UNIVERSITY OF TWENTE.

USING AGENT-BASED MODELING FOR HURRICANE SHELTER PLANNING IN DOMINICA

PRESENTATION – THESIS DEFENSE

MARTIN HILLJEGERDES, MSC CARTOGRAPHY, ITC TWENTE

CONTENT

OVERVIEW

- Introduction and Problem Statement
- Research Identification and Objectives
- Study Area and Data Description
- Methodology
- Results
- Discussion
- Conclusion and Future Research

INTRODUCTION

USING AGENT-BASED MODELING FOR HURRICANE SHELTER PLANNING

theguardian.com 2017
30 Sep 2017

INTRODUCTION

MOTIVATION AND PROBLEM STATEMENT

- **Natural hazards** pose risk to many regions
- Caribbean islands are **exposed** to natural risk, yet **not resilient**
- **Climate change** might lead to more severe phenomena
- Need to raise the islands **preparedness and resilience**
- From response and recovery to focus on **reduction of vulnerability**
- **Planning and organization** of shelters and evacuation routes

INTRODUCTION

MOTIVATION AND PROBLEM STATEMENT

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RESEARCH IDENTIFICATION

MAIN OBJECTIVE

MAIN OBJECTIVE

Develop a system that facilitates the combined analysis of infrastructure disturbances and evacuation behavior for planning purposes

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RESEARCH IDENTIFICATION

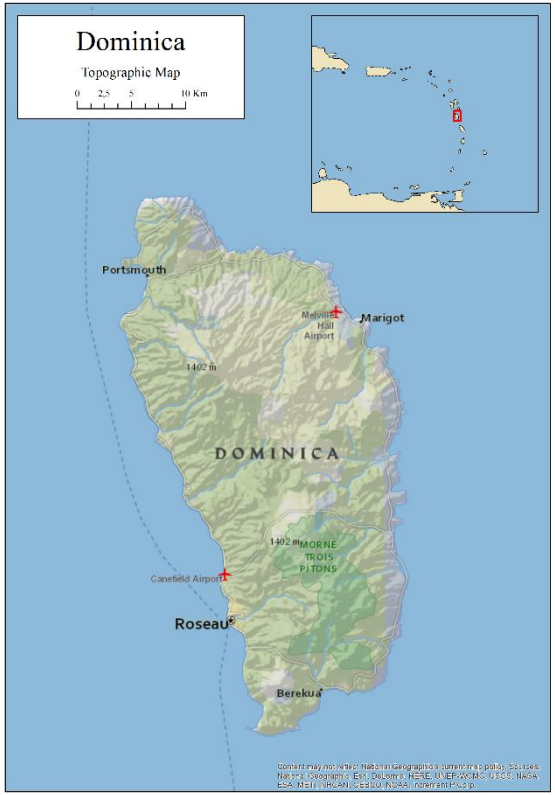
SUB-OBJECTIVES

SUB-OBJECTIVES

- Creation of a model that integrates infrastructure disturbances and people‘s behaviour in an evacuation event
- Evaluation of the visualization of the model outcome

