

Assessment of Social Vulnerability to Wildfire in Missouri, United States of America

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Received: April 25, 2019

Accepted: June 6, 2019

Online Published: July 30, 2019

doi:10.5539/jsd.v12n4p76

URL: <https://doi.org/10.5539/jsd.v12n4p76>

This research was supported from fund provided by the University of Missouri-Kansas City, School of Graduate Studies and Women's Council Graduate Assistant Fund (GAF).

Abstract

Wildfire is a major environmental hazard causing property damage and destruction including biodiversity loss in the United States. In order to reduce property loss and destruction arising from wildfire, this study assessed and identified social vulnerability to wildfire in Missouri using the American Community Survey data on social and demographic variables for the state of Missouri and social vulnerability index (S₀VI). The study divided Missouri into five geopolitical zones from which ten counties were randomly selected for this study. The selected counties formed the basis on which fourteen social and demographic indicators were identified and assessed using Bogardi, Birkmann and Cadona conceptual framework. The result of the analysis shows that S₀VI estimated for the five geopolitical zones of Missouri is moderate with a rating scale of 1.42 – 1.71. Education, income and marital status have a rating scale of 2.0 - 3.0 attributed for the high value of Social Vulnerability to wildfire. Race / ethnicity, language spoken, employment and percentage of house units that are mobile homes had a low S₀VI value of 1.0 thereby contributing positively to resilience to wildfire risk. The study observes that government involvement in wildfire risk reduction is quite impressive and should still be intensified. The policy implication of this study is that education and income are key variables that contribute to high wildfire risk in Missouri. The need for government to formulate a policy on environmental education of the populace especially for people of low income and education become imperative. This will go a long way in reducing damage and property loss arising from wildfire.

Keywords: wildfire, forest fire, social vulnerability, resilience, Missouri, United States

1. Introduction

Studies on wildfire becomes necessary in order to reduce property damages, destruction of homes, displacement of human population, and loss of local revenue (Paveglio et al., 2016). Forests are Missouri greatest renewable resources; Missouri is home to at least 730 species of wildlife. The state boasts more than 14 million acres of forest land (Missouri's Department of Conservation, 2008). It ranks seventh out of the 20 Northern east states in the amount of forested acreage. Only New York, Michigan, Maine, Pennsylvania, Minnesota and Wisconsin have more forest land. In the last 13 years, wildland fires burned an average of 24,209 acres per year and prescribed fires burned an average of 38,078 acres per year (NIFC, 2015). Forest fires are still a major threat to Missouri's forest. While most forest fires in Missouri are accidents and preventable, a full 40 percent of forest fires occur every year (Missouri Department of Conservation, 2016).

Despite the enormous resources that have been invested in fire prevention and suppression, the number of fires recurring in Missouri in the recent decades has continued to markedly increase. Much of forest fire research has focused on the biological and physical aspects of fire with comparatively less attention given to the importance of socioeconomic variables and risk assessment especially identifying pattern of human population most at risk and the factors that help explain performance of mitigation that can help reduce that risk.

Apart from the work of Akinola and Adegoke (2019) which assessed forest fire vulnerability zones in Missouri;

Brosofske et al., (2007) on factors influencing modern wildlife occurrence in the Mark Twain National Forest of Missouri and Yang et.al (2008) on spatial controls of occurrence and speed of wildfires in Missouri Ozark highlands, little or nothing exist in the literature on social vulnerability assessment to forest/wildfire in Missouri State. This is a crucial step towards developing a wildfire a policy for reducing wildfire risk and losses in the study area. This is where this study derives its relevance. The aim of this study therefore was to assess and identify social vulnerability of Missouri residents to wildfire risk.

1.1 Conceptual Framework

Vulnerability refers to the capacity of society and individuals exposed to a natural hazard, to be harmed, resist, cope with, or recover from impact (Dwyer et al., 2004; Wisner et al., 2004; Cutter and Finch, 2006). At present, there is no consensus on the definition of vulnerability, and therefore no single accepted method of assessing vulnerability in the literature. Despite this, there is still a fair amount of consensus in the literature that there exist three main types of vulnerability. These are biophysical vulnerability, social vulnerability, and a combination of the two (Ge et al., 2008, 2013).

