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RIESGOS
MULTI-RISIKO ANALYSE UND INFORMATIONSSYSTEMKOMPONENTEN FÜR DIE ANDENREGION

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Bayesian downscaling of building exposure models with remote sensing and ancillary information

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INTRODUCTION

HAZARD + **EXPOSURE** + VULNERABILITY = **RISK**

HAZARD
- Probability of occurrence
- Magnitude
- Intensity
- Location
- Influence of geological or meteorological factors

EXPOSURE
- People
- Buildings and structures
- Public facilities
- Environmental assets

VULNERABILITY
- Susceptibility of the elements exposed to the hazard

INTRODUCTION

- German Research Centre for Geosciences (GFZ) in collaboration with other research partners work together in the joint project RIESGOS
- RIESGOS project is innovative research in risk analysis of the various natural hazards for South America's Andes Regions
- The countries of the project are Chile, Peru, and Ecuador.

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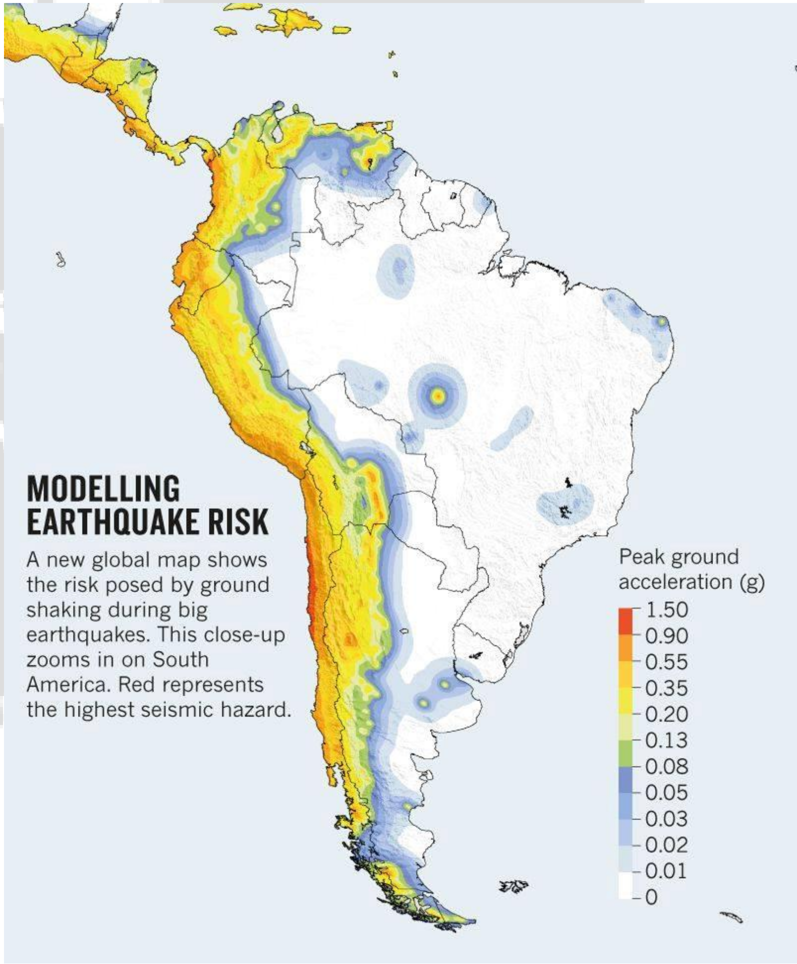
INTRODUCTION

- The South American region has a wide history of large and destructive earthquakes specially along the West Coast
- The subduction along the Pacific coast of South America dominates the geodynamics continent
- Chile is one of the most seismic countries in the world, the largest earthquake recorded took place in Chile (1960 Mw9.6, Valdivia)



M Pagani. et al./Global Earthquake Model

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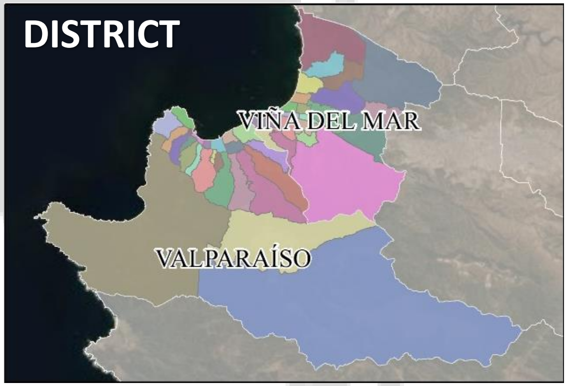
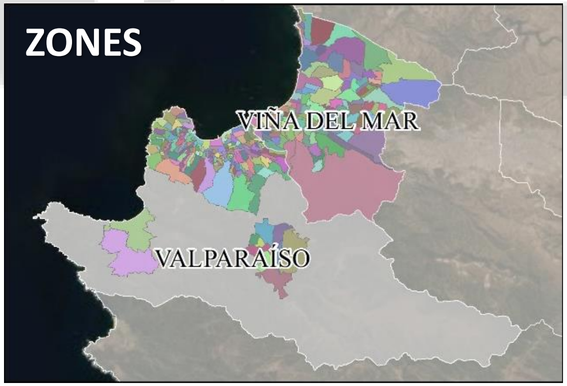
AREA OF STUDY





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OBJECTIVES

- Creation of geographical units for the spatial representation of the exposure model
- Downscaling the existing building exposure model using a probabilistic approach including:
    - Remote sensing products (buildings height and density)
    - Open Source Auxiliary information (buildings footprint area)
- Preliminary validation of the probabilistic models created

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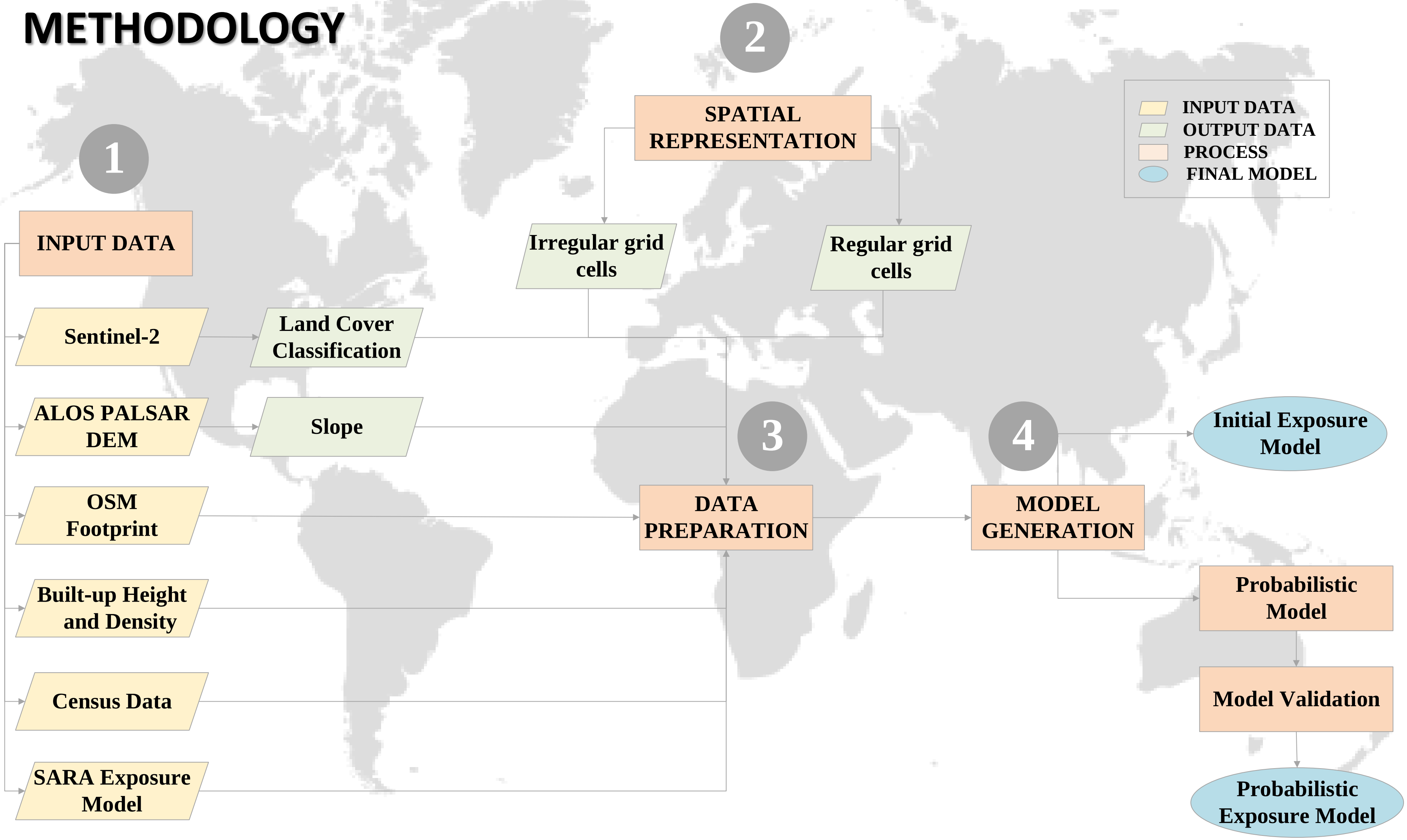
METHODOLOGY