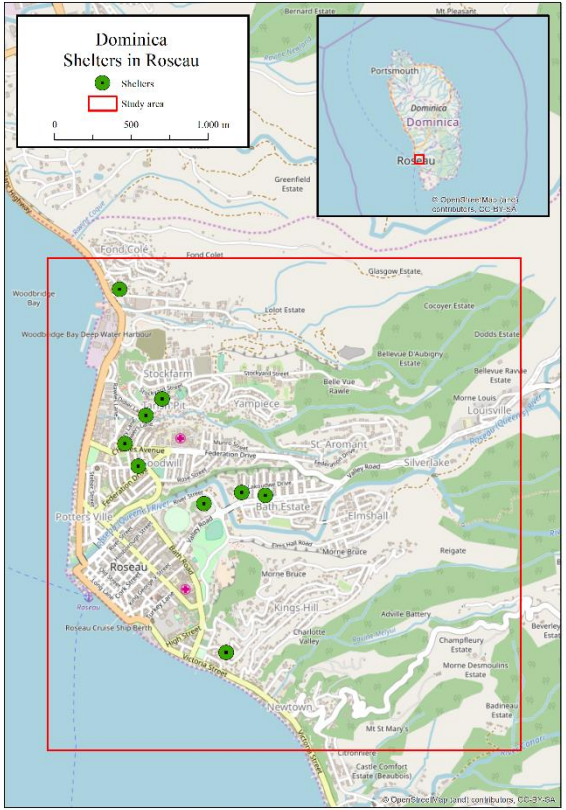
STUDY AREA AND DATA

STUDY AREA - INTRODUCTION



STUDY AREA AND DATA

STUDY AREA - SHELTERS



STUDY AREA AND DATA

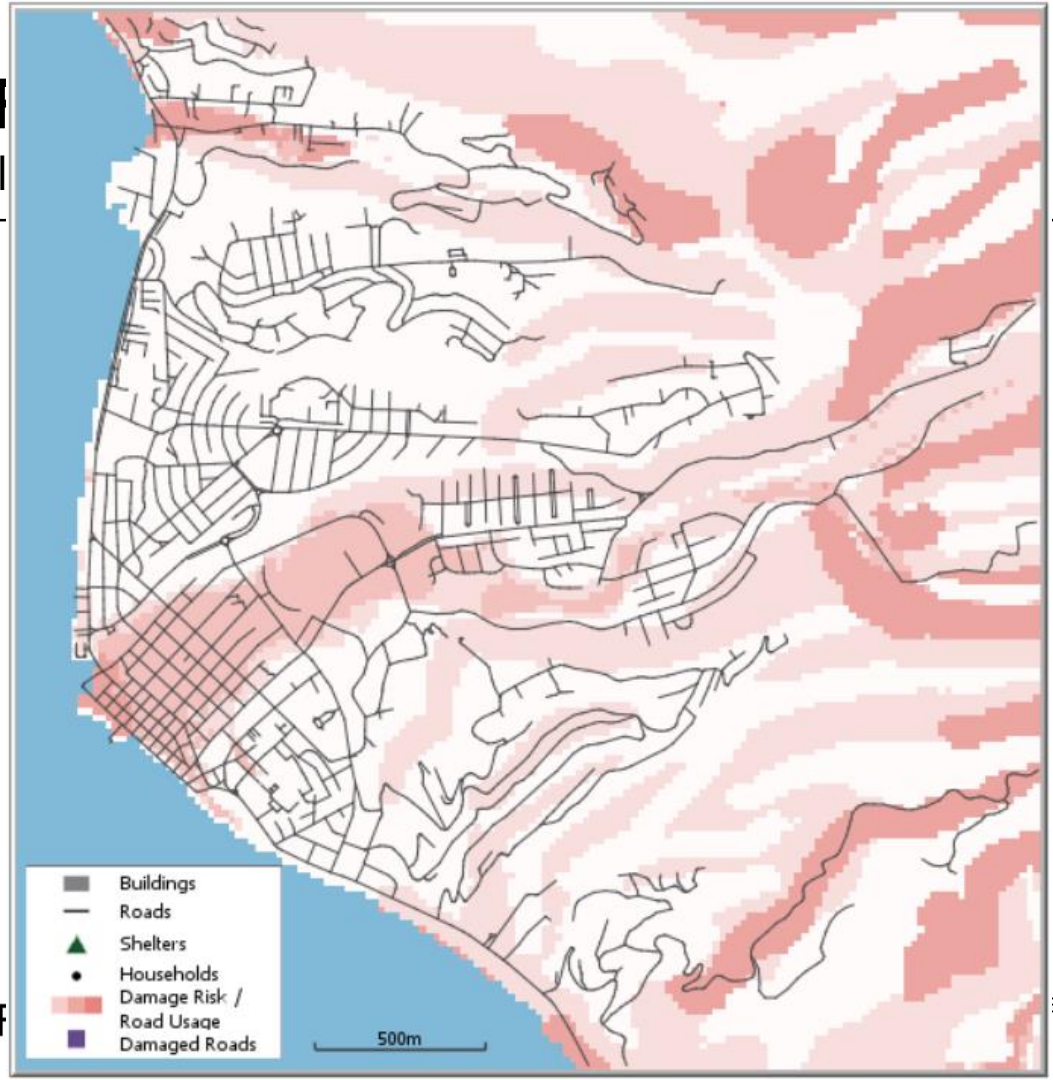
DATA DESCRIPTION

- Shelter data (CHARIM)
- Road data (OSM – updated by HOT)
- Building data (OSM)
- Risk zones (adapted from CHARIM)

Risk zone definition		Flood hazard extent				
		none	1:50 year rainfall	1:20 year rainfall	1:10 year rainfall	1:5 year rainfall
Landslide susceptibility	low	0	1	1	2	3
	medium	1	2	2	2	3
	high	3	3	3	3	3