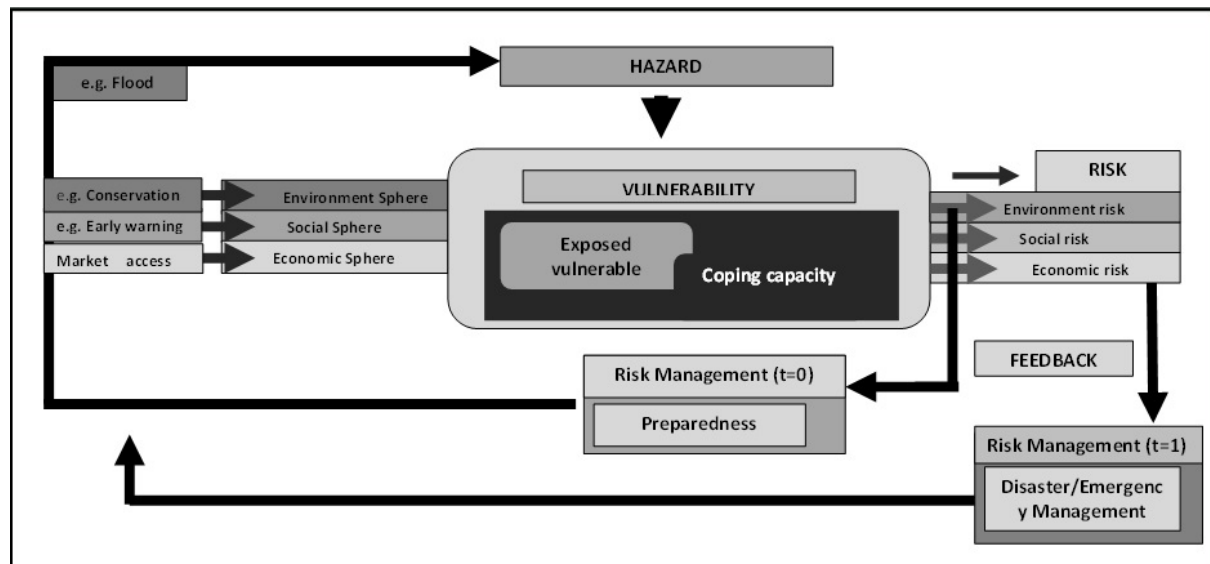


Figure 1. Conceptual framework for vulnerability

Source: Bogardi and Birkmann (2004); Cardona (1999, 2001)

In the past few decades, five major conceptual models have been proposed. These are: the risk-hazard (RH) model by Burton et al., 1978; the pressure and release (PAR) model (Blaikie et al., 1994); the hazard of place (HOP) model (Cutter, 1996); Turner and colleagues vulnerability framework (Turner et al., 2003); and the Bogardi – Birkmann – Cardona (BBC) model (Birkmann, 2006), have proposed for understanding social vulnerability. These conceptual models in vulnerability literature laid a sound theoretical basis for the analysis and assessment of social vulnerability.

This research adopts the Bogardi – Birkmann – Cardona (BBC) model (see figure 1) because it allows us to examine the three components of vulnerability. These are exposure, susceptibility and adaptive/capacity to wildfire in the study area. The framework also combines hazard and vulnerability in a risk reduction perspective. The concept was used to identify variables and interpret results.

1.2 Factors Affecting Social Vulnerability

The variables that influence social vulnerability which are always cited in the literature are listed in Table 1. The generally acceptable ones are age, gender, race, and socio-economic status. Others include disability factor, non – English speaking immigrants, the homeless, transients and seasoned tourists. The quality of human settlements (such as housing type and construction, infrastructure, and lifelines) and the built environment are important variables in understanding social vulnerability.