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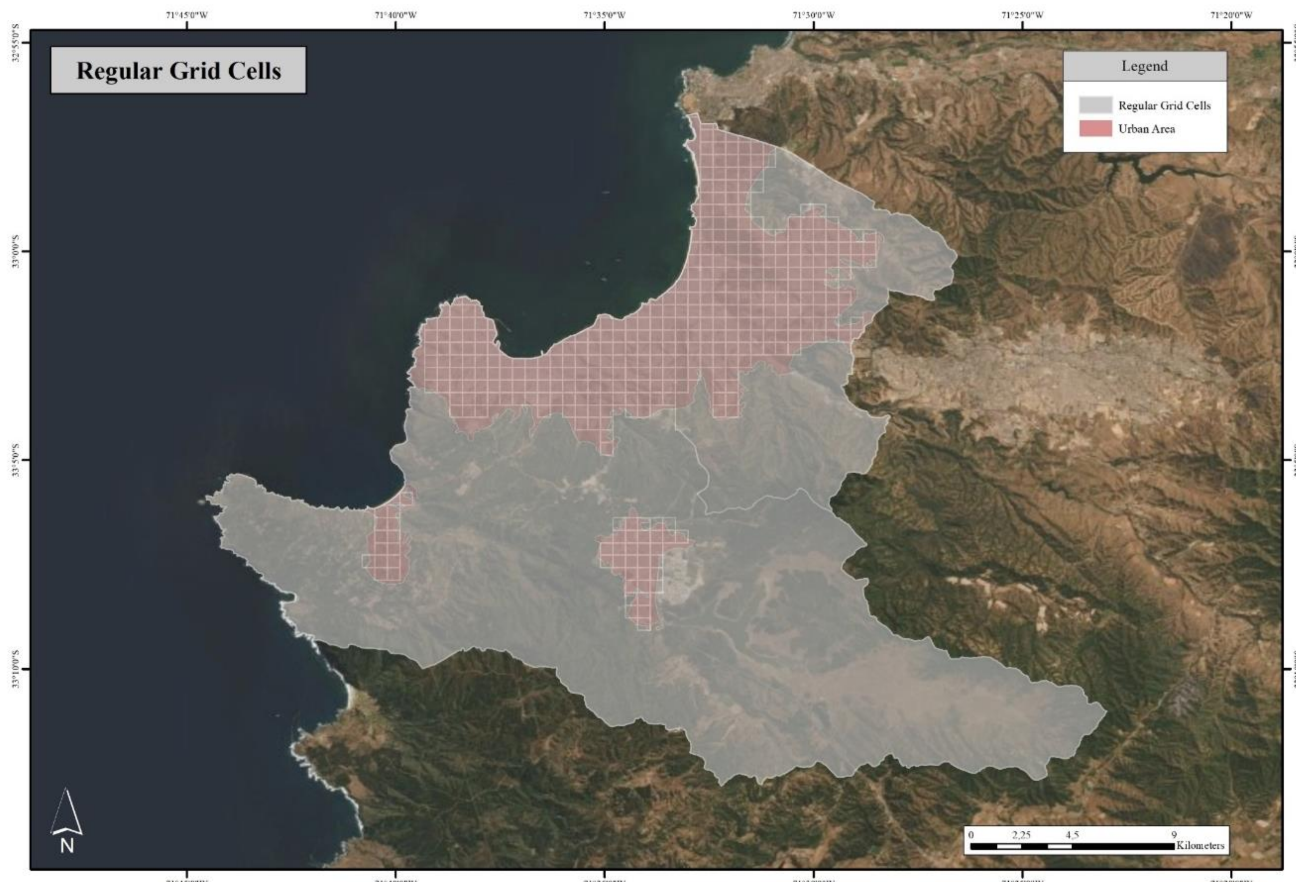
1. REGULAR GRID CELLS

- Simplify the integration of various datasets and provide a consistent framework
- Denotes all units are the same size and shape
- Advantages working over irregular zones



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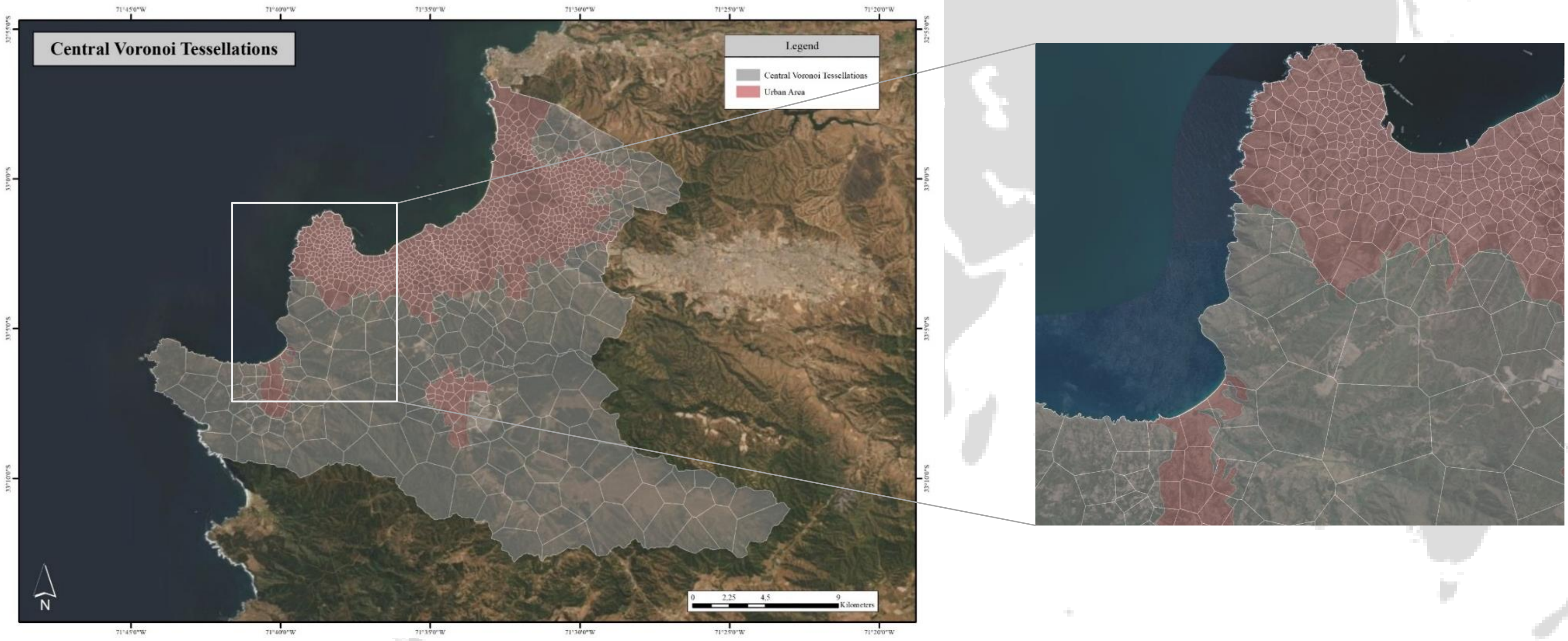
2. IRREGULAR GRID CELLS - CENTRAL VORONOI TESSELLATIONS

- The size and shape of the tessellations vary according to defined criteria in this case population density.
- It will be smaller in highly populated areas and will increase in sparsely inhabited areas.



BUILDING EXPOSURE DATABASE

Provides a spatial inventory of assets that are exposed to a hazard activity and are susceptible to be damaged

GEM GLOBAL EARTHQUAKE MODEL

PROJECT SOUTH AMERICAN RISK ASSESSMENT (SARA) 2013 - 2015

- Proposed to build a comprehensive repository of exposure data, that document, collect and homogenize data from sources to make them suitable to be used in risk assessment
- The project aims to calculate hazard and risk, as well as to estimate the compounding social and economic factors that aggravate the physical damage

https://sara.openquake.org/

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Regional and Integrated Risk Assessment

- Seismic hazard Assessment
- Exposure and vulnerability databases
- City scenarios
- Social economic losses

South American Risk Assessment Exposure Model (SARA)

- Number of dwellings
- Number of buildings
- Building classes
- Average floor area
- Replacement cost
- Population

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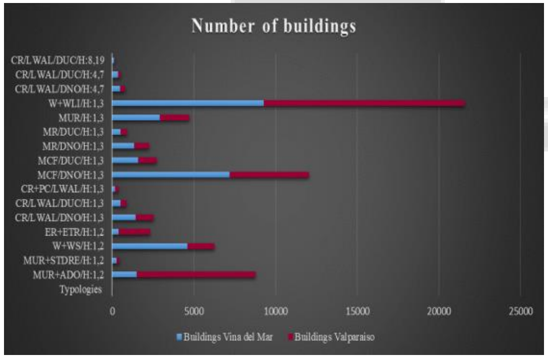
Description	Typologies
Reinforced rammed earth, between 1-2 stories	ER+ETR/H:1,2
Unreinforced masonry with adobe blocks, between 1-2 stories	MUR+ADO/H:1,2
Unreinforced masonry, Dressed stone, between 1-3 stories	MUR+STDRE/H:1,2
Solid wood, between 1-2 stories	W+WS/H:1,2
Unreinforced masonry, between 1-3 stories	MUR/H:1,3
Confined masonry non ductile, between 1-3 stories	MCF/DNO/H:1,3
Light wood members, between 1-3 stories	W+WLI/H:1,3
Reinforced concrete wall system, ductile, between 1-3 stories	CR/LWAL/DUC/H:1,3
Reinforced Concrete wall system, non-ductile, between 1-3 stories	CR/LWAL/DNO/H:1,3
Reinforced masonry ductile, between 1-3 stories	MR/DUC/H:1,3
Precast reinforced concrete wall system, between 1-3 stories	CR+PC/LWAL/H:1,3
Confined masonry ductile, between 1-3 stories	MCF/DUC/H:1,3
Reinforced masonry non ductile, between 1-3 stories	MR/DNO/H:1,3
Reinforced Concrete wall system, non-ductile, between 4-7 stories	CR/LWAL/DNO/H:4,7
Reinforced concrete wall system, ductile, between 4-7 stories	CR/LWAL/DUC/H:4,7
Reinforced concrete wall system, ductile, between 8-19 stories	CR/LWAL/DUC/H:8,19