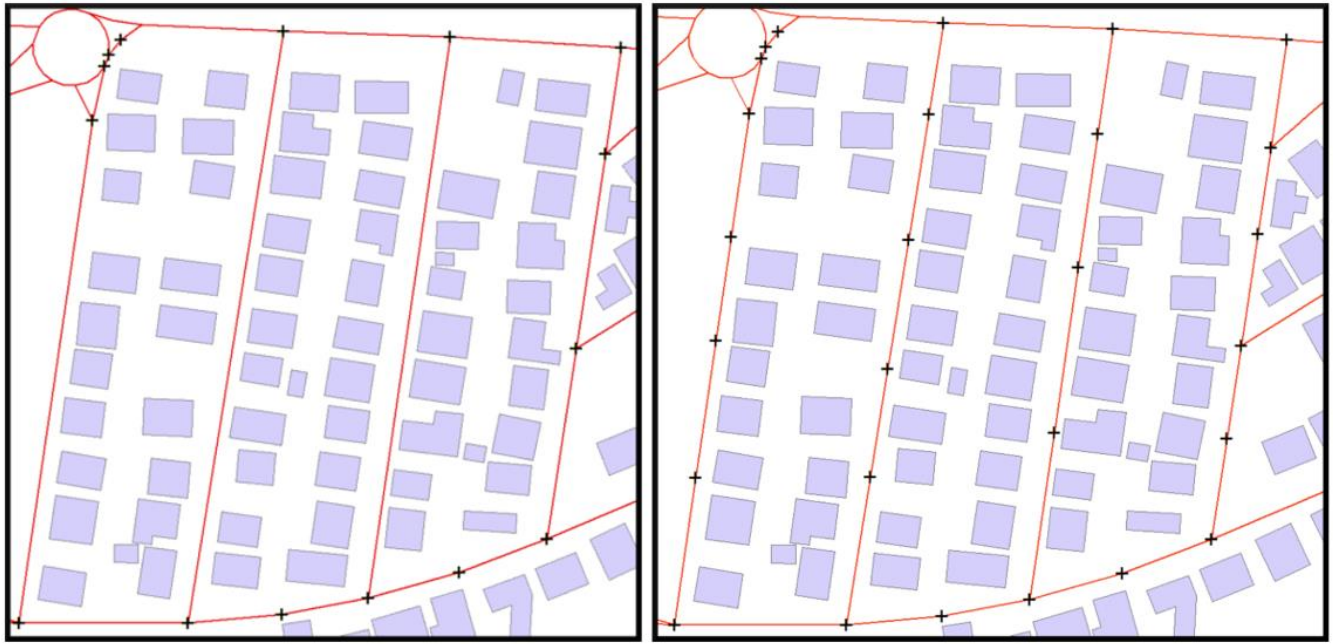
STUDY AI

DATA DESCRI



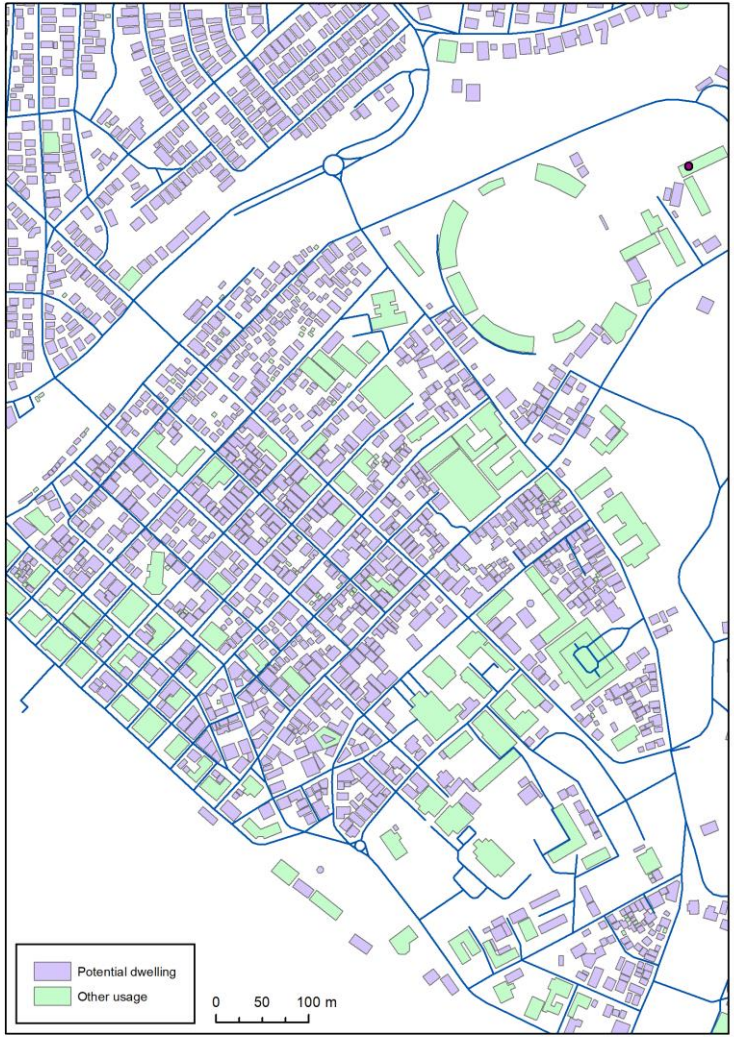
STUDY AREA AND DATA

DATA EDITING



STUDY AR

DATA EDITING



METHODOLOGY

OVERVIEW

- Model Description (Conceptual)
- Model Implementation (Technical)
- Interface and Visualization Considerations

METHODOLOGY

CONCEPTUAL MODEL I

- Entities overview
  - Households
    - Dynamic, moving agents
  - Roads (Nodes)
    - Defining road network – Network based routing
  - Shelters
    - Defining destination
  - Buildings
    - Defining homes / dwellings
  - Risk zones
    - Used for simulating road damages