These characteristics influence potential economic losses, injuries, and fatalities from natural hazards.

2. Methodology

The study used the American Community Survey data for the state of Missouri from 2012-2016 and social vulnerability index (S₀VI). Demographic data and socio-economic characteristics of Missouri residents were extracted from the published American Community Survey 2012-2016 data on Missouri. The scale of study is at sub regional level of Missouri. The state of Missouri was divided into geopolitical zones as defined by the government of Missouri. These are South west Missouri, Southeast Missouri, Central Missouri, Northwest Missouri and Northeast Missouri. Ten counties were randomly selected for study in each geopolitical zone to obtain the composite value for each zone.

Identification of variables and interpretation of results in this study were based on the BBC framework by Bogardi, Birkmann and Cardona (see Figure 1). The term “BBC” framework comes from the conceptual model developed by Bogardi and Birkmann (2004) and Cardona (1999, 2001). The assessment of vulnerability was based on fourteen variables identified in Table 1. These variables were selected based on a priori theory and knowledge from the literature. This approach is referred to as deductive approach for selecting social vulnerability indicators.

The indicators for the estimation of the level of vulnerability were based on the following rating scale : (0 – 1.0) low vulnerability; (1.1 – 2.0) moderate vulnerability; and (2.1 – 3.0) high vulnerability (see Table 2). Equal weights were assigned to indicators to calculate S₀VI. It has been argued by Cutter et al (2003) and Muyambo (2017) that there is no theoretical basis for assigning different weights to indicate different levels of significance to individual factors’ contribution to social vulnerability. The indices were then summed up and divided by the total number of indicators to obtain the SoVI for the five geopolitical zones of Missouri State (see Table 3).

The SoVI was calculated using the following mathematical equation:

$$V^{soc} = \sum_{i=n}^{12} W_i^{soc} V_i^{soc}$$

$$V^{soc} = f(W_1^{soc} V_1^{soc} + W_2^{soc} V_2^{soc} + W_3^{soc} V_3^{soc} + \dots + W_{12}^{soc} V_{12}^{soc} \tag{1}$$

Where: V_1^{soc} = age, V_2^{soc} = marital status, V_3^{soc} = Income, V_4^{soc} = education;

V_5^{soc} = race/ethnicity; V_6^{soc} = employment; V_7^{soc} = language spoken; V_8^{soc} = persons in households; V_9^{soc} = ;

V_{10}^{soc} = length of stay in residence; V_{11}^{soc} = disability; V_{12}^{soc} = age of structures.

W_i^{soc} = equal weighting factor for all variables.

Table 1. Selected social vulnerable indicators

Indication (Variable)	Measure	Relationship with Vulnerability
1 Age	>65yrs. <18yrs. More old and under age	Higher vulnerability
2 Marital status	Married, Single or Separated	Single/separated-high Vulnerability
3 Income	Annual income earned	Low income- high Vulnerability
4 Education	Level of education	More education-low Vulnerability
5 Race/Ethnicity	Percentage of white to non-whites	More whites- less Vulnerability
6 Employment Status	Percentage of unemployment adults	High rate of Unemployment- high Vulnerability
7 Language spoken	Percentage that speaks in English	More population that speaks English – low Vulnerability
8 Person in households	Percentage of householders, spouse and children	Few persons – low Vulnerability
9 Length of stay in residence	Percentage of residents who stayed less than 5years	The more the years – low Vulnerability
10 Disability	Percentage of disabled in population	Larger number of disabled – high Vulnerability
11 Age of structures	Percentage of structures older than 50yrs.	Older structures – high Vulnerability
12 Availability of infrastructure	Percentage of residence with infrastructure such as telephone	Poor infrastructure – high Vulnerability
13 Ownership of housing Unit	Percentage of occupied housing unit	Vacant housing unit – high Vulnerability
14 Rural/Urban	Percentage population in urban/rural	Clerical and service sector – high Vulnerability more urban- low Vulnerability.

