Estimating the Greenhouse Gas Emissions of Flood Damages

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1. Overview

Problem: The effects of floods and storms on greenhouse gas (GHG) emissions are not well-understood, and planners lack tools to incorporate them into decision-making for flood risk management (FRM) projects. A method to estimate the GHG emissions associated with flood events is needed to develop more sustainable FRM strategies.

Objective: Develop and demonstrate a framework to estimate the life-cycle GHG emissions that result from flood damages to single-family residential structures.

Methods: Use component-level depth-damage estimates to generate economic demand vectors for five residential structure types across a range of flood depths. Input demand vectors into U.S. EPA's USEEIO LCIA model to produce structure-level depth-emissions curves for each structure type. Apply framework to Mississippi River Valley case study.

Results: Depth-emissions curves were produced for five residential structure types. Case study results show that damages from the 100-year flood could produce 1.85 - 2.66 x 10^8 kg CO_{2eq} in the Burlington-Davenport region and 1.11 - 3.01 x 10^8 kg CO_{2eq} in the Paducah-Cairo region.

2. Data and Methods

2.1. Depth-Emissions Curves

Depth-damage estimates for contents and structural components for 5 residential structure types from USACE report produced based on data from 39 homeowner surveys and panel of 9 industry experts[1].

Sample Expert Opinion Depth-Damage Estimates for One-Story on Pier Structure

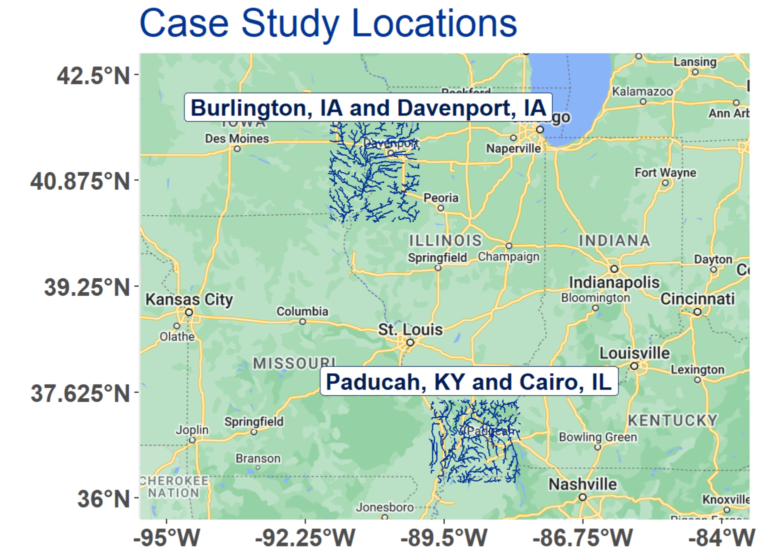
	FLOOD DEPTH RELATIVE TO FIRST FLOOR ELEVATION (FT)									
	-1	0	1	2	4	6	8	10	12	15
CONTENTS										
BOOKCASE/ENTERTAINMENT CENTER	0	97	313	467	1,427	1,490	1,490	1,490	1,490	1,490
COUCH/SOFA	0	104	1,106	1,106	1,106	1,106	1,106	1,106	1,106	1,106
STEREO EQUIPMENT	0	6	35	78	251	367	367	367	367	367
TABLES/CHAIRS	0	17	90	274	274	345	356	356	356	356
STRUCTURE										
BOTTOM CABINETS	0	314	2,746	2,746	2,746	2,746	2,746	2,746	2,746	2,746
EXTERIOR WALL/SIDING	0	0	429	1,143	1,771	2,714	3,229	3,229	3,229	3,229
STRUCTURAL FRAME	0	143	679	679	679	679	679	679	679	679
WALL INSULATION	0	137	901	1,109	1,850	2,124	2,124	2,124	2,124	2,124

We mapped items to specific industry with NAICS code and aggregated damage cost values by code to produce an economic demand vector for each flood depth.

USEEIO Model v2.0 developed by U.S. EPA[2] used to estimate the GHG emissions produced by the economic activity specified by a demand vector. We input demand vectors for flood depths from -1 to 15ft relative to first floor elevation (FFE) into the USEEIO model to produce depth-emissions curves for each structure type.