METHODOLOGY

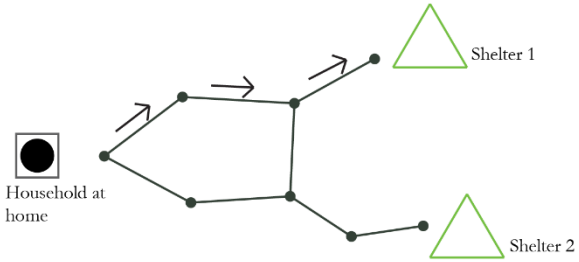
CONCEPTUAL MODEL II

Model phase	Concept
0	**Evacuation phase.** Population moving to shelters. Time concept: By second.
1	**Event phase.** Population in shelters. Hurricane active, damages to roads. Time concept: Abstract
2	**Post event phase.** Population returning home. Time concept: By second.
3	**Phase between events.** Population at home. Time concept: Abstract
4 to 6	Repetition of 1 to 3.
7	**Phase after second event.** Population at home.

METHODOLOGY

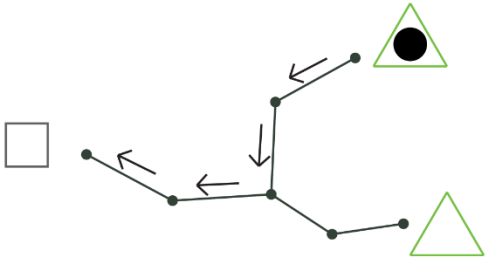
CONCEPTUAL MODEL III

Evacuation before event 1



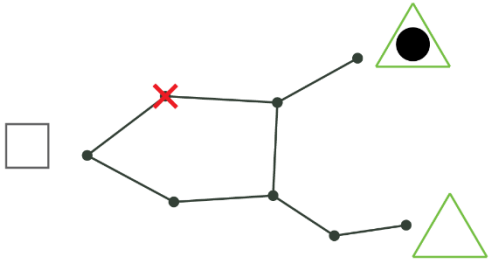
- Household agent moves from home to shelter, using the optimal route

Returning home after event 1



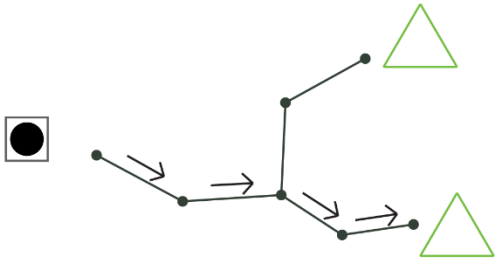
- The household moves home, adapting its route

Event 1



- During the event, damages may occur, disturbing the road network

Evacuation before event 2



- For the second event, a different shelter may be closer

... repeat step 1 - 3

METHODOLOGY

MODEL IMPLEMENTATION I

- Important procedures overview
  - Setup
  - Create-agents
  - Go (and move)
    - Model phases...
  - Calculate-path

METHODOLOGY

MODEL IMPLEMENTATION II

- Logic of implementation

Model phase	Procedures	Description
before	setup	Loading data and setting up environment.
before	create-agents	Creation of household agents, including first path calculation.
0	move	Household agents moving to shelters.
1	count-shelter-1, damage-to-nodes, calculate-path-home	Counting number of households per shelter. Causing damage to road network. Path home is calculated.
2	move-back	Household agents moving back home.
3	calculate-path	Household agents calculate path from home to shelter.
4	move	Household agents moving to shelters.
5	count-shelter-2, damage-to-nodes, calculate-path-home	Counting number of households per shelter. Causing damage to road network. Path home is calculated.
6	move-back	Household agents moving back home.

METHODOLOGY

INTERFACE CONSIDERATIONS

- Users‘ needs
  - Organization, arrangement and grouping of elements/functions
  - Clear communication of interactive elements
  - Additional monitors and plots
- Using NetLogo‘s interface options

METHODOLOGY

VISUALIZATION CONSIDERATIONS

- Visualization of geospatial elements in NetLogo‘s model view
- Considerations
  - Distinguishable entities
  - Changes over time, dynamics, easy to follow and perceptible
- After simulation run...
  - ...Results (patterns) should be perceived easily
- Cartographic elements
  - Spatial scale and legend

