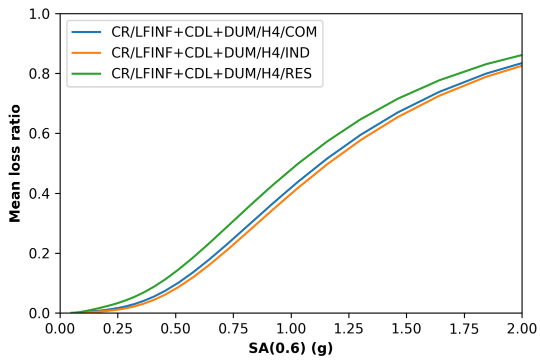

Mean loss ratio
SA(1.0) (g)
CR/LFINF+CDL+DUL/H5/COM
CR/LFINF+CDL+DUL/H5/IND
CR/LFINF+CDL+DUL/H5/RES

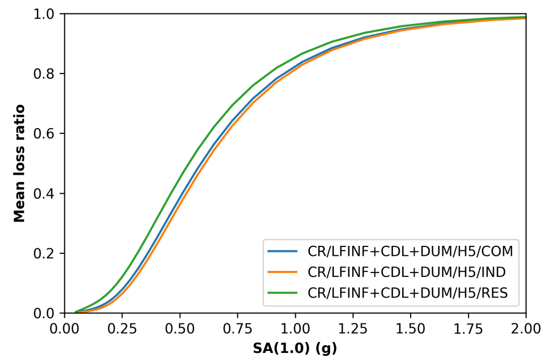

Mean loss ratio
SA(1.0) (g)
CR/LFINF+CDL+DUL/H6/RES

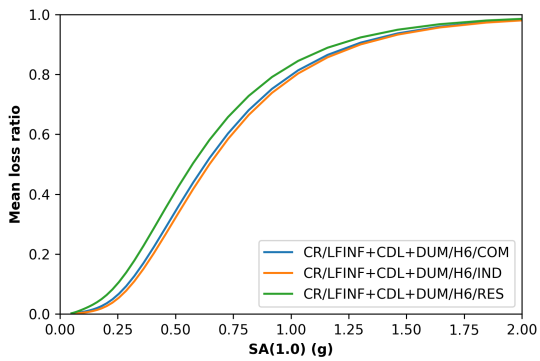

Mean loss ratio
PGA (g)
CR/LFINF+CDL+DUM/H1/RES

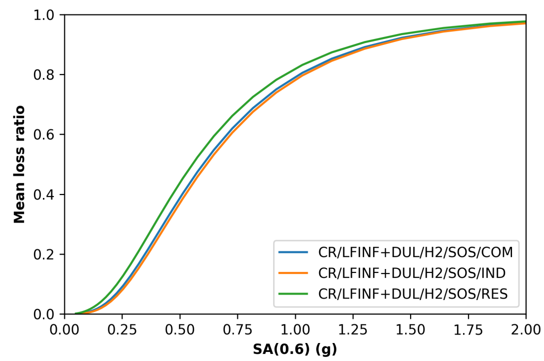

Mean loss ratio
SA(0.6) (g)
CR/LFINF+CDL+DUM/H2/COM
CR/LFINF+CDL+DUM/H2/IND
CR/LFINF+CDL+DUM/H2/RES

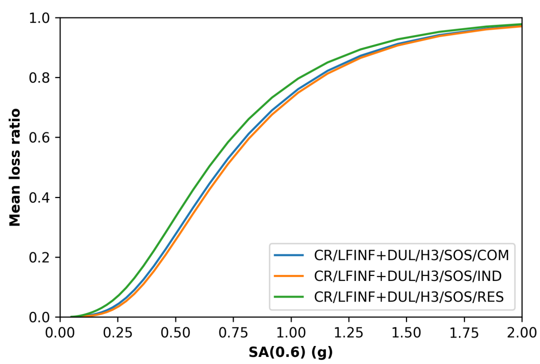

Mean loss ratio
SA(0.6) (g)
CR/LFINF+CDL+DUM/H3/COM
CR/LFINF+CDL+DUM/H3/IND
CR/LFINF+CDL+DUM/H3/RES

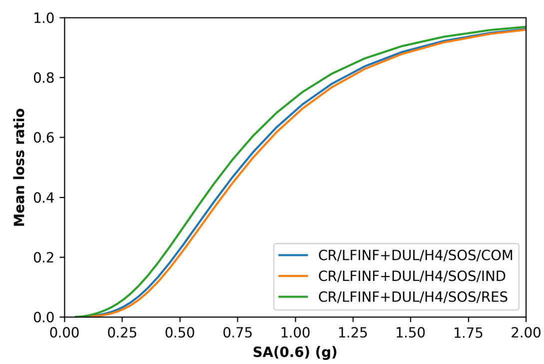