2.2. Case Study

Case Study Locations

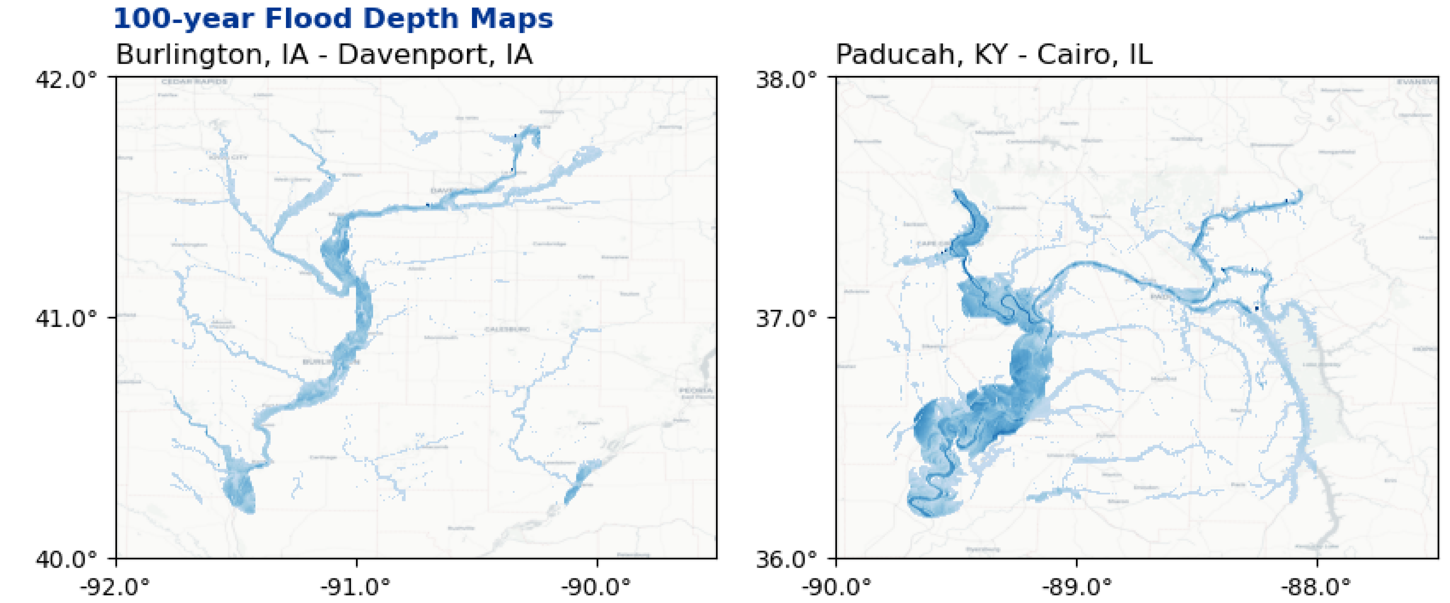


Study Area Residential Structures Stats

	N	MEAN VALUE	MEAN AREA (FT^2)
BURLINGTON, IA AND DAVENPORT, IA			
ONE STORY	497,968	$324,477	1,463
TWO STORY	144,855	$423,059	2,406
THREE STORY	19,382	$462,411	2,684
MOBILE HOME	19,772	$100,004	1,186
PADUCAH, KY AND CAIRO, IL			
ONE STORY	260,484	$263,731	1,612
TWO STORY	53,162	$412,955	3,023
THREE STORY	6,577	$467,329	3,618
MOBILE HOME	32,062	$136,476	1,553

Autoroute/FloodSpreader used to generate 100-year flood depth grid for each location using minimum, maximum, and mean stream flow estimates.

100-year Flood Depth Maps



National Structures Inventory used to determine location, elevation, and structure type of residential buildings.