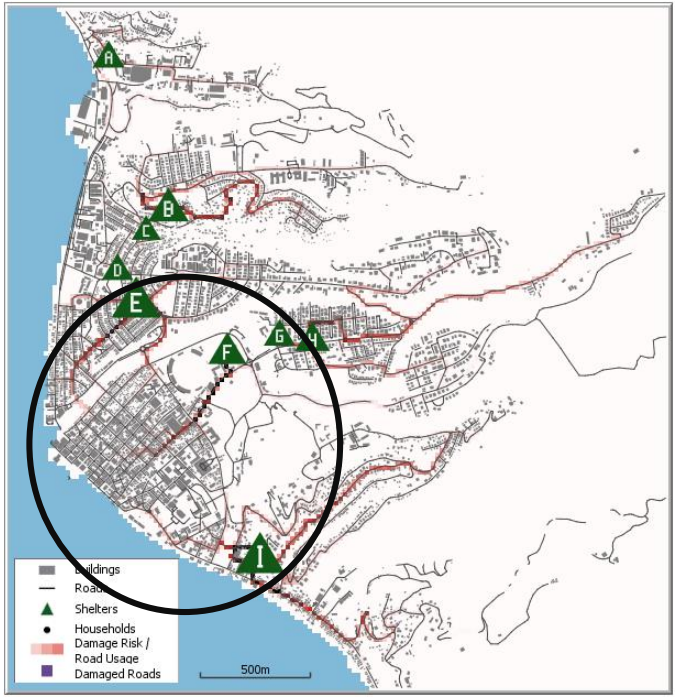
METHODOLOGY

FINAL VERSION

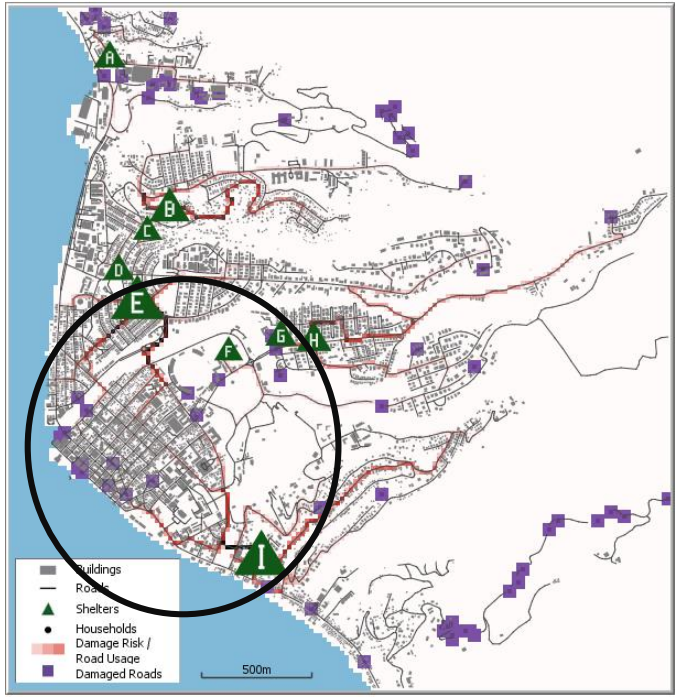
- Demo video of a simulation run
- Access link: https://youtu.be/4C-LH_g--As