CR/LFINF+CDL+DUM/H4/COM
CR/LFINF+CDL+DUM/H4/IND
CR/LFINF+CDL+DUM/H4/RES
Mean loss ratio
SA(0.6) (g)

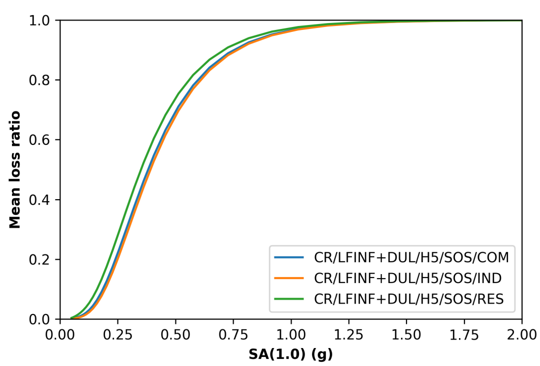

CR/LFINF+CDL+DUM/H5/COM
CR/LFINF+CDL+DUM/H5/IND
CR/LFINF+CDL+DUM/H5/RES
Mean loss ratio
SA(1.0) (g)

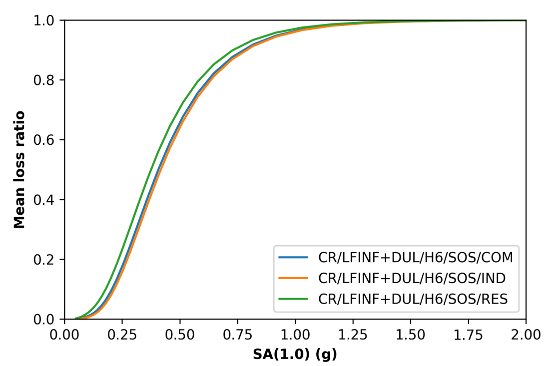

CR/LFINF+CDL+DUM/H6/COM
CR/LFINF+CDL+DUM/H6/IND
CR/LFINF+CDL+DUM/H6/RES
Mean loss ratio
SA(1.0) (g)

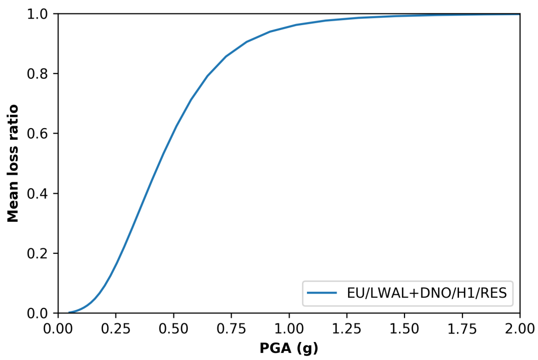

CR/LFINF+DUL/H2/SOS/COM
CR/LFINF+DUL/H2/SOS/IND
CR/LFINF+DUL/H2/SOS/RES
Mean loss ratio
SA(0.6) (g)

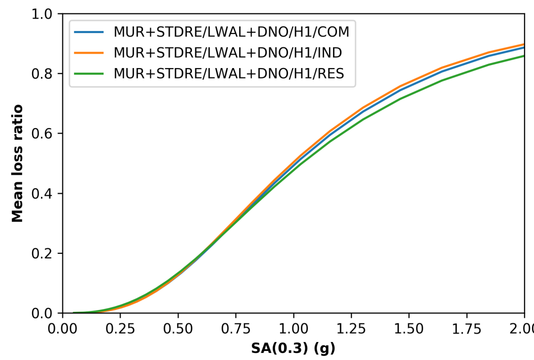

CR/LFINF+DUL/H3/SOS/COM
CR/LFINF+DUL/H3/SOS/IND
CR/LFINF+DUL/H3/SOS/RES
Mean loss ratio
SA(0.6) (g)