Source: Cutter, Boruff and Shirley (2001) and Heinz Centre for Science, Economics and the Environment (2002).

Table 2. Graduated scale for social vulnerability indicators in Missouri

S/N	Social Indicator	Range of Values	Scores
1	Age	<20% <18 and >65yrs	1
		20 - 49% <18 and >65yrs	2
		≥50% <18 and >65yrs	3
2	Marital Status	<20% singles/separated	1
		20-49 % singles/separated	2
		≥ 50 % singles/separated	3
3	Education	<20% college degree	3
		20-49 % college degree	2
		≥ 50% college degree	1
4	Household Incomes	<20 % earn less than \$35000	1
		20-49 % more than \$35000	2
		≥ 50 % earn less than \$35000	3
5	% Disability	<10% disabled	1
		10-15% disabled	2
		≥ 16% disabled	3
6	% Mobile Homes	<10% with mobile homes	1
		10-19% with mobile homes	2
		≥ 20% with mobile homes	3
7	Race/Ethnicity	≥70% white	1
		50-69% white	2
		<50% white	3
8	Language Spoken	≥70% speak English	1
		35-69% speak English	2
		<35% speak English	3
9	Insurance	< 10% without insurance	1
		10-19% without insurance	2
		≥19% without insurance	3
10	% Women	<25% Women	1
		25 -49% Women	2
		≥50 Women	3
11	Telephone	< 10% without telephone	1
		10-19% without telephone	2
		≥19% without telephone	3
12	Age of Structure	<20%: 50 years old	1
		20% – 49: 50 years old	2
		≥ 50%: 50 years	2
13	Tenancy (Renters)	<20% renters	1
		20 – 49% Renters	2
		≥50 %Renters	3
14	Unemployment	<10% Unemployed	1
		10-19% Unemployed	2
		≥20% Unemployed	3

3. Results and Discussion

The summary of social indicators and their contribution to social vulnerability to wildfire are presented in Table 3 and Figure 2. The results of the social vulnerability assessment of Missouri residents to wildfire indicators show a moderate vulnerability. Four indicators, namely income, education, ratio of day to night population and availability of telephone contribute more significantly to wildfire risk in Missouri. These variables all scored 3 in the vulnerability assessment, which is rated as high vulnerability.

Table 3. Estimation of social vulnerability index to wildfire in Missouri

Social Indicator	Southwest Missouri	Southeast Missouri	Central Missouri	Northeast Missouri	Northwest Missouri
Age	2	2	1	2	2
Marital Status	2	2	2	2	2
Education	3	3	2	3	1
Income	2	2	2	2	2
Disability	1	2	1	1	2
% Women	2	1	2	2	2
Telephone	1	1	1	1	1
Age of Structure	1	2	2	2	2
Mobile Homes	1	2	1	1	1
Tenancy	2	2	2	1	2
Employment Status	1	1	1	1	1
Race	1	1	1	1	1
Language Spoken	1	1	1	1	1
Insurance	1	2	1	1	2
Total Score	21	24	20	21	22
SoVI index	1.50	1.71	1.42	1.50	1.57

SoVI rating: (0-1) low Vulnerability; (1.1 – 2.0) moderate vulnerability, and (2.1 – 3.0) high vulnerability

