FOOD SECURITY, RURAL LIVELIHOODS, & CLIMATE RESILIENCE

Vulnerability analysis of agricultural production systems in the Department of La Paz, Bolivia

BACKGROUND & OBJECTIVES

The impacts of climate change on food security are predicted to be greatest in areas already vulnerable to food insecurity (Wheeler & von Braun, 2013), where marginalized, poor farming and pastoral communities are most impacted by and least able to adapt to climate variability and extreme weather (McDowell & Hess, 2012; Miranda, Hastings, Aldy, & Schlesinger, 2011). Models predict that crop yields across South America will decrease by 2050 due to changes in precipitation, temperature, and greenhouse gas concentrations (Wheeler & von Braun, 2013). These changes will exacerbate the precariousness of agricultural production in the Department of La Paz, Bolivia, where smallholder farmers cultivate crops and raise livestock in challenging environmental, social, economic, and political conditions. General circulation models predict that increased annual temperature in the western Bolivian highlands will be coupled with more frequent warm nights, frost days, and heat waves, leading to greater thermal stress on crops (Thibeault, Seth, & Garcia, 2010). Higher temperatures will heighten water scarcity due to glacial recession (Rangecroft et al., 2013). Reduced average annual precipitation will be characterized by delayed onset of rain during growing season, less frequent but more intense precipitation, and increased frequency of flooding and droughts (Seiler, Hutjes, & Kabat, 2013;Valdivia et al., 2010).

The primary objective of this analysis is to identify the municipalities whose agricultural production systems and agricultural producers are most vulnerable to climate change. The secondary objective is to compare the dominant agricultural land uses across municipalities of different vulnerability levels. This model could be used in collaboration with vulnerable populations to identify policy approaches and prioritize resources to improve climate resilience in agricultural production systems, support rural livelihoods, and promote regional self-reliance.

METHODS

This analysis uses the Intergovernmental Panel on Climate Change (IPCC) framework for vulnerability to climate change, which defines vulnerability as a "function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity" (Pachauri & IPCC, 2008, p. 89). The methodology is adapted from two relevant studies that employed geographic information systems (GIS) to analyze the vulnerability of agricultural systems at a subnational level (Gizachew & Shimelis, 2014; Li et al., 2015).

To address the first objective, this analysis consists of three sub-indices for exposure, sensitivity, and adaptive capacity, and an aggregate index for vulnerability at the municipal level. For each sub-index, there are four to seven indicators, each assigned equal weight. These indicators were prepared using data from Bolivia's 2012 National Population and Housing Census and the 2013 National Agricultural Census, along with shapefiles from GeoBolivia, Bolivia's national spatial data infrastructure. After cleaning and preparing the data, categorical variables were reclassified for low, mid, and high vulnerability, and continuous variables were reclassified using terciles. Data for each indicator were converted to raster, then summed within each sub-index. The aggregate index was then calculated by summing the three sub-indices, and was summarized by mean vulnerability at the municipal level. Final municipal vulnerability levels were determined by terciles. Lastly, spatial autocorrelation was analyzed using both Global and Local Moran's Indices.

To address the second objective, agricultural land uses were summarized by area for each municipal vulnerability level.

RESULTS & LIMITATIONS

The agricultural systems with the highest vulnerability are located in municipalities in the arid, high-elevation Altiplano in the southern part of the Department, as well as throughout the Andes Mountains in the central region of the Department. The Global Moran's Indices for each of the indices shows significant clustering of high and low vulnerability. However, the Local Moran's Indices indicate that there are unique high-high and low-low clusters for each index. This suggests that municipalities may need different resilience strategies and policy approaches to address climate change vulnerability. For example, a municipality with high vulnerability with respect to sensitivity may focus on increasing crop diversity, whereas a municipality with high vulnerability with respect to adaptive capacity may focus on increasing the area of irrigated cropland.