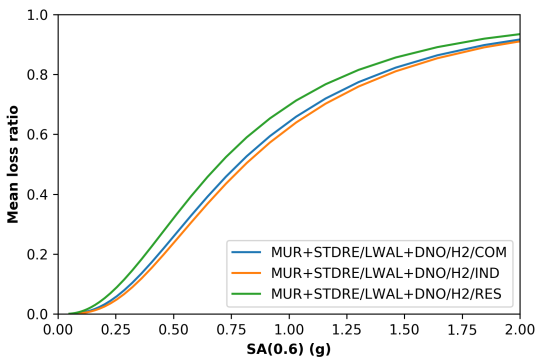

CR/LFINF+DUL/H4/SOS/COM
CR/LFINF+DUL/H4/SOS/IND
CR/LFINF+DUL/H4/SOS/RES
Mean loss ratio
SA(0.6) (g)

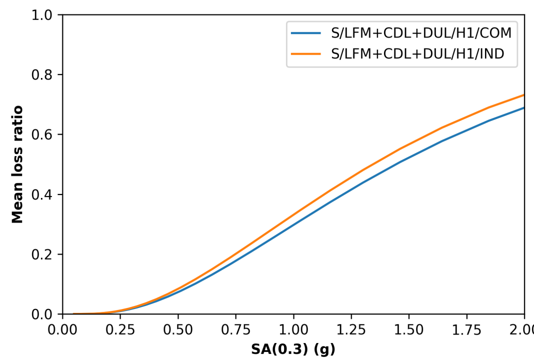

CR/LFINF+DUL/H5/SOS/COM
CR/LFINF+DUL/H5/SOS/IND
CR/LFINF+DUL/H5/SOS/RES
Mean loss ratio
SA(1.0) (g)

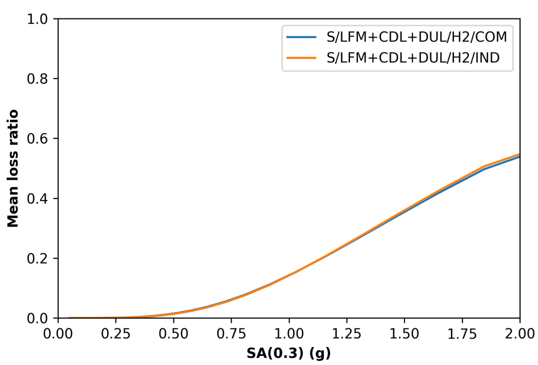

CR/LFINF+DUL/H6/SOS/COM
CR/LFINF+DUL/H6/SOS/IND
CR/LFINF+DUL/H6/SOS/RES
Mean loss ratio
SA(1.0) (g)