(Yepes-Estrada, 2017)



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DATA PREPARATION

Rise	Typology	Percentages of Buildings			
		Viña del Mar	**Rise**	**Valparaiso**	**Rise**
Low-rise buildings	ER-ETR-H1-2	1%	96%	5%	98%
	MUR-ADO-H1-2	5%		19%	
	MUR-STDRE-H1-2	1%		1%	
	W-WS-H1-2	14%		13%	
	MCF-DNO-H1-3	21%		13%	
	MUR-H1-3	9%		5%	
	W-WLI-H1-3	27%		31%	
	CR-LWAL-DNO-H1-3	4%		3%	
	CR-LWAL-DUC-H1-3	2%		1%	
	MCF-DUC-H1-3	5%		3%	
	CR-PC-LWAL-H1-3	1%		1%	
	MR-DNO-H1-3	4%		2%	
	MR-DUC-H1-3	2%		1%	
High-rise buildings	CR-LWAL-DNO-H4-7	1,4%	4%	1%	2%
	CR-LWAL-DUC-H4-7	0,6%		0,6%	
	CR-LWAL-DUC-H8-19	2%		0,4%	

https://sara.openquake.org/

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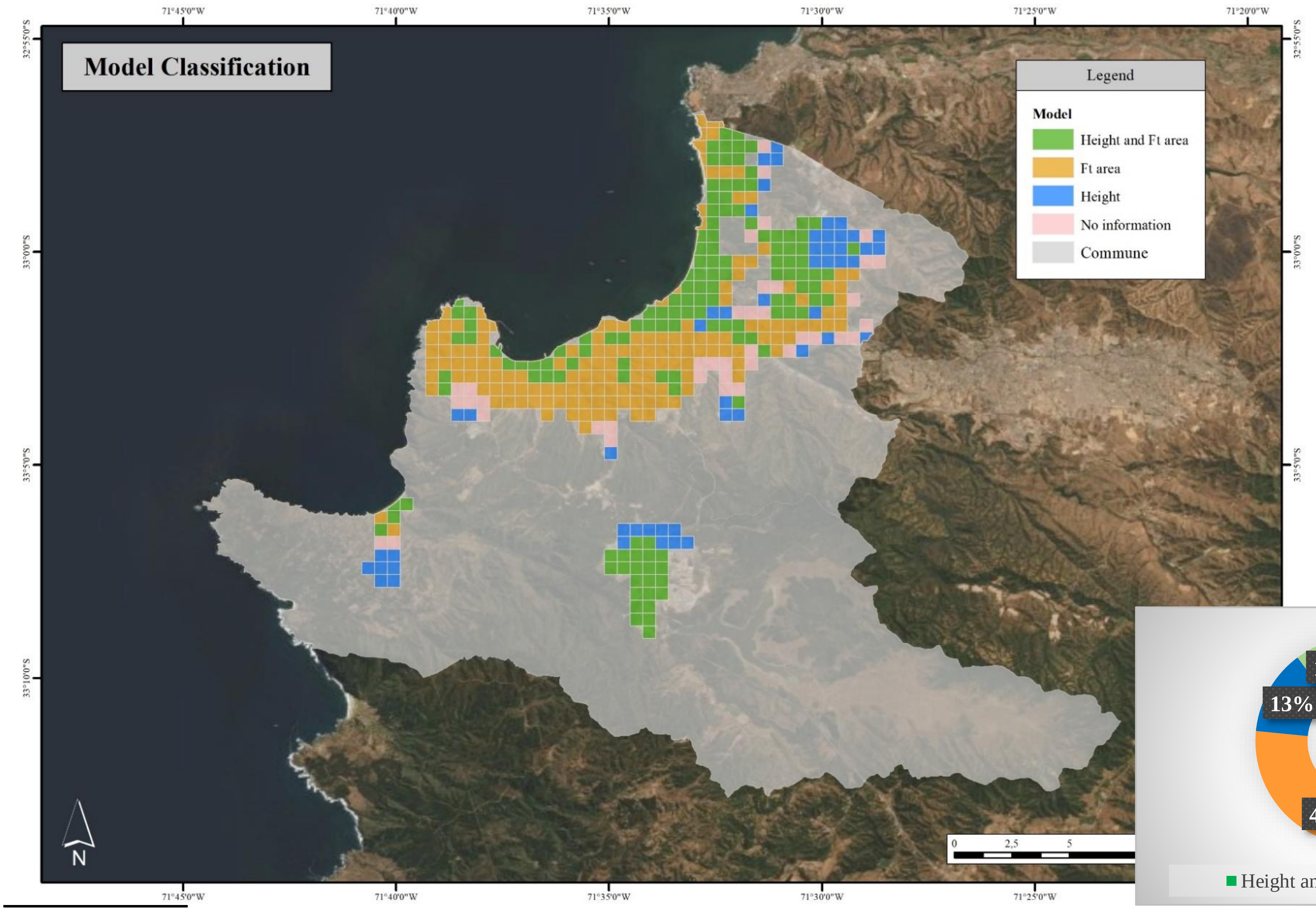
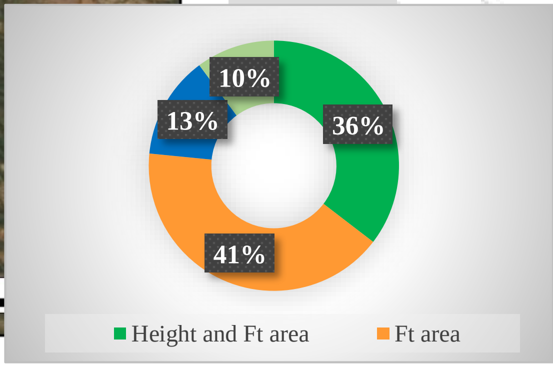
2. INTEGRATION INFORMATION – REGULAR GRID CELLS





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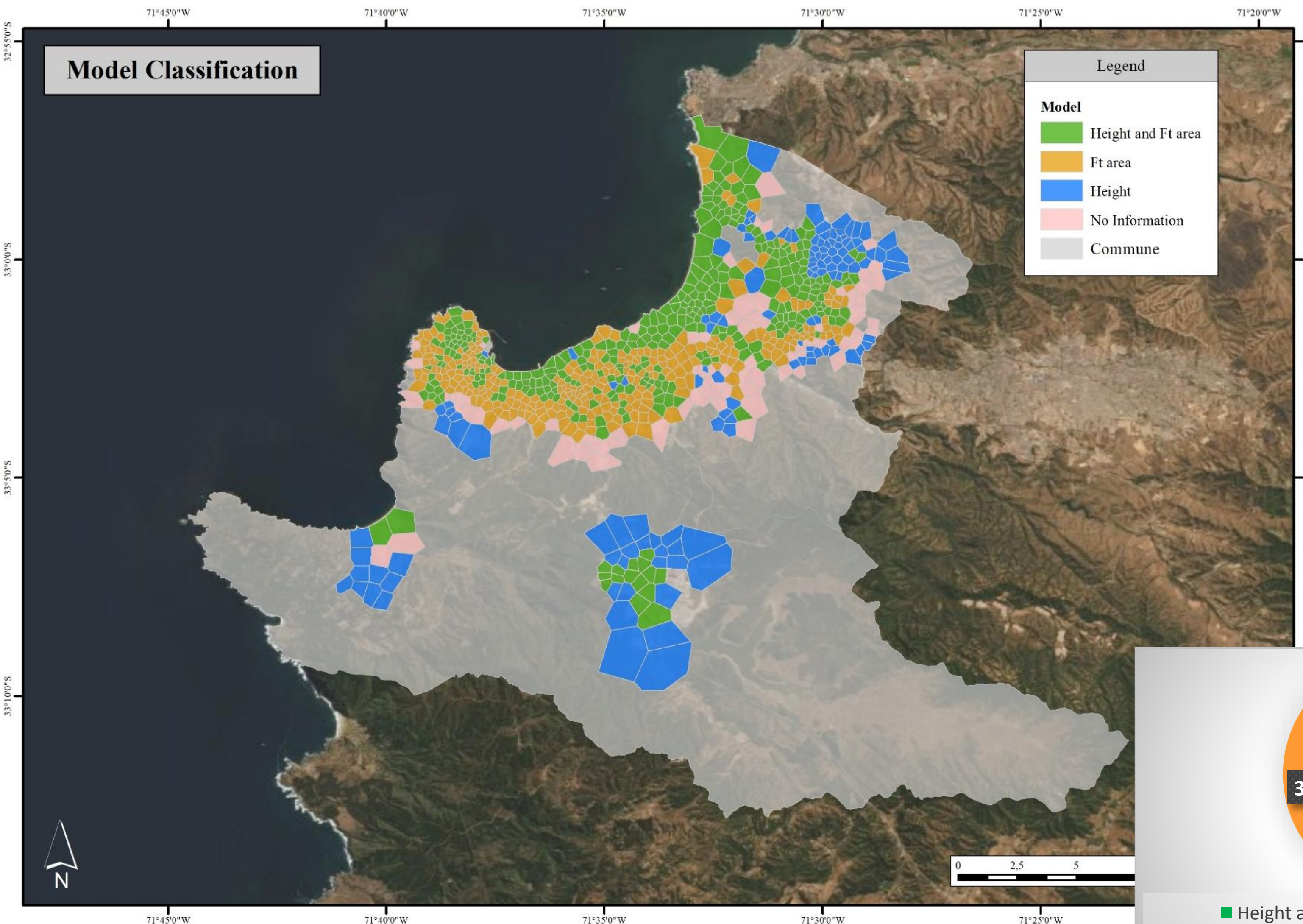
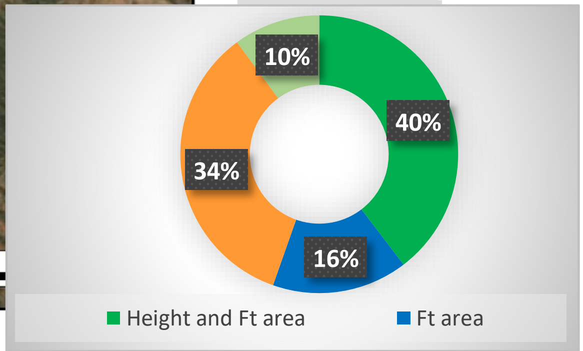
2. INTEGRATION INFORMATION – CENTRAL VORONOI TESSELLATIONS