Social Vulnerability Index (SoVI) = Total Score ÷ No of Indicators

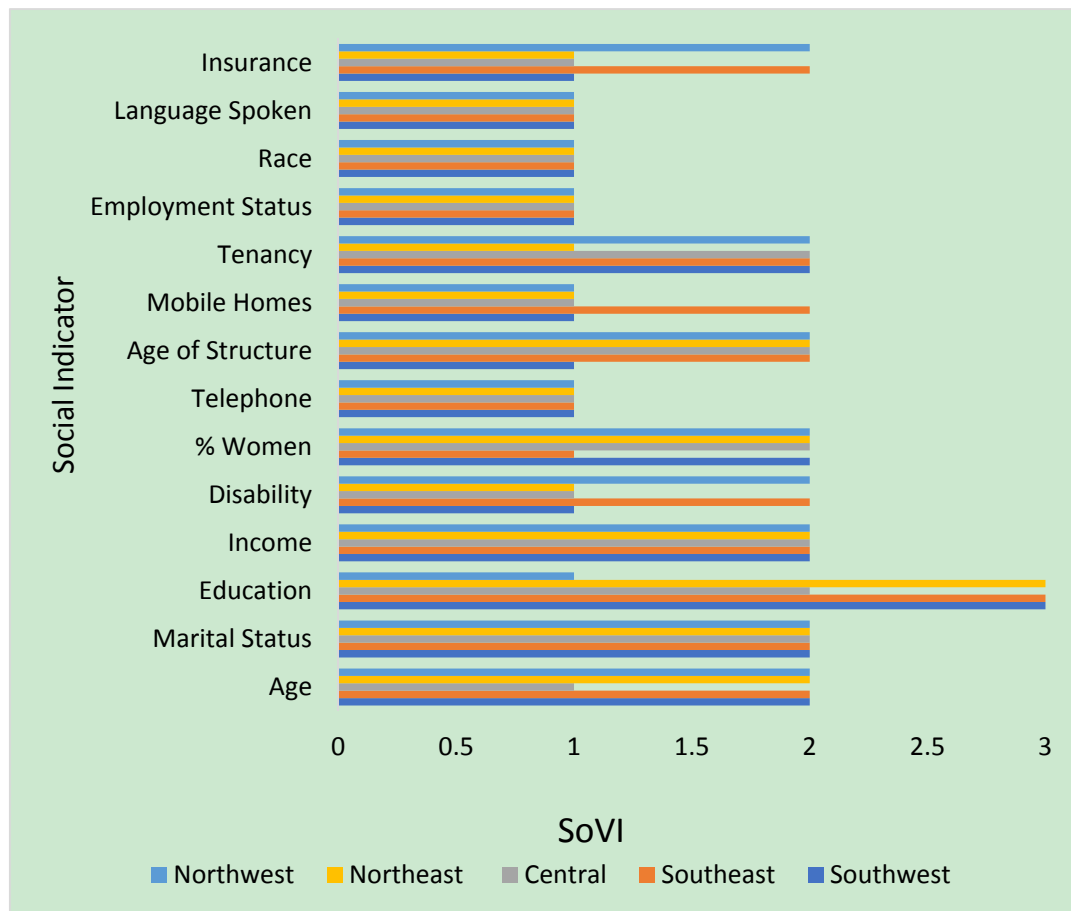


Figure 2. Chart of social vulnerability index to wildfire in Missouri

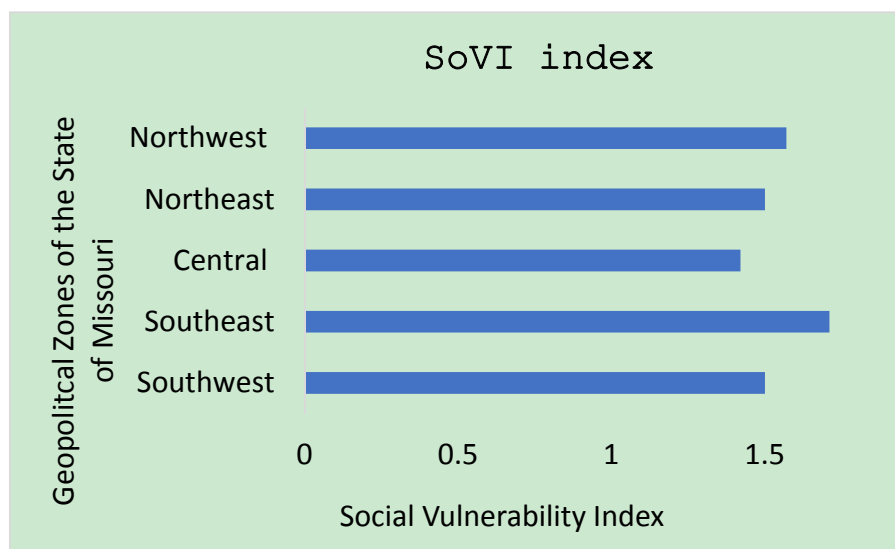


Figure 3. Comparison of SoVI of the Geopolitical Zones

Age, marital status, employment status, disability, age of buildings or structures and level of poverty which scored 2.0 contribute moderately to social vulnerability. However, race/ethnicity, language spoken, number in households and length of stay in residence scored low in social vulnerability index and they therefore positively contribute to resilience to wildfire risk in Missouri.

A comparison of social vulnerability indicators among the five geopolitical zones shows that they are all moderate but with higher values recorded in Southeast and Northwest geopolitical zones of Missouri. The lowest SoVI value was recorded in Central Missouri.

These findings correlate with the works of Caroll et al., 2005; and Collins, 2009, 2012 on the influence of socio and demographic characteristics on solid vulnerability of wildfire risk. Although it should be stated that income is just one of many socio demographic characteristics that scholars disagree about when discussing factors influencing social vulnerability. Others include educational level, length of tenure in an area, primary versus secondary house owner (Kanclerz and Dechano – Cevk, 2013; Martin et al., 2007).