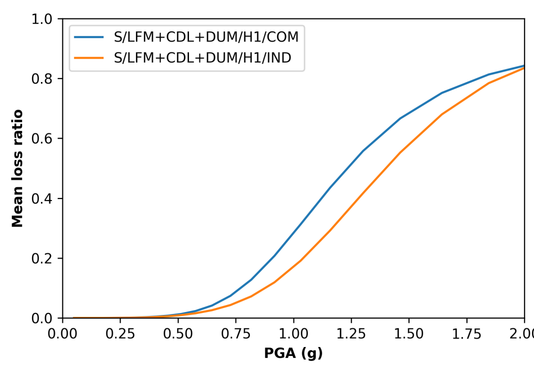




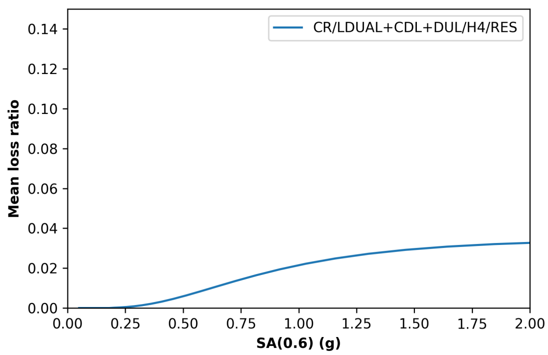


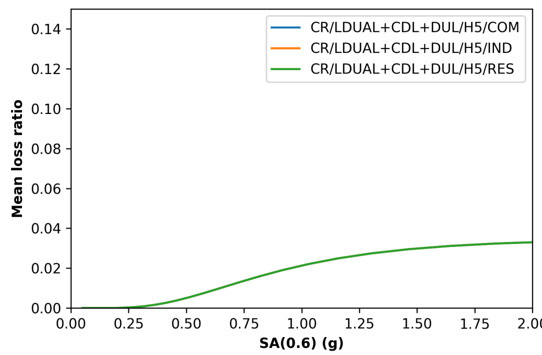


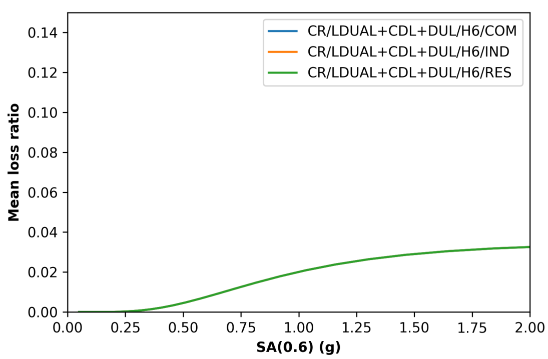


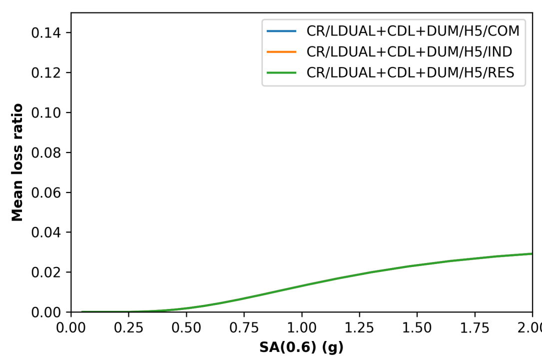


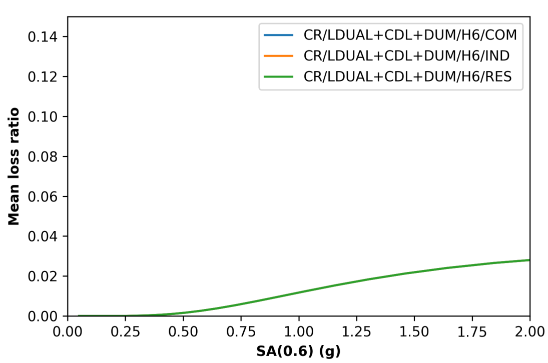
The seismic fatality vulnerability models are shown in the following plots:

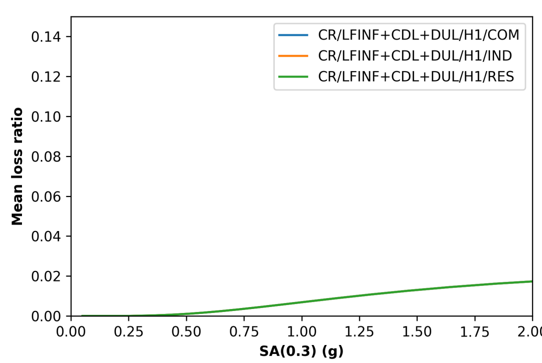

CR/LDUAL+CDL+DUL/H4/RES
Mean loss ratio
SA(0.6) (g)