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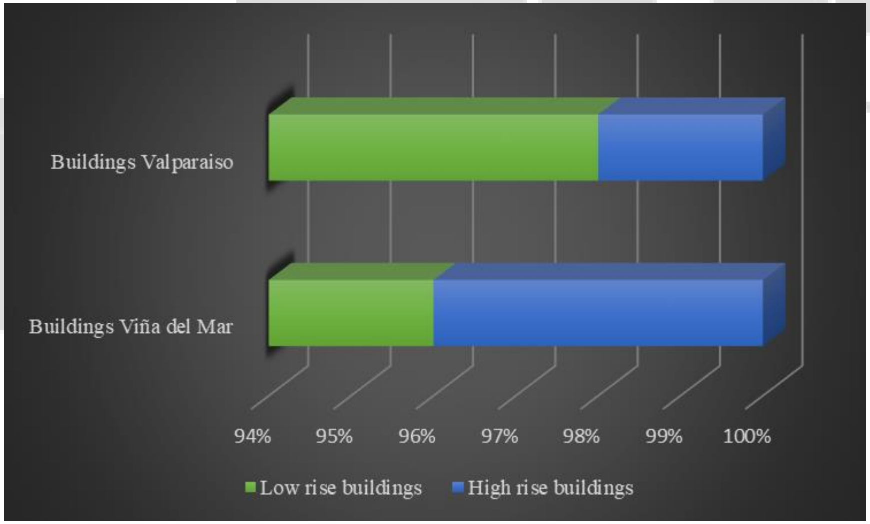
1. INITIAL EXPOSURE MODEL

The initial model of exposure assigns to the grid cells and tessellations the original information of exposure coming from the reduced SARA exposure model. This model will represent the direct downscaling of the model without any probabilistic approach, just considering the information provided as it is and relating it with the available information from the census data.



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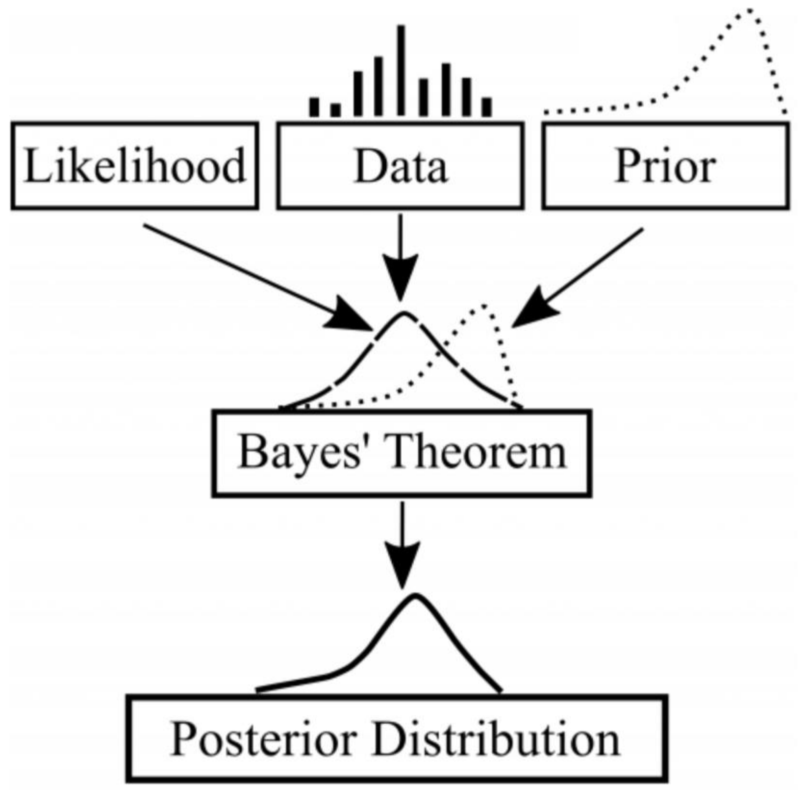
2. PROBABILISTIC EXPOSURE MODEL

Bayes' theorem is used to update the probability for a hypothesis as more evidence or information becomes available.



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2. PROBABILISTIC EXPOSURE MODEL

$$P(A|B) = \frac{P(B|A)P(B)}{P(A)}$$

$P(A|B)$ = Conditional probability of event A occurring given that B is true

$P(B|A) =$ Conditional probability of event B occurring given that A is true

P(A) and P(B) probabilities of observing A and B without conditioning each other

Posterior **Likelihood** **Prior**

$$P(Model|Observed\ Data) = \frac{P(Observed\ Data|Model)\ P(Model)}{P(Observed\ Data)}$$

Observable

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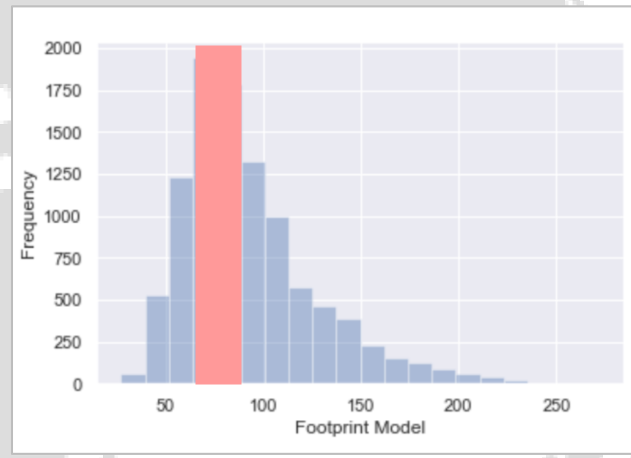
2.1 PROBABILISTIC EXPOSURE MODEL FOOTPRINT AREA

Observed data
Mean Footprint area = 81 m^2

Mean footprint area distribution



How likely will it be to observe the mean footprint area (81 m^2) given the ϑ low rise buildings model?

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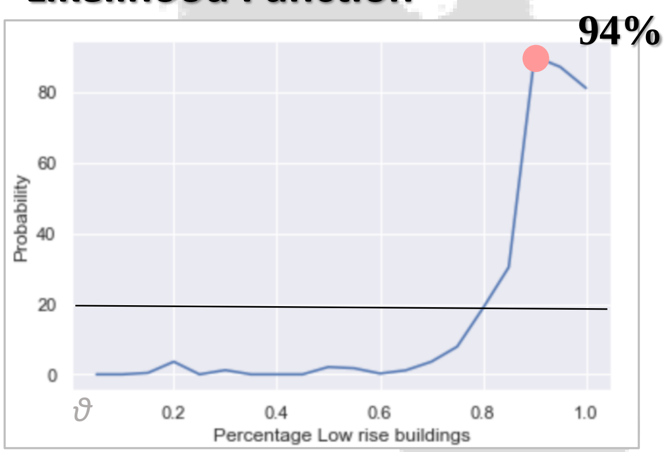
2.1 PROBABILISTIC EXPOSURE MODEL FOOTPRINT AREA

$$Mean\ footprint\ model = \sum_{i=1}^{k} \theta_i * ftp_{bi}$$

Likelihood Function

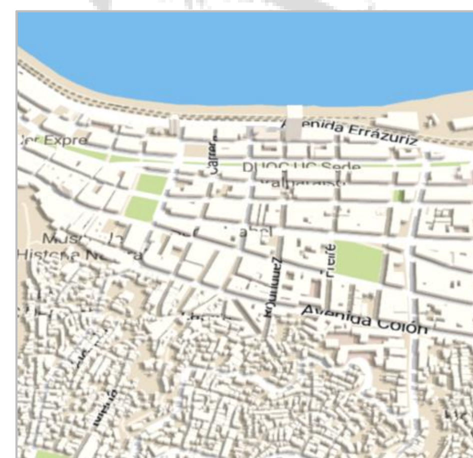


Maximum Likelihood

$$\vartheta = \underset{\vartheta}{\operatorname{argmax}}(P(\vartheta|obs) = \underset{\vartheta}{\operatorname{argmax}}\left(\frac{P(obs|\vartheta)P(\vartheta)}{P(obs)}\right)$$

$$\vartheta = \underset{\theta}{\operatorname{argmax}}(P(\vartheta|obs) = \underset{\theta}{\operatorname{argmax}}\left(P(obs|\vartheta)\right)$$