RESULTS

MODEL RESULTS I



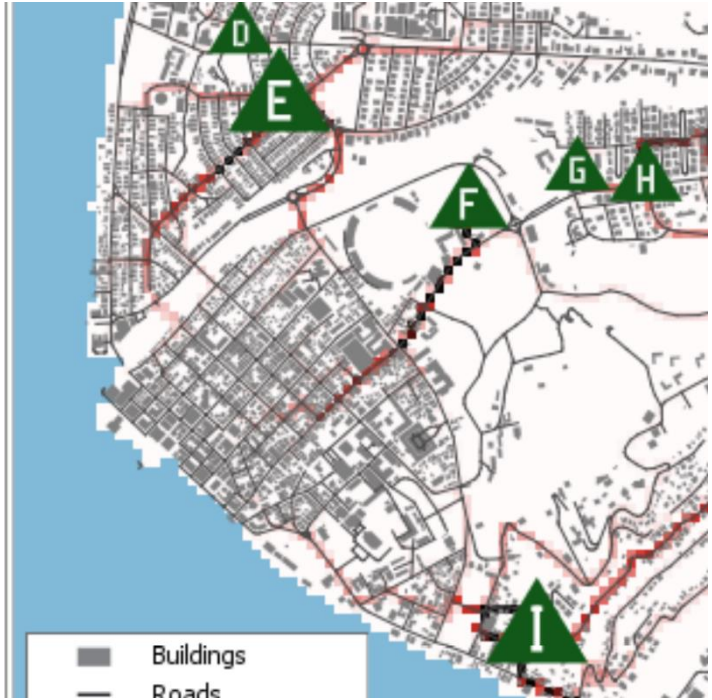
Road usage Evacuation 1



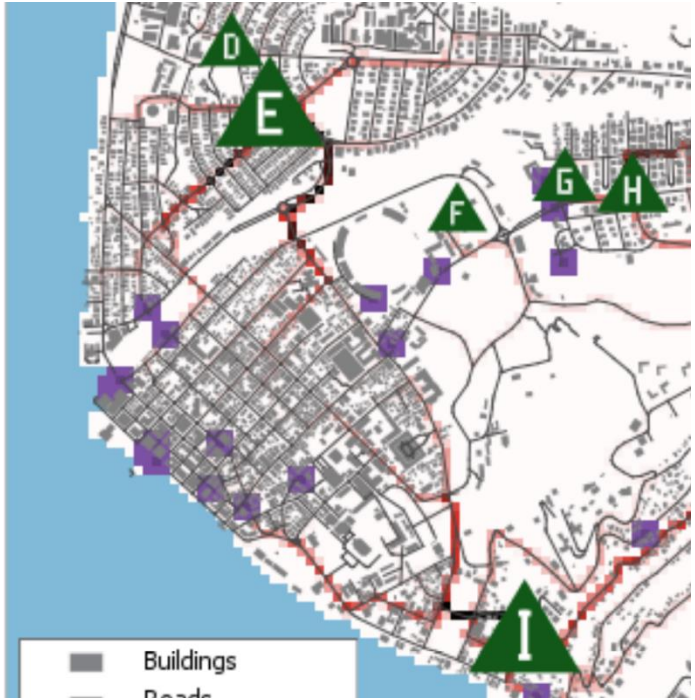
Road usage Evacuation 2

RESULTS

MODEL RESULTS I



Road usage Evacuation 1



Road usage Evacuation 2

RESULTS

MODEL RESULTS II

Result table: Households per shelter

Shelter	Event 1	Event 1 Percentage	Event 2	Event 2 Percentage	Tendency	Stuck in shelter
A	300	6	300	6	=	20
B	709	14,18	709	14,18	=	12
C	105	2,1	105	2,1	=	6
D	221	4,42	221	4,42	=	0
E	1146	22,92	1361	27,22	↑	60
F	595	11,9	85	1,7	↓	11
G	264	5,28	264	5,28	=	22
H	374	7,48	374	7,48	=	113
I	1203	24,06	1498	29,96	↑	34
Stuck home	83	1,66	83	1,66		