It has also been observed that both socio demographics characteristics and perceptual factors continue to be the focus of literature on wildfire vulnerability and adaptive capacity. Figure 4 presented the different identified social indicators and their contribution to social vulnerability to wildfire. It is an extraction of the vulnerability segment from the BBC model showing the interaction of the component of vulnerability, exposure, susceptibility and coping capacity (Birkmann, 2006).

Apart from race/ethnicity, language spoken (that is English language), number living in households and length of stay in residence which fall within the coping capacity component, and which contribute to resilience to wildfire risk, all the other indicators contributed to social vulnerability in Missouri.

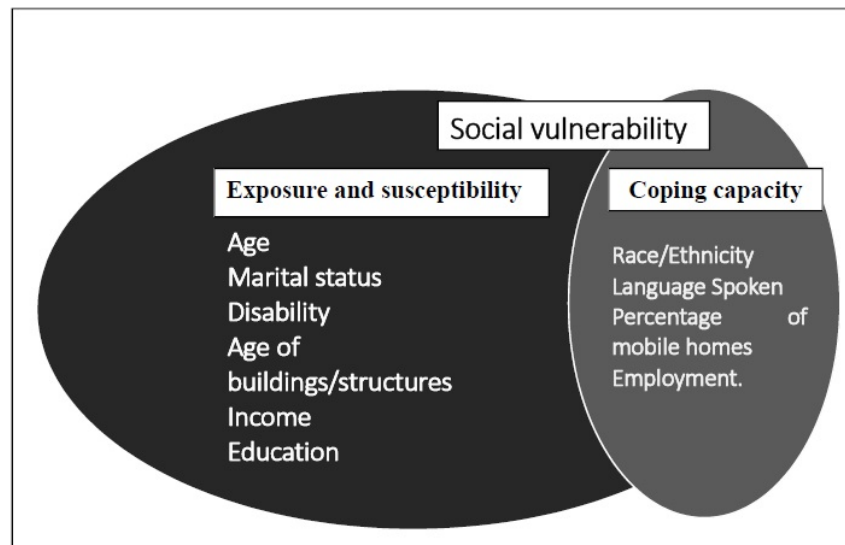


Figure 4. Summary of indicators using the BBC conceptual framework (Birkmann, 2006)

4. Conclusion and Recommendation

This study has assessed and identified the social vulnerability to wildfire in Missouri, United State of America using socio- demographics variables from the American Community Survey 2012-2016 data and SoVI. Results show that the social vulnerability of Missouri to wildfire is moderate. Income, education, availability of telephone, age, marital status, employment status, disability, age of buildings are the major vulnerability factors to wildfire risk in Missouri. Arising from this study, the paper recommended that Missouri should develop a state policy on wildfire risk reduction to guide countries and block levels. There is need for government to formulate a policy that will encourage more people to acquire education up to college degree. This may enhance their income and thereby increasing resilience to wildfire risk.