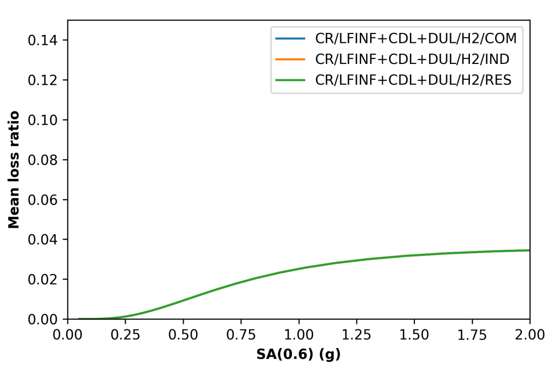

CR/LDUAL+CDL+DUL/H5/COM
CR/LDUAL+CDL+DUL/H5/IND
CR/LDUAL+CDL+DUL/H5/RES
Mean loss ratio
SA(0.6) (g)

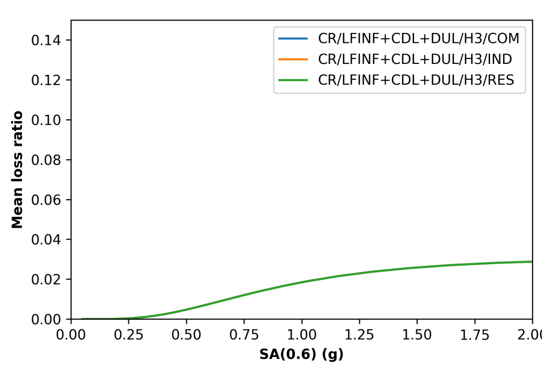

CR/LDUAL+CDL+DUL/H6/COM
CR/LDUAL+CDL+DUL/H6/IND
CR/LDUAL+CDL+DUL/H6/RES
Mean loss ratio
SA(0.6) (g)

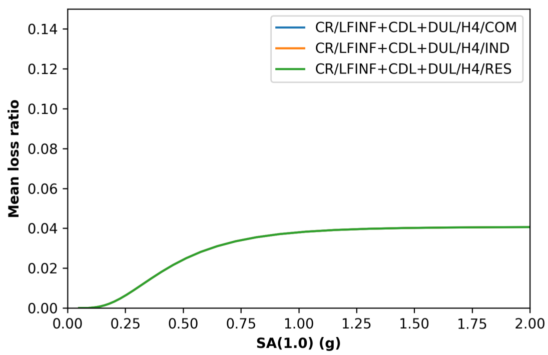

CR/LDUAL+CDL+DUM/H5/COM
CR/LDUAL+CDL+DUM/H5/IND
CR/LDUAL+CDL+DUM/H5/RES
Mean loss ratio
SA(0.6) (g)

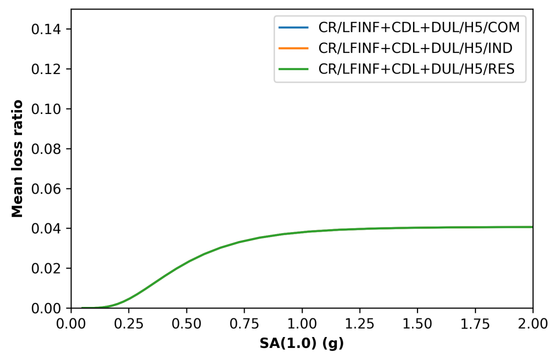

CR/LDUAL+CDL+DUM/H6/COM
CR/LDUAL+CDL+DUM/H6/IND
CR/LDUAL+CDL+DUM/H6/RES
Mean loss ratio
SA(0.6) (g)

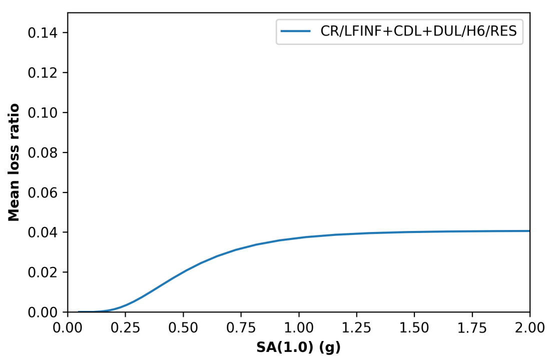

CR/LFINF+CDL+DUL/H1/COM
CR/LFINF+CDL+DUL/H1/IND
CR/LFINF+CDL+DUL/H1/RES
Mean loss ratio
SA(0.3) (g)