Agricultural land uses vary between vulnerability levels, although there is similarity between mid and high levels. Just over half of mixed agricultural land and pasture land is located in highly vulnerable areas, whereas virtually all of the land dedicated to livestock production is in municipalities with low vulnerability. Cropland is more evenly distributed between areas of high and low vulnerability.

It merits further consideration as to whether the selected indicators have equal influence in crop and livestock systems. A possible future development would be to build separate models with unique indicators to assess the vulnerability of crop and livestock systems separately. Also, given the drastic climatic and environmental differences between the arid, high-elevation Altiplano in the southern region of the Department and the humid, low-elevation Amazon in the northern region of the Department, indicators about water access and irrigated cropland may have variable importance relative to sensitivity and adaptive capacity. It may be helpful to include an indicator for precipitation.

INDICATORS

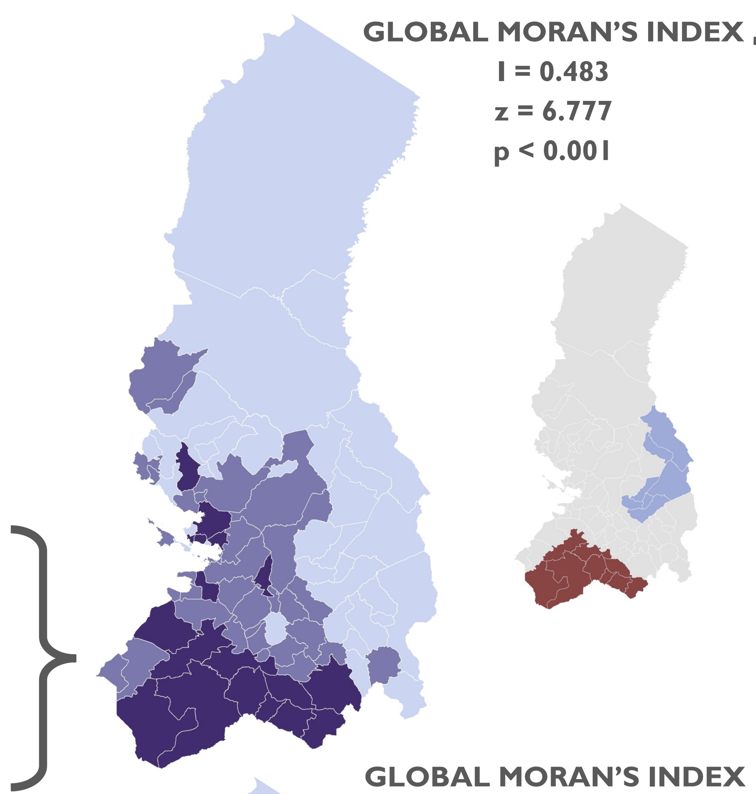
SELECTION OF INDICATORS

Climate change vulnerability analysis assesses social-ecological systems, and therefore includes both socioeconomic and biophysical components (Metternicht, Sabelli, & Spensley, 2014). Recognizing that farmer livelihoods are intrinsically tied to the environment, it is appropriate to include environmental variables, in addition to socioeconomic and political variables, as vulnerability indicators (Brooks, Adger, & Kelly, 2005). This analysis includes seventeen indicators, all of which have precision at the municipal scale or smaller.

EXPOSURE

Weather events

RISK OF FLOOD (+)
RISK OF DROUGHT (+)
RISK OF FROST (+)
RISK OF HAILSTORM (+)