References

- Akinola, O. V., & Adegoke, J. (2019). Assessment of forest fire vulnerability zones in Missouri, United States of America. *International Journal of Sustainable Development & World Ecology*, 26(3), 251-257. <https://doi.org/10.1080/13504509.2018.1551815>
- Birkmann, J. (2013). Measuring vulnerability to normal hazards. In J. Birkmann (Ed.), *Towards Disaster Resilient Societies* (pp. 53-70). United Nations University Press, United Nations University, Tokyo.
- Blaikie, P., Cannon, T., Davis, I., & Wisner, B. (1994). *At risk: natural hazards, people's vulnerability, and*

- disasters*. Routledge, New York.
- Bogardi, J. J., & Birkmann, J. (2004). Vulnerability assessment: The first step towards sustainable risk reduction. In D. Malzahn, & T. Plapp (Eds.), *Disasters and Society: From Hazard Assessment to Risk Reduction* (pp. 75-82). Logos Verlag Berlin, Berlin.
- Brosofske, K. D., Cleland, D. T., & Saunders, S. R. (2007). Factors in influencing modern wildfire occurrence in the Mark Twain National Forest, Missouri. *Southern Journal of Applied Forestry*, 31(2), 73-84.
- Burton, I., Kate, R. W., & White, G. F. (1978). *The Environment as Hazard*. Oxford University Press, New York.
- Cardona, O. D. (1999). Environmental management and disaster prevention: Two related topics: A holistic risk assessment and management approach. In J. Ingleton (Eds.), *Natural Disaster Management*. Tudor Rose, London.
- Cardona, O. D. (2001). Estimacion Holistica de Riesgo Sismico Utilizando sistemas Dinamicos Comple Technical University of Catalonia, Barcelona.
- Carroll, M. S., Cohn, P. J., Seesholtz, D. N., & Higgins, L. L. (2005). Fire as a galvanizing and fragmenting influence on communities: The case of the Rodeco-Chidiski fire. *Society and Natural Resources*, 18, 301-320. <https://doi.org/10.1080/08941920590915224>
- Collins, T. (2012). A landscape typology of residential wildfire risk. In Paton, & F. Tedim (Eds.), *Wildfire and Community: Facilitating Preparedness and Resilience* (pp. 3-65). Charles C. Thomas, Springfield.
- Collins, T. W. (2009). Influences on wildfire hazard exposure in Arizona's high country. *Society and Natural Resources*, 22, 211-229. <https://doi.org/10.1080/08941920801905336>
- Cutter, S. L. (1996). Vulnerability to environmental hazards. *Progress in Human Geography*, 20, 529-539. <https://doi.org/10.1177/030913259602000407>
- Cutter, S. L., & Finch, C. (2008). Temporal and spatial changes in social vulnerability to natural hazards. *Proceedings of the National Academic of Science, USA*, 105(7), 2301-2306. <https://doi.org/10.1073/pnas.0710375105>
- Cutter, S. L., Boruff, B. J., & Shirley, W. L. (2003). Social Vulnerability to environmental hazards. *Social Science Quarterly*, 84, 242-261. <https://doi.org/10.1111/1540-6237.8402002>
- Dwyer, A., Zoppou, C., Nielsen, O., Day, S., & Robert, S. (2004). Quantifying social vulnerability: A methodology for identifying those at risk to natural hazards. *Geoscience Australia. Record 2004/14*.
- Ge, Y., Dou, W., Gu, Z., Qian, X., Wang, J., Xu, W., ... Chen, Y. (2013). Assessment of social vulnerability to natural hazards in the Yangtze River Delta, China. *Stochastic Environmental Research and Risk Assessment*, 27, 1899-1908. <https://doi.org/10.1007/s00477-013-0725-y>
- Ge, Y., Liu, J., Li, F., & Shi., P. (2008). Quantifying social vulnerability for flood disasters of insurance company: a case study of Changsha, China. *Journal of Southeast University (Natural Science Edition)*, 24, 147-150.
- Gude, P. H., Jones, K., Rasker, R., & Greenwood, M. C. (2013). Evidence for the effect of homes on wildfire suppression costs. *International Journal of Wildland Fire*, 22, 537-548. <https://doi.org/10.1071/WF11095>
- H. John Heinz III Centre for Science, Economics, and the Environment. (2000). *The hidden costs of coastal hazards: Implications for risk assessment and mitigation*. Covello, CA. Island Press.
- H. John Heinz III Centre for Science, Economics, and the Environment. (2002). *Human links to coastal disasters*. Washington, D.C.
- Kancelerz, L., & Dechano- Cook, L. M. (2013). Understanding wildfire vulnerability of residents in Teton county, Wyoming. *Disaster Prevention Management*, 22(2), 104-118. <https://doi.org/10.1108/09653561311325262>
- Martin, I. M., Bender, H., & Raish, C. (2007). What motivates individuals to protect themselves from risk: the case of wildland fires. *Risk Analysis*, 27(4), 887-899. <https://doi.org/10.1111/j.1539-6924.2007.00930.x>
- Missouri Department of Conservation. (2008). *Missouri forestry and wood products, Public Profile 2008-6*. Jefferson City, MO. Missouri Department of Conservation.
- Muyambo, F., Jordaan, A. J., & Bahta, Y. T. (2017). Assessing social vulnerability to drought in South Africa: Policy implication for drought risk reduction. *Jamba: Journal of Disaster Risk Studies*, 9(1), 1-7. <https://doi.org/10.4102/jamba.v9i1.326>
- Natural Resources Conservation Service. (2010). *Plants Database* Baton Rouge, LA., US.