Observed data
Mean Footprint = 81 m^2
Previous ϑ value = 98%
Updated ϑ value = 94%



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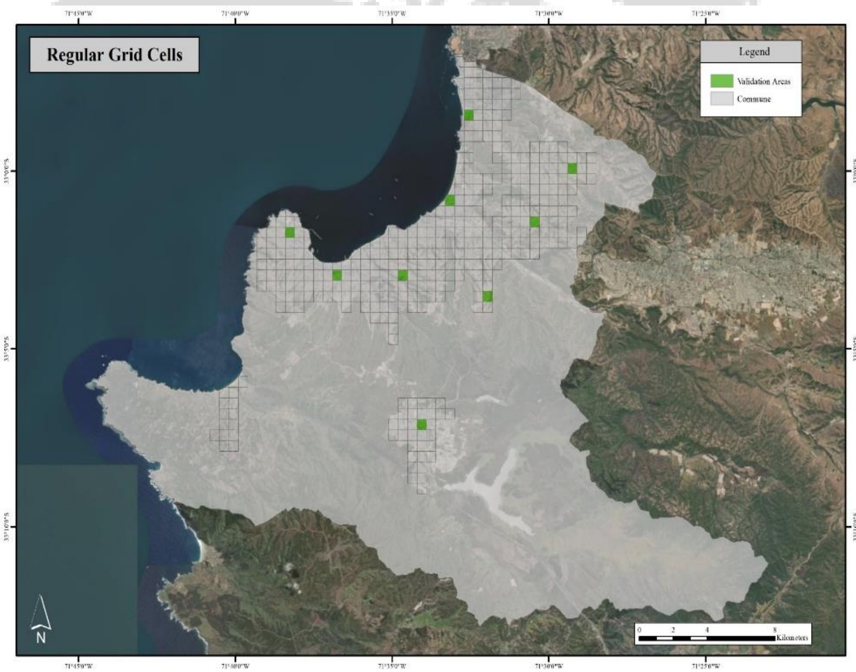
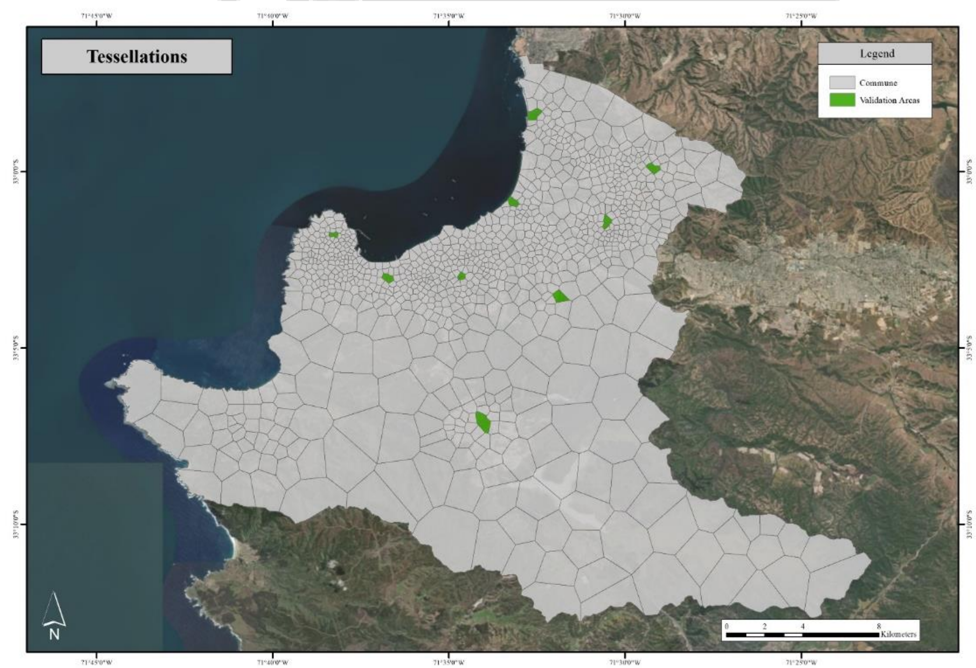
3. PRELIMINARY MODEL VALIDATION

REGION VALIDATION





Regular grid cells

Central Voronoi Tessellations

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RESULTS

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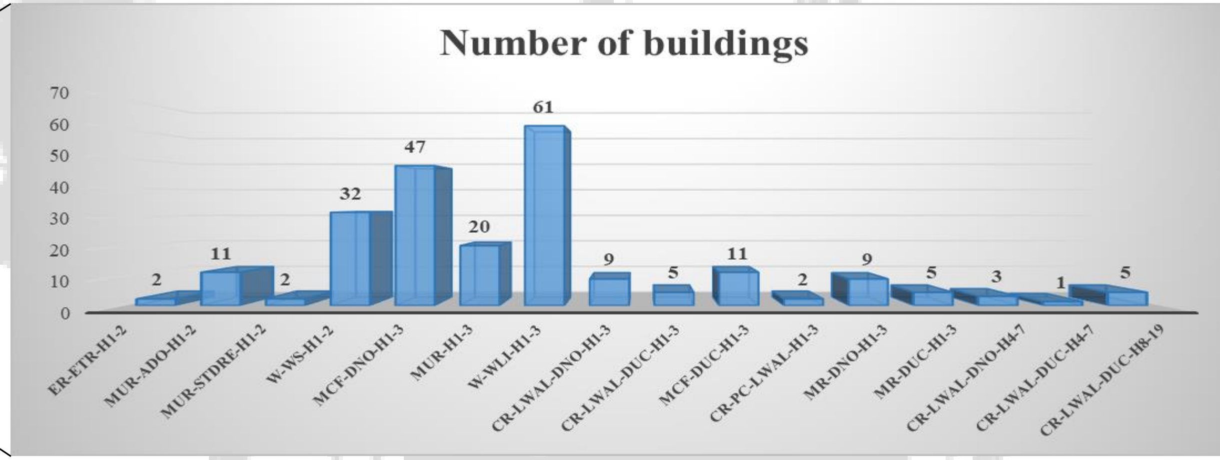

Typology	Number of buildings	Viña del Mar	Rise	
ER-ETR-H1-2	2	1%	96%	Low-rise buildings
MUR-ADO-H1-2	11	5%		
MUR-STDRE-H1-2	2	1%		
W-WS-H1-2	32	14%		
MCF-DNO-H1-3	47	21%		
MUR-H1-3	20	9%		
W-WLI-H1-3	61	27%		
CR-LWAL-DNO-H1-3	9	4%		
CR-LWAL-DUC-H1-3	5	2%		
MCF-DUC-H1-3	11	5%		
CR-PC-LWAL-H1-3	2	1%		
MR-DNO-H1-3	9	4%		
MR-DUC-H1-3	5	2%		
CR-LWAL-DNO-H4-7	3	1,4%	4%	High-rise buildings
CR-LWAL-DUC-H4-7	1	0,6%		
CR-LWAL-DUC-H8-19	5	2%		