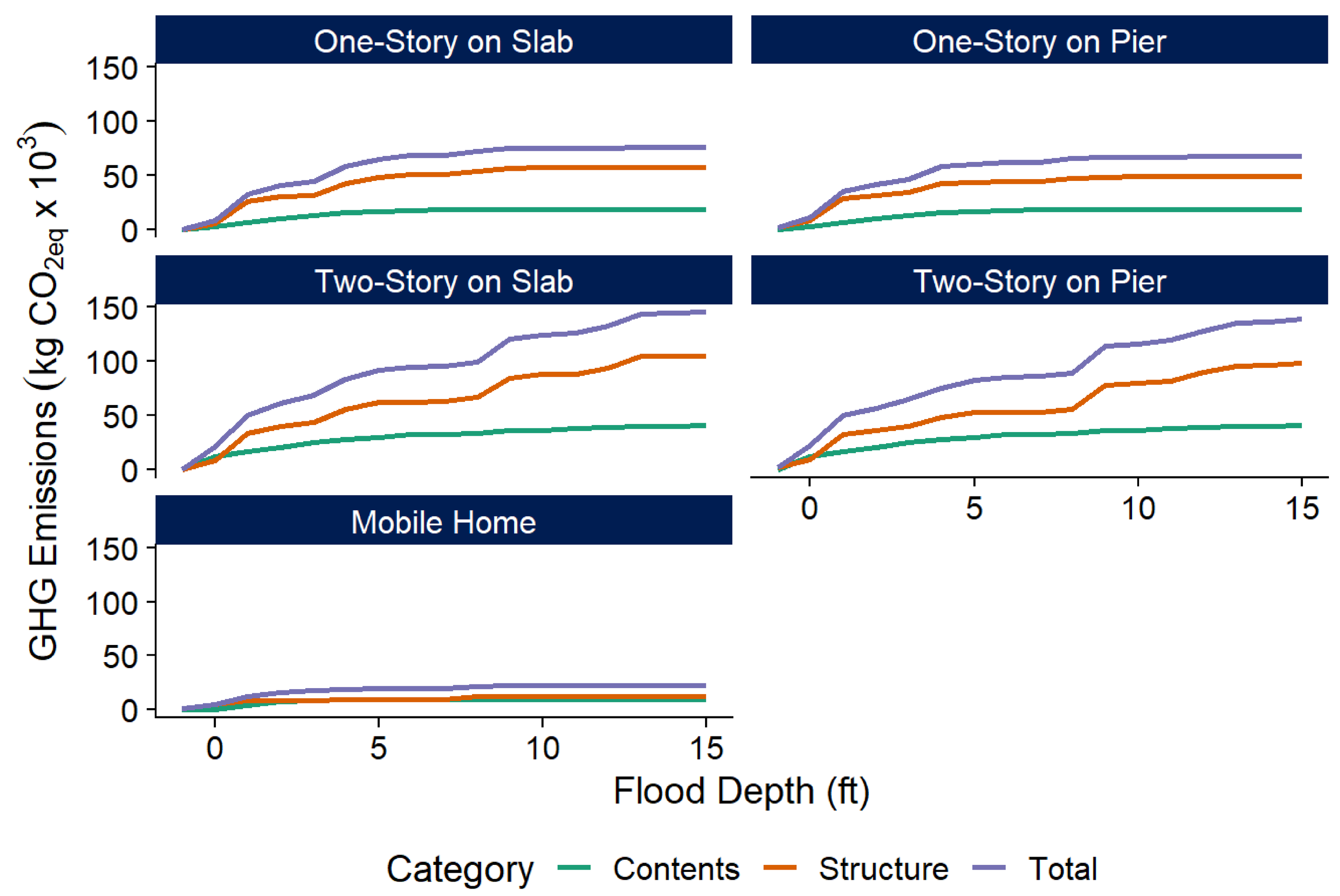
We used the depth grids to determine flood depth at each structure in the study area, and applied the appropriate depth-emissions curve to determine the GHG emissions associated with the damage.