- Paveglio, T. B., Prato, T., & Hardy, M. (2013). Simulating effects of land use Policies on extent of the wildland-urban interface and wildfire risk in Flathead county, Montana. *Journal of Environmental Management*, 130(3), 20-31. <https://doi.org/10.1016/j.jenvman.2013.08.036>
- Paveglio, T. B., Prato, T., Edgeley, C., & Nalle, D. (2016). Evaluating the characteristics of social vulnerability to wildfire: Demographics, perceptions, and parcel characteristics. *Environmental Management*, 58, 534-548. <https://doi.org/10.1007/s00267-016-0719-x>
- Platt, R. V. (2010). The wildland-urban interface: evaluating the definition effect. *Journal of Forestry*, 108(1), 9-15.
- Rufat, S., Tate, E., Burton, C., & Maroof, A. S. (2015). Social vulnerability to floods: A review of case studies and implications for measurement. *International Journal of Disaster Risk Reduction*, 14, 470-486. <https://doi.org/10.1016/j.ijdr.2015.09.013>
- Turner, B. L., Matson, P. A., McCarthy, J. J., Corell, R. W., Christensen, L., Eckley, N., ... Tyler, N. (2003). Illustrating the coupled human-environment system for vulnerability analysis: three case studies. *Proceedings of the National Academic of Science*, 100(14), 8080-8085. <https://doi.org/10.1073/pnas.1231334100>
- Wisner, B., Blaikie, P., Cannon, T., & Davis, I. (2004). *At risk: natural hazards, people's vulnerability, and disasters*. Routledge, London.
- Yang, J., He, H., & Shifley, S. R. (2008). Spatial controls of occurrence and spread of wildfires in the Missouri Ozark highlands. *Ecological Applications*, 18(5), 1212-1225. <https://doi.org/10.1890/07-0825.1>
- Yoon, D. K. (2012). Assessment of social vulnerability to natural disaster: A comparative study. *Natural Hazards*, 63, 823. <https://doi.org/10.1007/s11069-012-0189-2>

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