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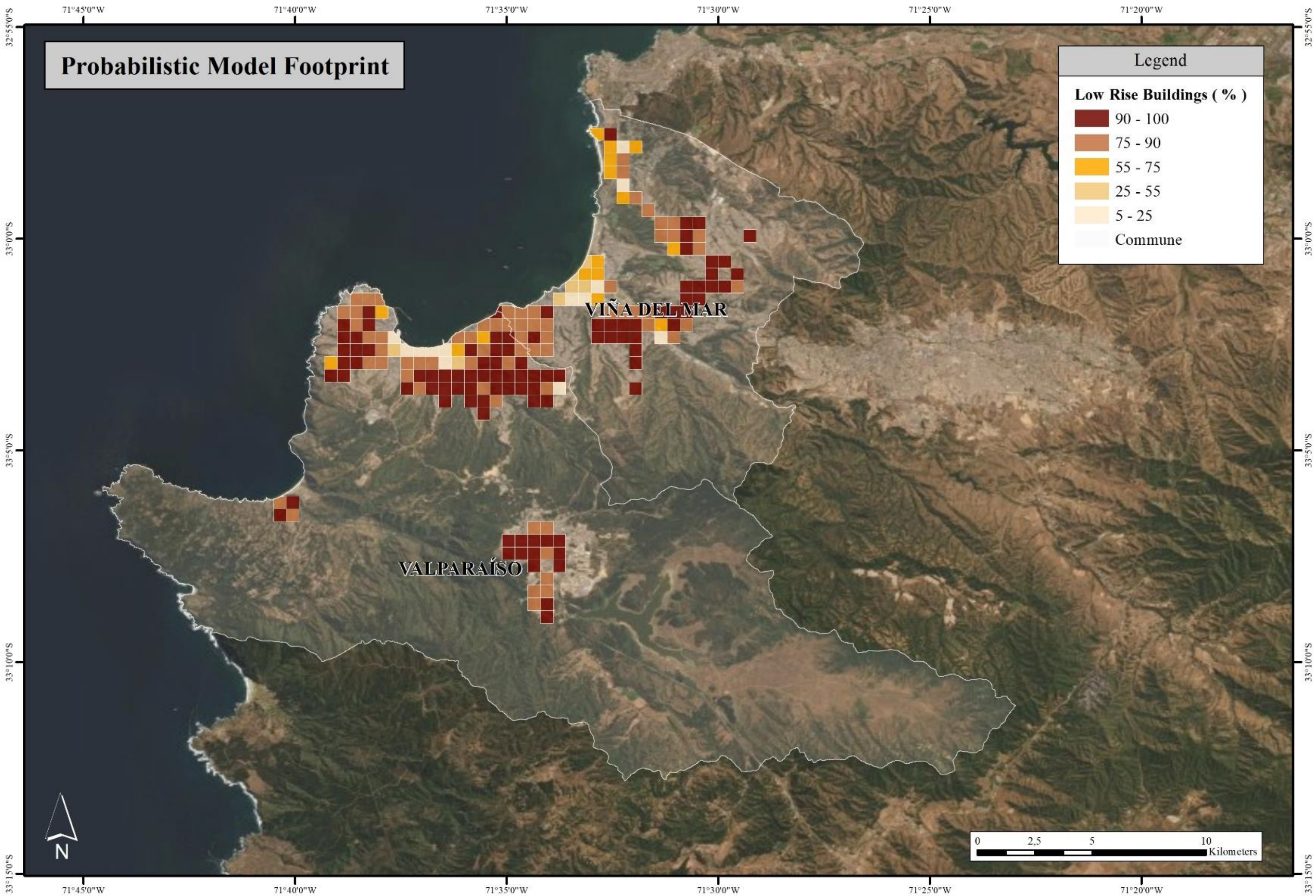
PROBABILISTIC EXPOSURE MODEL CONSTRAINED BY FOOTPRINT AREA



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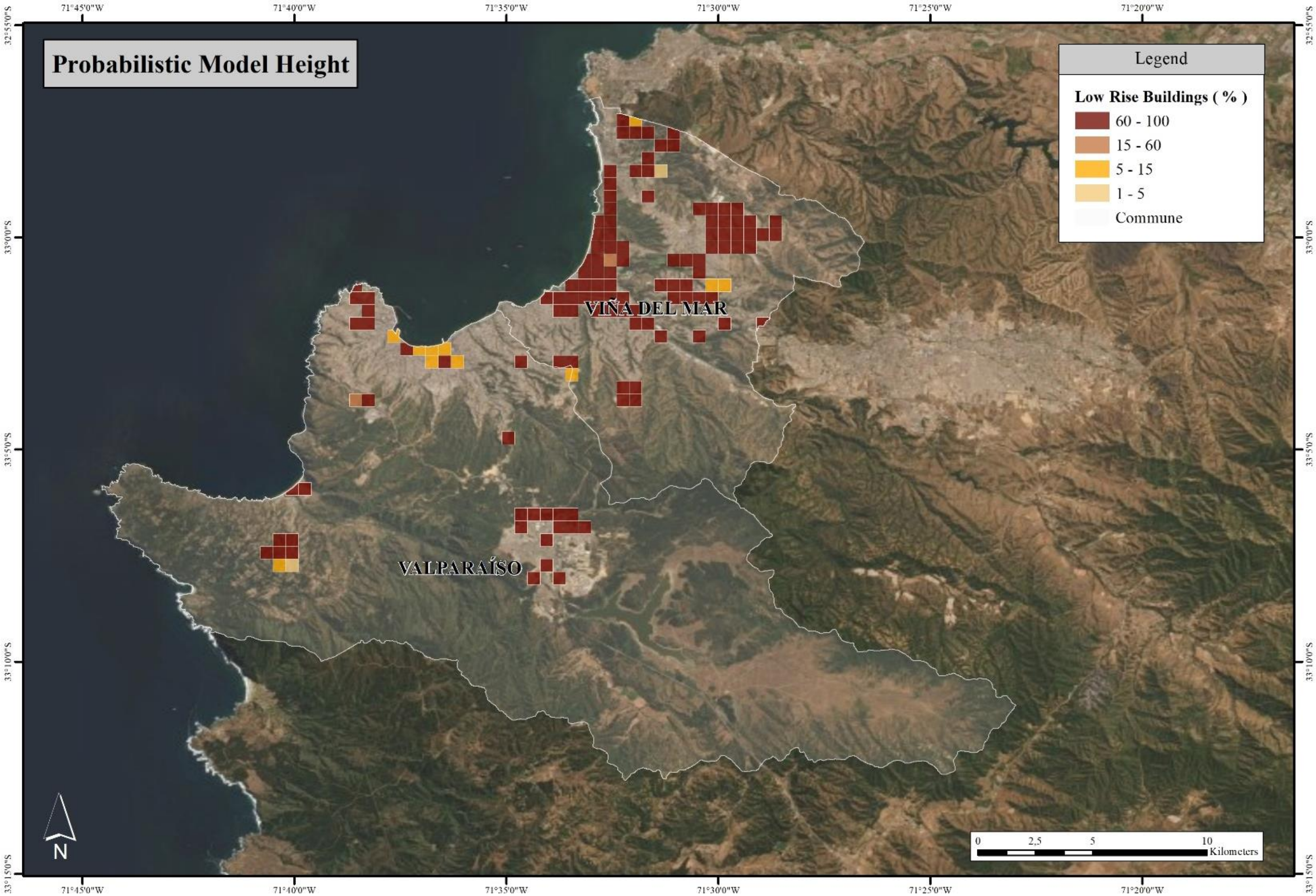
PROBABILISTIC EXPOSURE MODEL CONSTRAINED BY BUILD-UP HEIGHT AND DENSITY



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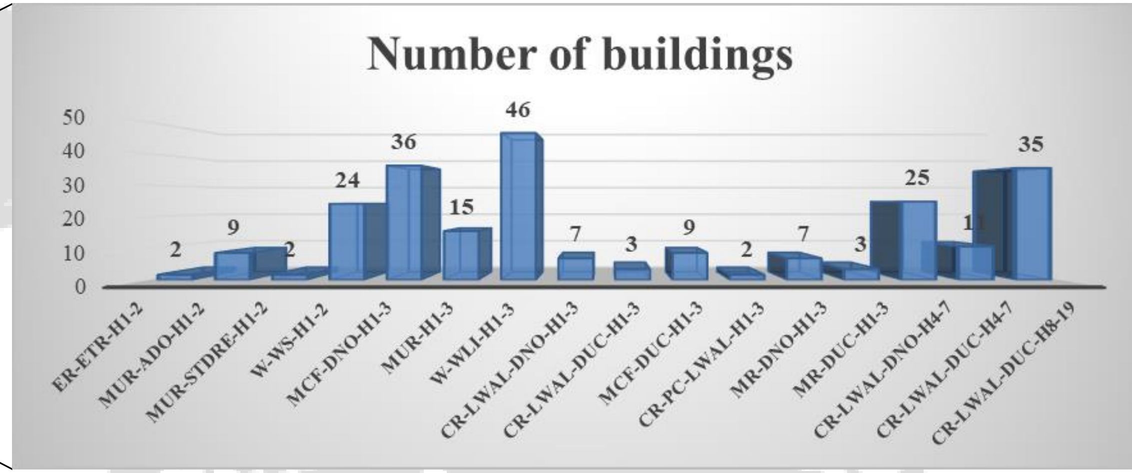

Typology	Number of buildings	Viña del Mar	Rise	
ER-ETR-H1-2	2	1%	70%	Low-rise buildings
MUR-ADO-H1-2	9	4%		
MUR-STDRE-H1-2	2	1%		
W-WS-H1-2	24	10%		
MCF-DNO-H1-3	36	15%		
MUR-H1-3	15	7%		
W-WLI-H1-3	46	20%		
CR-LWAL-DNO-H1-3	7	3%		
CR-LWAL-DUC-H1-3	3	1%		
MCF-DUC-H1-3	9	4%		
CR-PC-LWAL-H1-3	2	1%		
MR-DNO-H1-3	7	3%		
MR-DUC-H1-3	3	1%		
CR-LWAL-DNO-H4-7	25	11%	30%	High-rise buildings