3. Results

Damage-induced GHG emissions by flood depth (kg CO_{2eq} x 10^3)

	FLOOD DEPTH RELATIVE TO FIRST FLOOR ELEVATION (FT)																
	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
MOBILE HOME																	
STRUCTURE	1.73	5.17	8.31	8.86	9.02	9.47	9.80	9.82	9.93	12.23	12.61	12.76	12.76	12.76	12.76	12.76	12.76
CONTENTS	0.00	0.01	4.00	7.41	8.55	9.34	9.67	9.83	9.89	9.89	9.89	9.89	9.89	9.89	9.89	9.89	9.89
TOTAL	1.73	5.18	12.31	16.27	17.58	18.81	19.47	19.65	19.82	22.12	22.50	22.65	22.65	22.65	22.65	22.65	22.65
ONE-STORY ON PIER																	
STRUCTURE	1.18	8.32	28.82	31.14	33.58	42.59	43.42	43.92	44.03	47.06	48.33	48.51	48.64	48.71	48.80	48.87	48.97
CONTENTS	0.00	2.08	6.44	9.84	12.58	15.39	16.49	17.72	17.98	18.12	18.17	18.17	18.17	18.17	18.17	18.17	18.17
TOTAL	1.18	10.40	35.26	40.98	46.15	57.98	59.91	61.64	62.01	65.18	66.49	66.68	66.81	66.88	66.97	67.04	67.14
ONE-STORY ON SLAB																	
STRUCTURE	0.00	5.51	26.05	30.22	31.24	42.58	48.12	50.27	50.33	53.46	56.60	56.94	57.00	57.00	57.21	57.21	57.21
CONTENTS	0.00	2.08	6.44	9.84	12.58	15.39	16.49	17.72	17.98	18.12	18.17	18.17	18.17	18.17	18.17	18.17	18.17
TOTAL	0.00	7.59	32.49	40.06	43.82	57.97	64.61	67.99	68.31	71.58	74.77	75.10	75.16	75.16	75.38	75.39	75.39
TWO-STORY ON PIER																	
STRUCTURE	2.26	9.50	32.92	36.01	39.71	47.82	52.54	52.93	53.21	55.58	77.71	80.01	81.92	89.51	95.51	96.48	98.14
CONTENTS	0.06	12.37	16.76	20.70	24.86	27.51	30.12	32.36	32.85	33.11	36.11	36.11	37.89	38.78	39.55	40.21	40.55
TOTAL	2.32	21.87	49.68	56.71	64.57	75.34	82.66	85.28	86.06	88.68	113.82	116.12	119.81	128.28	135.06	136.68	138.69
TWO-STORY ON SLAB																	
STRUCTURE	0.00	8.78	33.26	40.10	43.94	55.96	61.92	62.49	62.60	66.34	84.15	87.70	88.33	93.54	104.46	104.46	104.54
CONTENTS	0.06	12.37	16.76	20.70	24.86	27.51	30.12	32.36	32.85	33.11	36.11	36.11	37.89	38.78	39.55	40.21	40.55
TOTAL	0.06	21.15	50.02	60.80	68.81	83.47	92.04	94.85	95.45	99.45	120.26	123.81	126.22	132.31	144.01	144.66	145.09

Depth-Emissions Curves for Single-Famly Residential Structures



Lifecycle GHG Emissions From 100-Year Flood Damages (kg CO_{2eq})

	STREAMFLOW ESTIMATE SCENARIO		
	MIN	MEAN	MAX
BURLINGTON-DAVENPORT	1.85×10^8	2.27×10^8	2.66×10^8
PADUCAH-CAIRO	1.12×10^8	1.71×10^8	3.01×10^8

4. Discussion

The framework demonstrated here provides FRM planners a method to rapidly extend traditional flood risk assessments to include life-cycle GHG emissions. The USEEIO LCIA approach also allows planners to incorporate other economic impacts such as lost business revenue that can be formatted as a demand vector. The model currently appears to be greatly overestimating the GHG emissions that would be induced by the flood damages.

The maximum estimated GHG emissions per building area produced by the model are about twice the average estimated embodied carbon for new construction homes[3]. Next steps include refining model parameters to address possible causes of overestimation, expanding the framework to incorpore demand reductions due to business down time, and expanding the case study to include LCIA possible FRM project alternatives.

5. References

1. Gulf Engineers and Consultants. Depth-Damage Relationships for Structures, Contents, and Vehicles and Content-to-Structure Value Ratios (CSVR) in Support of the Donaldsonville to the Gulf, Louisiana Feasibility Studies. Baton Rouge, Louisiana, USA: U.S. Army Corps of Engineers New Orleans District; 2006. https://www.mvn.usace.army.mil/Portals/56/docs/PD/Donaldsv-Gulf.pdf
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