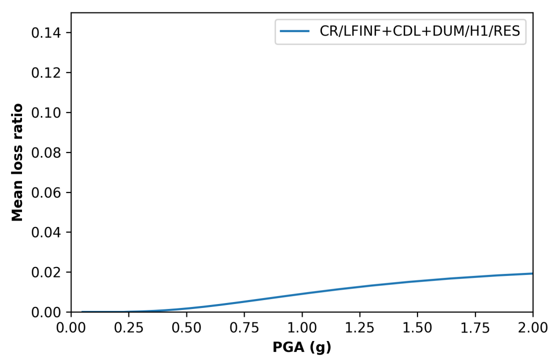

CR/LFINF+CDL+DUL/H2/COM
CR/LFINF+CDL+DUL/H2/IND
CR/LFINF+CDL+DUL/H2/RES
Mean loss ratio
SA(0.6) (g)

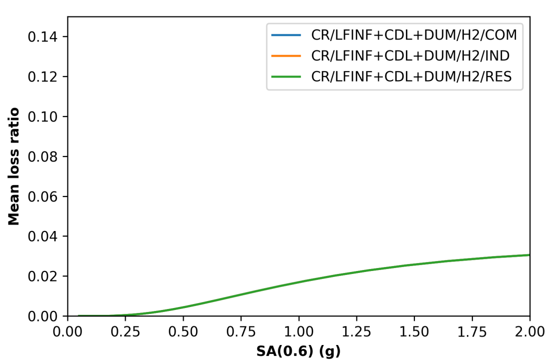

CR/LFINF+CDL+DUL/H3/COM
CR/LFINF+CDL+DUL/H3/IND
CR/LFINF+CDL+DUL/H3/RES
Mean loss ratio
SA(0.6) (g)

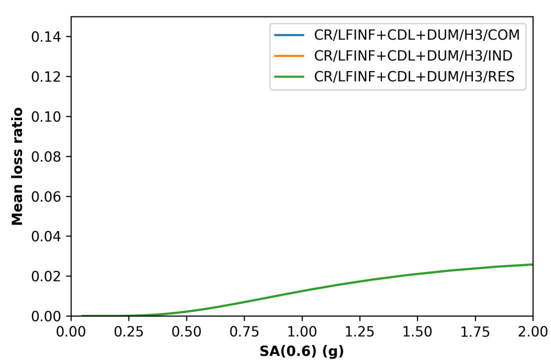

CR/LFINF+CDL+DUL/H4/COM
CR/LFINF+CDL+DUL/H4/IND
CR/LFINF+CDL+DUL/H4/RES
Mean loss ratio
SA(1.0) (g)

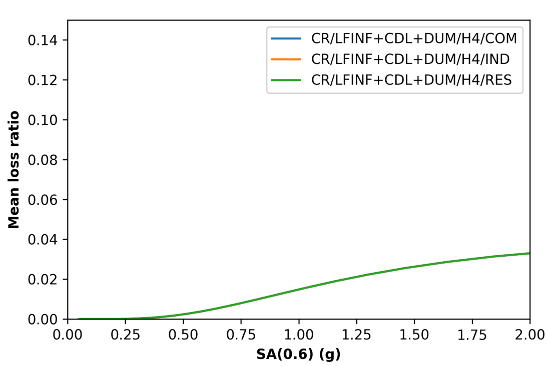

CR/LFINF+CDL+DUL/H5/COM
CR/LFINF+CDL+DUL/H5/IND
CR/LFINF+CDL+DUL/H5/RES
Mean loss ratio
SA(1.0) (g)

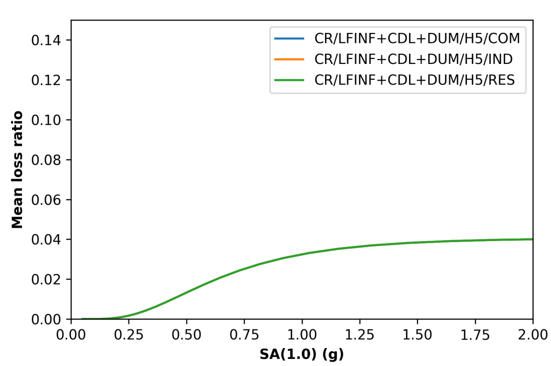

CR/LFINF+CDL+DUL/H6/RES
Mean loss ratio
SA(1.0) (g)