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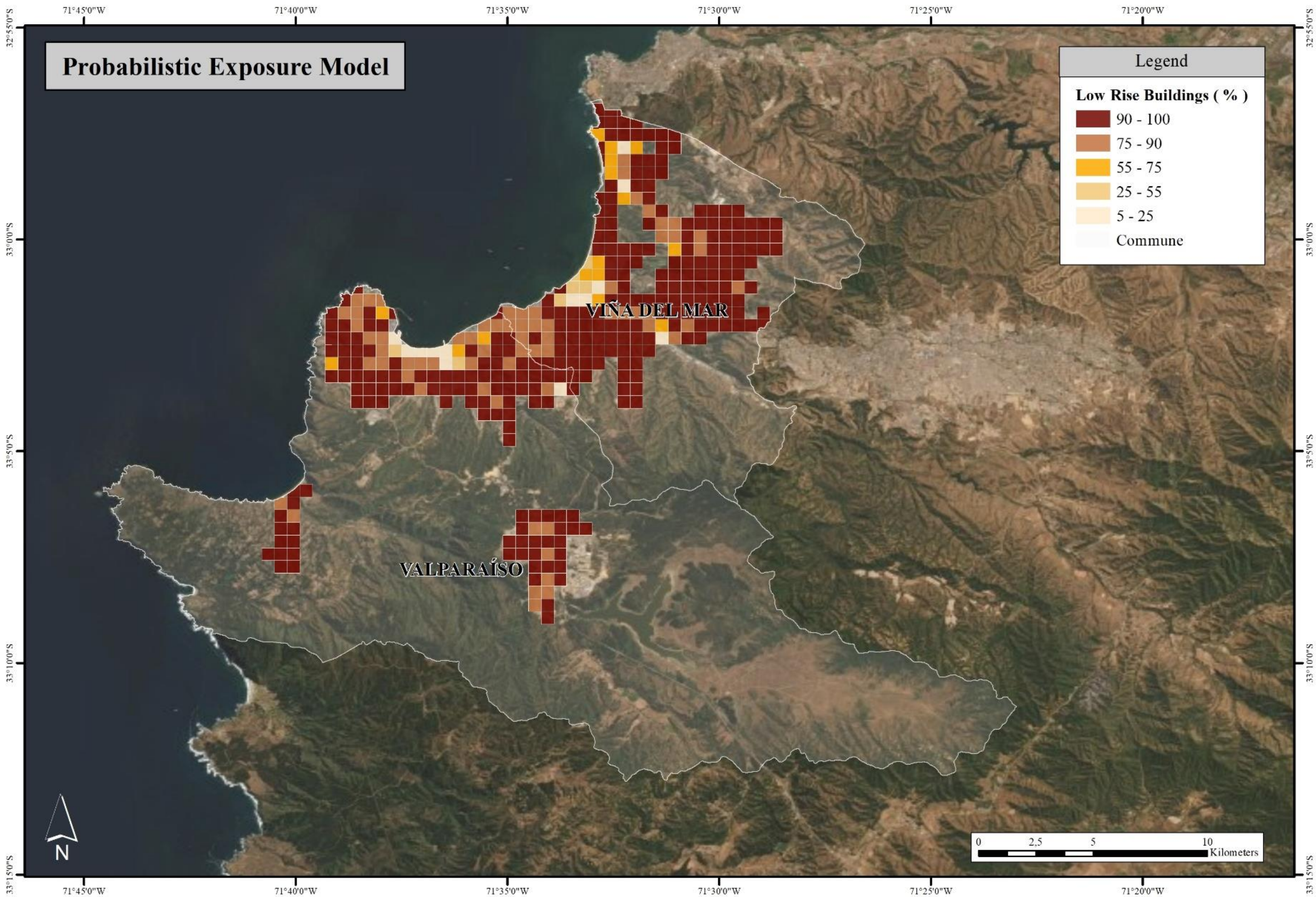

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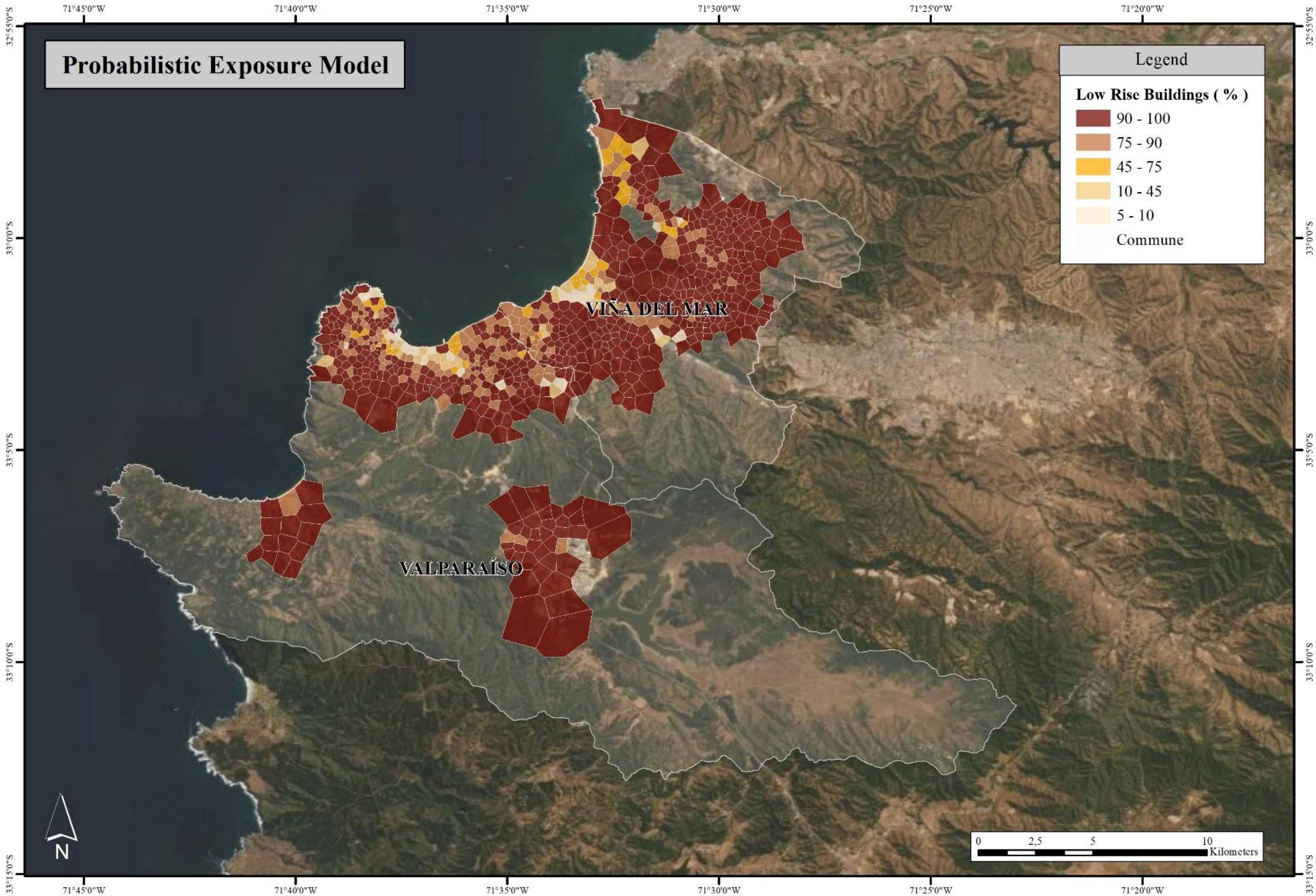

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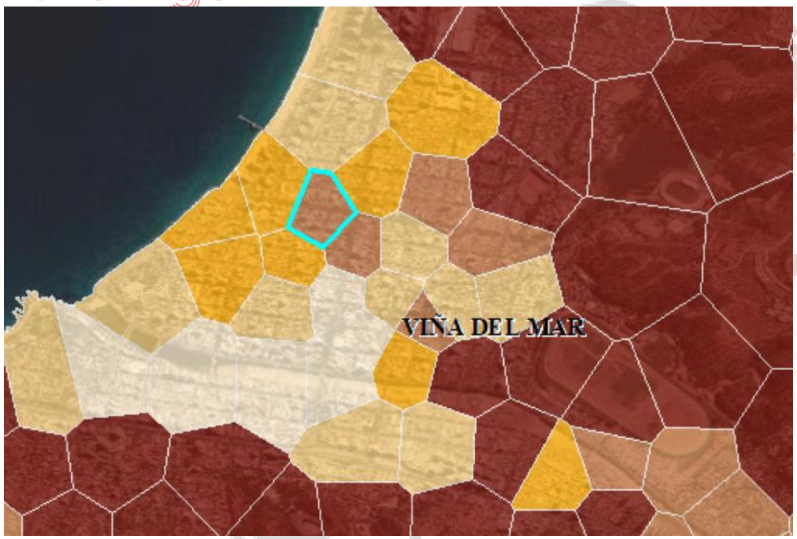
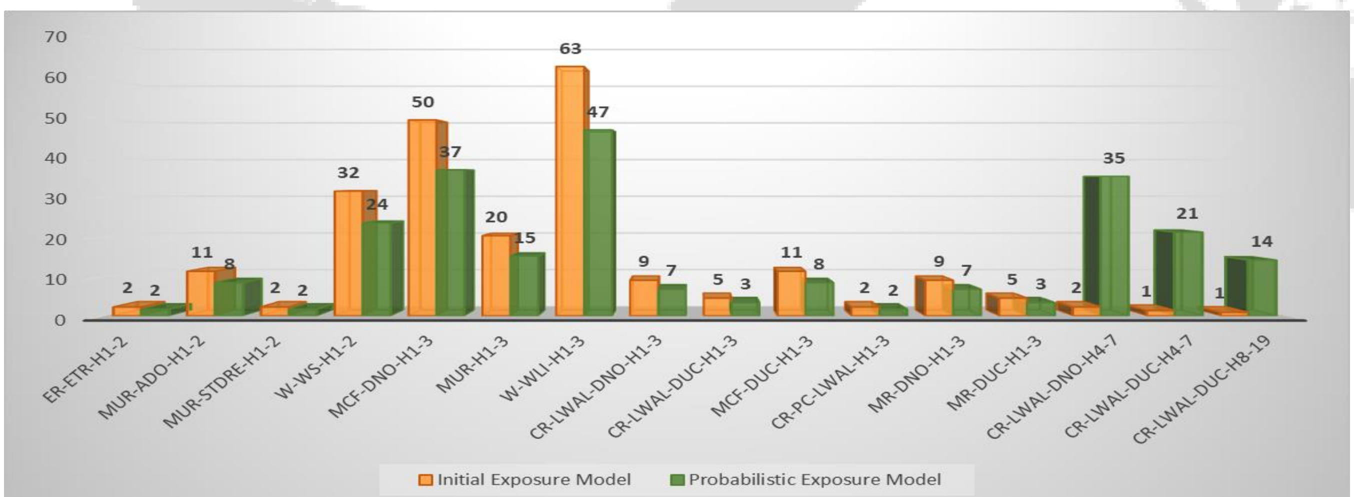