RESULTS

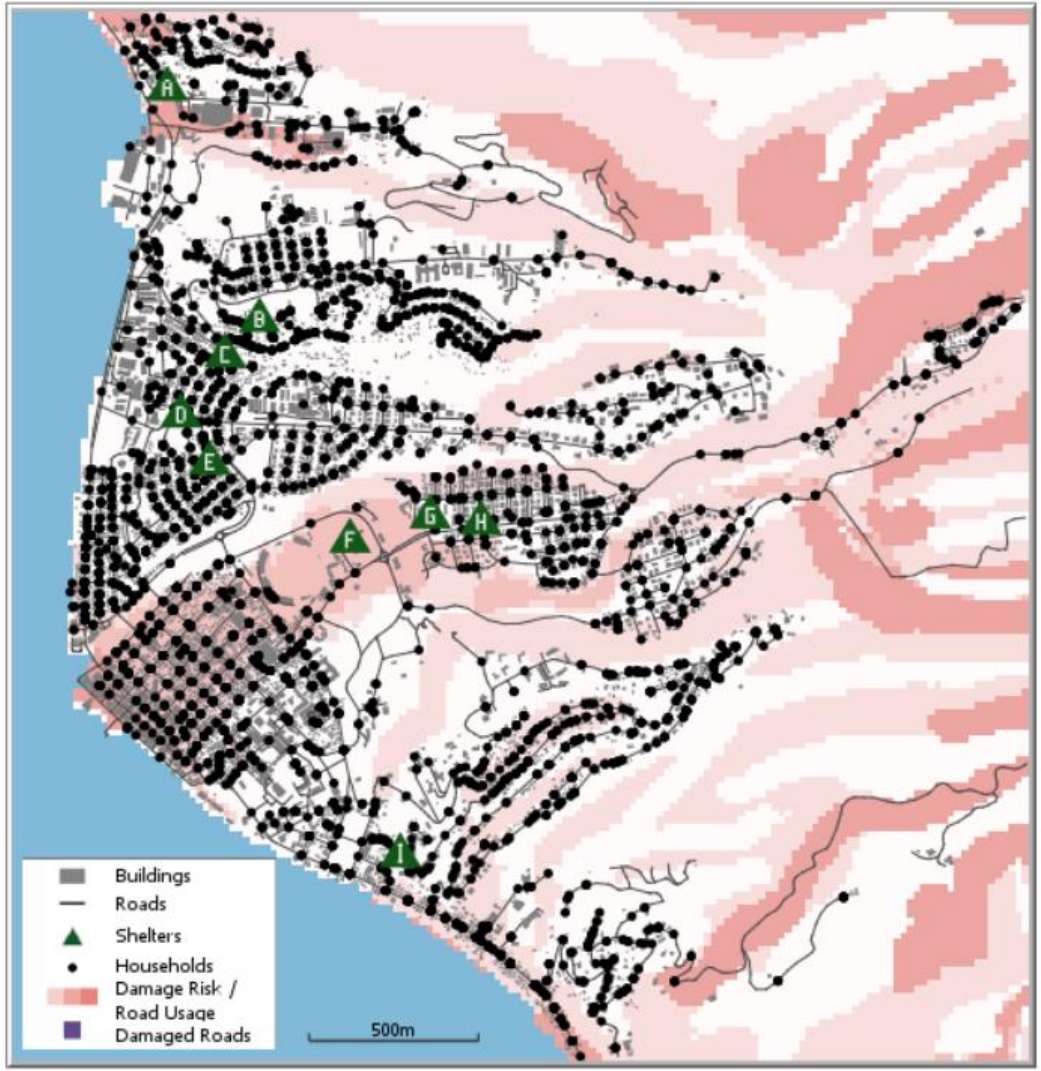
MODEL RESULTS III

- Summarizing - Comparing both evacuation events
  - Changes in the movement pattern were observed
  - Changes in shelter allocation were observed

- Changes in mean evacuation time were observed but...
  - Evacuation 1: 14:54 min (mean)
  - Evacuation 2: 14:20 min (mean)
  - Outliers!

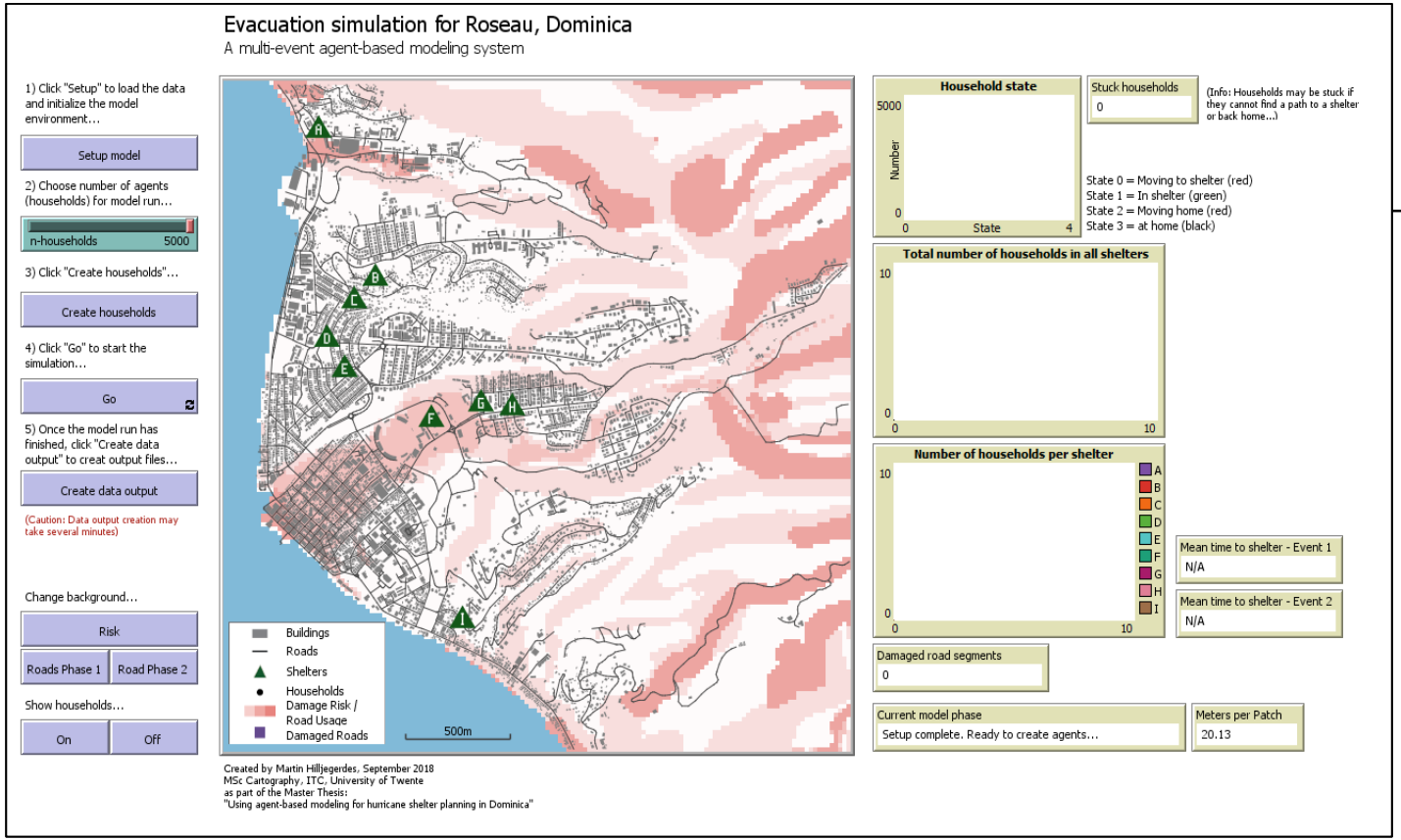
RESU

MODEL


A
B
C
D
E
F
G
H
I
Buildings
Roads
Shelters
Households
Damage Risk / Road Usage
Damaged Roads
500m