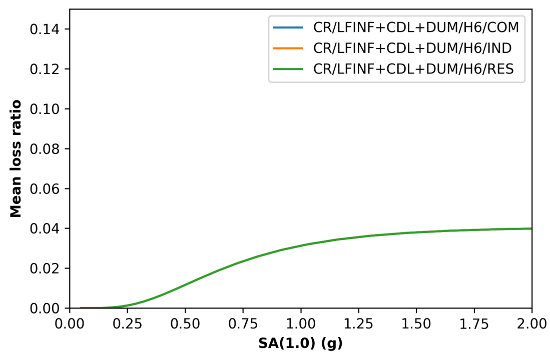

CR/LFINF+CDL+DUM/H1/RES
Mean loss ratio
PGA (g)

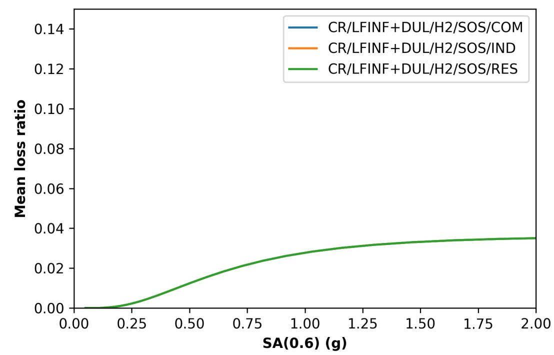

CR/LFINF+CDL+DUM/H2/COM
CR/LFINF+CDL+DUM/H2/IND
CR/LFINF+CDL+DUM/H2/RES
Mean loss ratio
SA(0.6) (g)

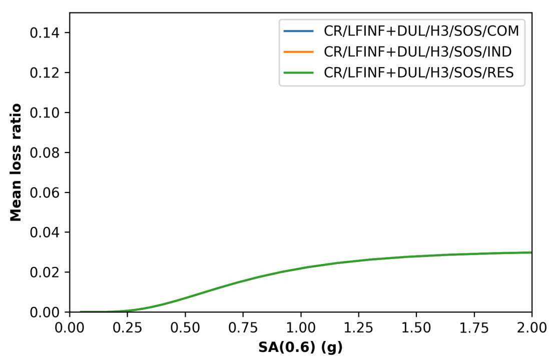

CR/LFINF+CDL+DUM/H3/COM
CR/LFINF+CDL+DUM/H3/IND
CR/LFINF+CDL+DUM/H3/RES
Mean loss ratio
SA(0.6) (g)

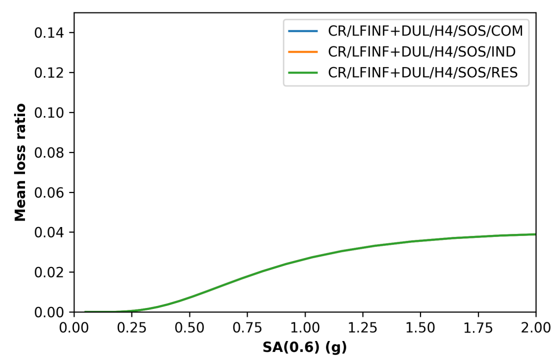

CR/LFINF+CDL+DUM/H4/COM
CR/LFINF+CDL+DUM/H4/IND
CR/LFINF+CDL+DUM/H4/RES
Mean loss ratio
SA(0.6) (g)

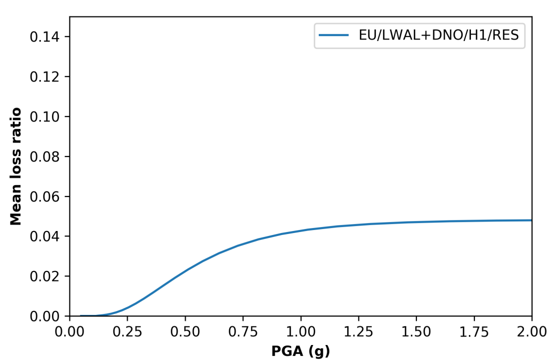

CR/LFINF+CDL+DUM/H5/COM
CR/LFINF+CDL+DUM/H5/IND
CR/LFINF+CDL+DUM/H5/RES
Mean loss ratio
SA(1.0) (g)