	Initial Exposure Model		Probabilistic Exposure Model	
Typology	**%**	**Rise**	**%**	**Rise**
ER-ETR	1%		1%	
MUR-ADO	5%		4%	
MUR-STDRE	1%		1%	
W-WS	14%		10%	
MCF-DNO	21%		15%	
MUR	9%		7%	
W-WLI	27%	96%	20%	70%
CR-LWAL-DNO	4%		3%	
CR-LWAL-DUC	2%		1%	
MCF-DUC	5%		4%	
CR-PC-LWAL	1%		1%	
MR-DNO	4%		3%	
MR-DUC	2%		1%	
CR-LWAL-DNO	1,40%		11%	
CR-LWAL-DUC	0,60%	4%	5%	30%
CR-LWAL-DUC	2%		15%	



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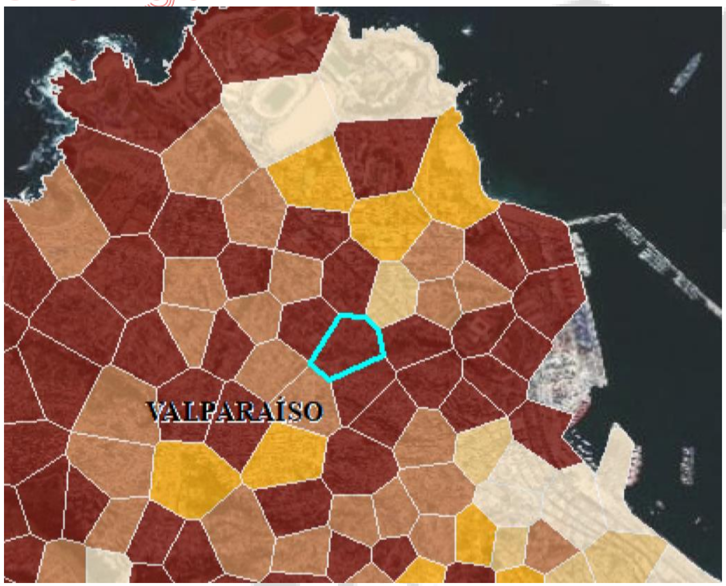
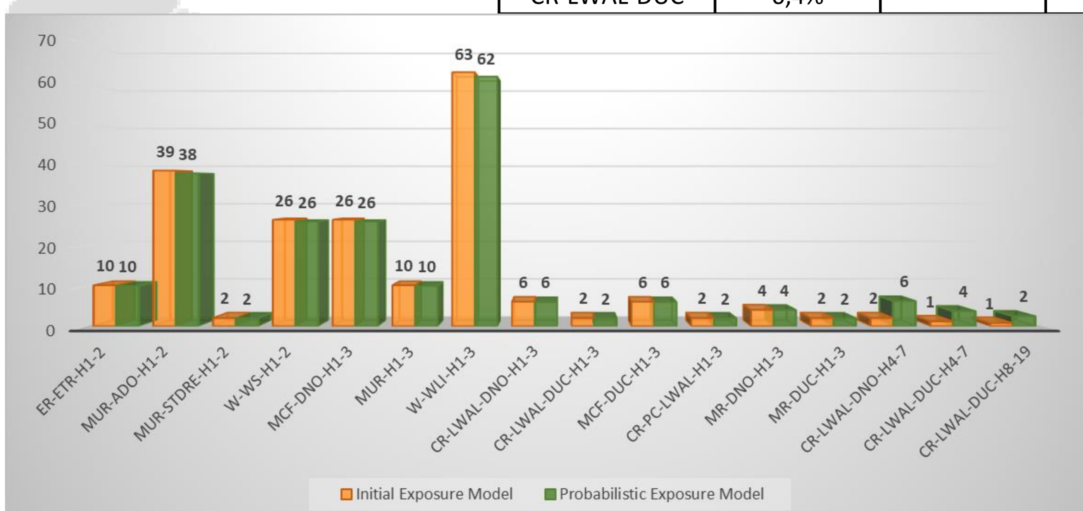


	Initial Exposure Model		Probabilistic Exposure Model	
Typology	**%**	**Rise**	**%**	**Rise**
ER-ETR	5%		5%	
MUR-ADO	19%		18%	
MUR-STDRE	1%		1%	
W-WS	13%		12%	
MCF-DNO	13%		12%	
MUR	5%		5%	
W-WLI	31%	98%	30%	94%
CR-LWAL-DNO	3%		3%	
CR-LWAL-DUC	1%		1%	
MCF-DUC	3%		3%	
CR-PC-LWAL	1%		1%	
MR-DNO	2%		2%	
MR-DUC	1%		1%	
CR-LWAL-DNO	1%		3%	
CR-LWAL-DUC	0,6%	2%	2%	6%
CR-LWAL-DUC	0,4%		1%	



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CONCLUSIONS

- The downscaling of the already existing building exposure model based on a probabilistic approach with Bayesian updating is proposed.
- Exposure building models for risk and loss estimations are usually defined in terms of building classes to categorize the building inventory into particular schemas, aggregated over geographical units in this case in Commune administration level.
- Downscaling of exposure models can be characterized at different geographic representations and resolution, depending on the requirements of the risk study. In this thesis, the representation of the probabilistic models is carried out over two different types of spatial aggregations, regular grid cells and Central Voronoi Tessellations.

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CONCLUSIONS

- Using Central Voronoi Tessellations as a spatial representation can be advantageous as they can be used to provide higher spatial resolution in densely inhabited areas.
- The model has been initialized using a set of proportions coming from the already existing aggregated building exposure model. These proportions are updated using Bayesian methodology with the integration of field observations as evidence. Different resulting models considering remote sensing products, and open-source volunteered geoformation have been developed and tested.
- The combination of an heterogeneous spatial aggregation and Bayesian updating approach gives the possibility to work with adaptive exposure models that dynamically integrate observed field data with a probabilistic approach within the framework of risk assessment.

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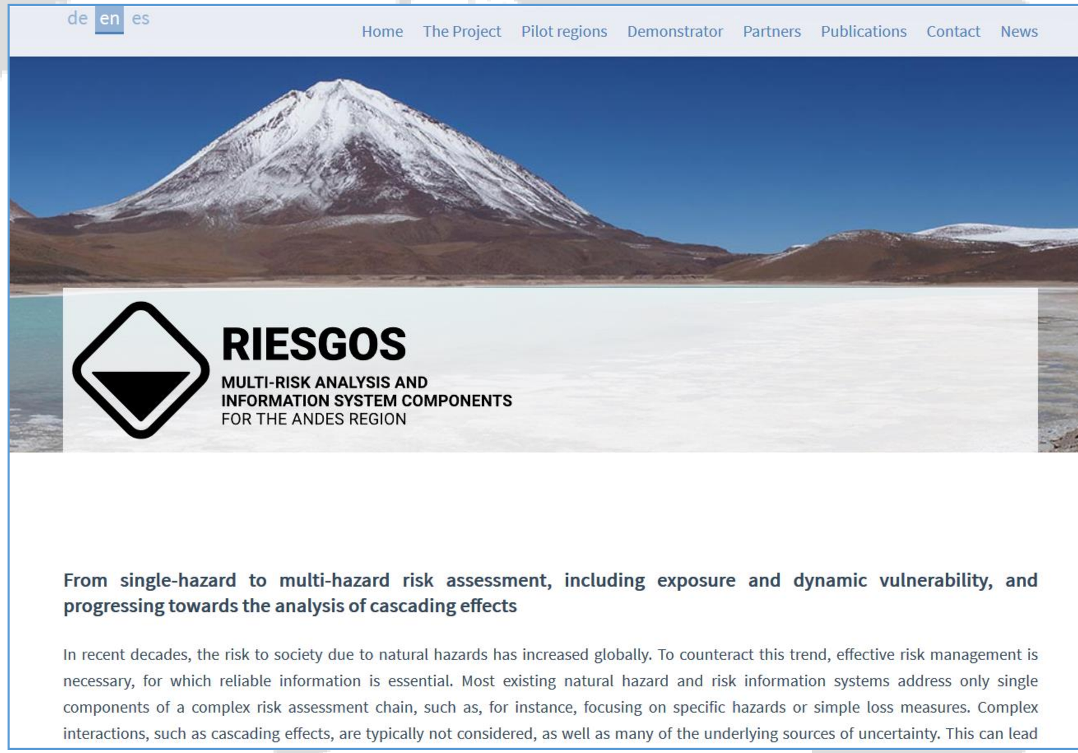

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