RESULTS

INTERFACE DESIGN


Evacuation simulation for Roseau, Dominica
A multi-event agent-based modeling system
1) Click "Setup" to load the data and initialize the model environment...
Setup model
2) Choose number of agents (households) for model run...
n-households 5000
3) Click "Create households"...
Create households
4) Click "Go" to start the simulation...
Go
5) Once the model run has finished, click "Create data output" to creat output files...
Create data output
(Caution: Data output creation may take several minutes)
Change background...
Risk
Roads Phase 1
Road Phase 2
Show households...
On
Off
Buildings
Roads
Shelters
Households
Damage Risk / Road Usage
Damaged Roads
500m
Household state
5000
Number
0
State
4
Stuck households
0
(Info: Households may be stuck if they cannot find a path to a shelter or back home...)
State 0 = Moving to shelter (red)
State 1 = In shelter (green)
State 2 = Moving home (red)
State 3 = at home (black)
Total number of households in all shelters
10
0
Number of households per shelter
A
B
C
D
E
F
G
H
I
Mean time to shelter - Event 1
N/A
Mean time to shelter - Event 2
N/A
Damaged road segments
0
Current model phase
Setup complete. Ready to create agents...
Meters per Patch
20.13
Created by Martin Hilljegerdes, September 2018
MSc Cartography, ITC, University of Twente
as part of the Master Thesis:
"Using agent-based modeling for hurricane shelter planning in Dominica"

- ① ② ③

RESULTS
VISUALIZATION

Entity	Symbol	Dynamic visualization	Description
Household			Changing color based on agent state. Move in space
Shelter			Changing size based on number of people in shelter
Road			Removal of segments based on damage
Building		-	-
Risk zone / road usage		-	User can change visualization of patches, to compare the road usage of both evacuations.
Road damage location		-	Occurring on patches where damage occurred

RESULTS
VISUALIZATION

DISCUSSION

OVERVIEW

- Potential usage of model results
- Model improvements
  - Simplifications and limitations
- Interface, visualization and usability

DISCUSSION

POTENTIAL USAGE OF MODEL RESULTS

- Define critical **road** segments
  - Decide for road improvements and fortifications
  - Prioritization of road reconstruction
- Evaluate location and spatial distribution of **shelters**
- Allow user to perform experiments („what-if“ scenarios)

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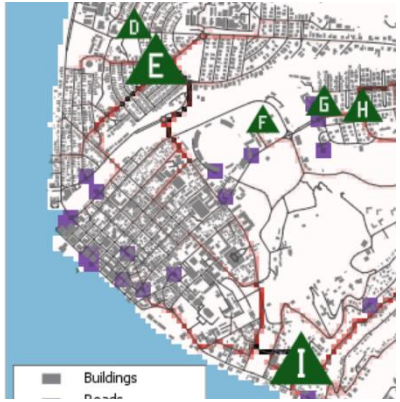

DISCUSSION

MODEL IMPROVEMENTS – SIMPLIFICATIONS AND LIMITATIONS I

- Include more attributes and functionalities to (household) agents
  - Assess and implement influencing attributes
  - Individuals instead of households
  - Synthetic population
  - Decision-making process
    - More intelligence
    - Irrational decisions

DISCUSSION

MODEL IMPROVEMENTS – SIMPLIFICATIONS AND LIMITATIONS II

- More information (data) about environment
  - Shelters, buildings and roads
- Redefinition of risk zone raster and damage concept
- More realistic scheduling systematic
- Multiple simulation runs for statistical evidence
- Cooperation with other disciplines
  - Integration of submodels

DISCUSSION

INTERFACE, VISUALIZATION AND USABILITY

- Involve the potential user!
  - Who are the users? What do they need?
  - User studies (requirements, usability)

- Limited navigation in NetLogo software

- Examine possibilites of using output data for further visualizations
- Assess spatio-temporal (stochastic) visualization options

CONCLUSION

SUMMARY

- Prototype in the objective‘s context successfully created
  - Purpose of multi-event scenario with network-based routing described...
  - ... Allowing to assess influences of damages to infrastructure to movement patterns

- Considerations for interface design and visualization of the model included

CONCLUSION

FUTURE RESEARCH

- Further development of the model concept and the prototype
  - Leading to a more realistic model with more reliable output
- Multiple simulation runs and statistical analysis
- Creation of a cartography extension or similar for NetLogo
- Extensive user research is required for further development

THE END

USING AGENT-BASED MODELING FOR HURRICANE SHELTER PLANNING

- Thank you for your attention!

- Any questions?

- Discussion!

CONTACT

USING AGENT-BASED MODELING FOR HURRICANE SHELTER PLANNING

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- Supervisor
  - Ellen-Wien Augustijn (ITC Twente)

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