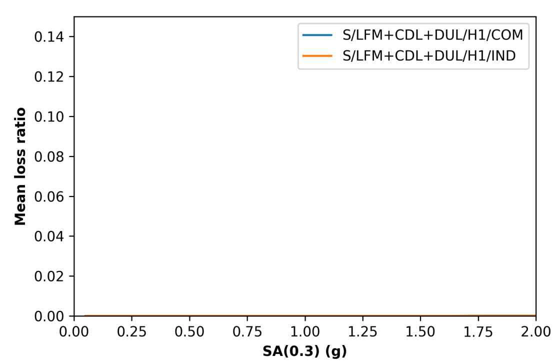

CR/LFINF+CDL+DUM/H6/COM
CR/LFINF+CDL+DUM/H6/IND
CR/LFINF+CDL+DUM/H6/RES
Mean loss ratio
SA(1.0) (g)

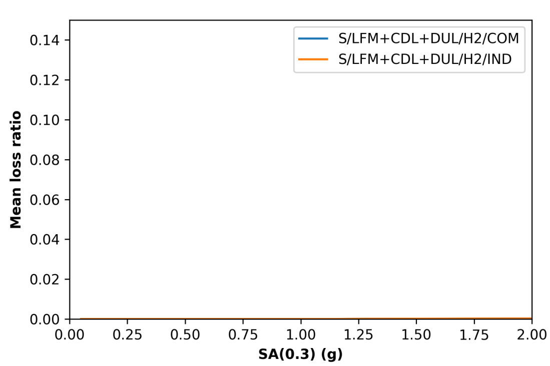

CR/LFINF+DUL/H2/SOS/COM
CR/LFINF+DUL/H2/SOS/IND
CR/LFINF+DUL/H2/SOS/RES
Mean loss ratio
SA(0.6) (g)

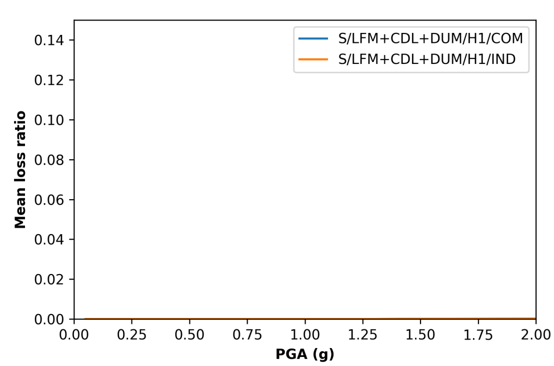

CR/LFINF+DUL/H3/SOS/COM
CR/LFINF+DUL/H3/SOS/IND
CR/LFINF+DUL/H3/SOS/RES
Mean loss ratio
SA(0.6) (g)


CR/LFINF+DUL/H4/SOS/COM
CR/LFINF+DUL/H4/SOS/IND
CR/LFINF+DUL/H4/SOS/RES
Mean loss ratio
SA(0.6) (g)


EU/LWAL+DNO/H1/RES
Mean loss ratio
PGA (g)


S/LFM+CDL+DUL/H1/COM
S/LFM+CDL+DUL/H1/IND
Mean loss ratio
SA(0.3) (g)


S/LFM+CDL+DUL/H2/COM
S/LFM+CDL+DUL/H2/IND
Mean loss ratio
SA(0.3) (g)


S/LFM+CDL+DUM/H1/COM
S/LFM+CDL+DUM/H1/IND
Mean loss ratio
PGA (g)

Appendix 4: Social Vulnerability Models

Click the link to view social vulnerability variables:
https://drive.google.com/drive/folders/1BTARqfPaMOyWomRS3xh1zEB5V7BmFk8y?usp=share_linkHx3azeMoJ-Us4rE-Tna_PTYSdY/edit?usp=sharing