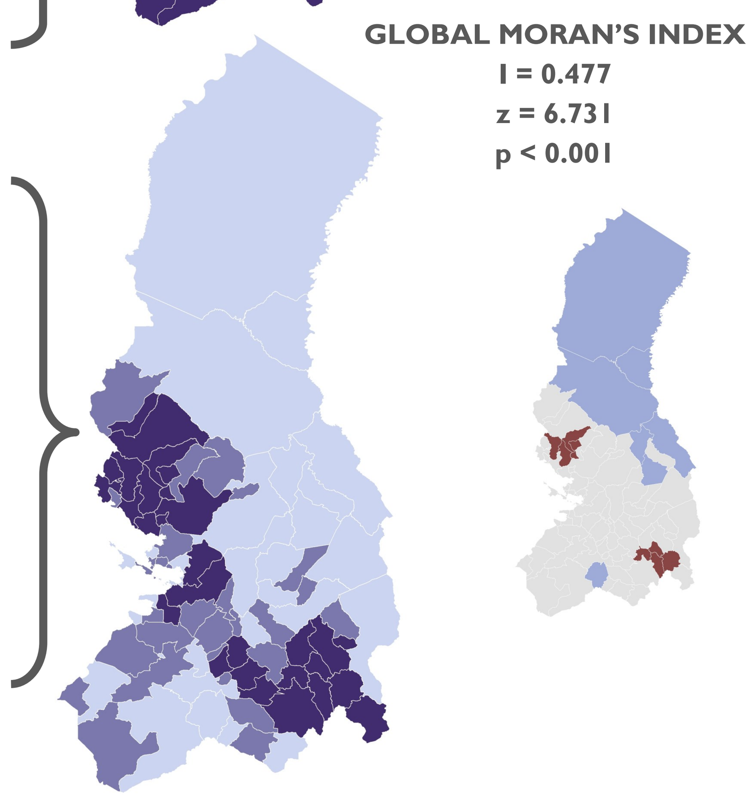
SENSITIVITY

Human sensitivity

RURAL POPULATION DENSITY (+)
DEPENDENCY RATIO (+)

Livelihood sensitivity

AGRICULTURAL POPULATION (+)
CROP DIVERSITY (–)
DISTANCE TO WATER SOURCE (+)
SLOPE (+)



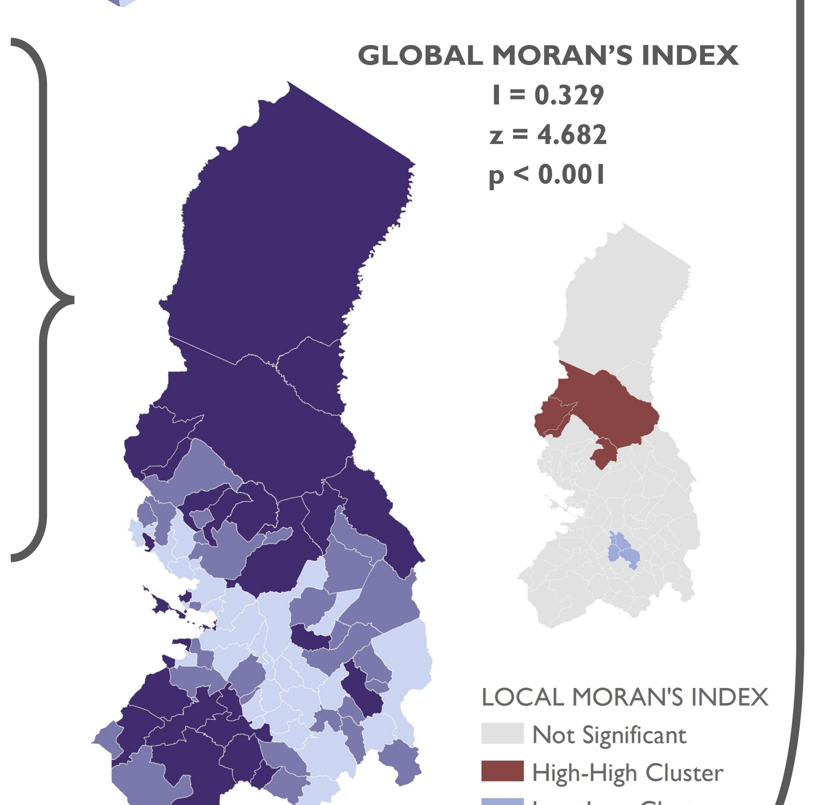
ADAPTIVE CAPACITY

Socioeconomic assets

RURAL ILLITERACY RATE (+)
AGRICULTURAL INSURANCE (–)
FARM ASSETS (–)

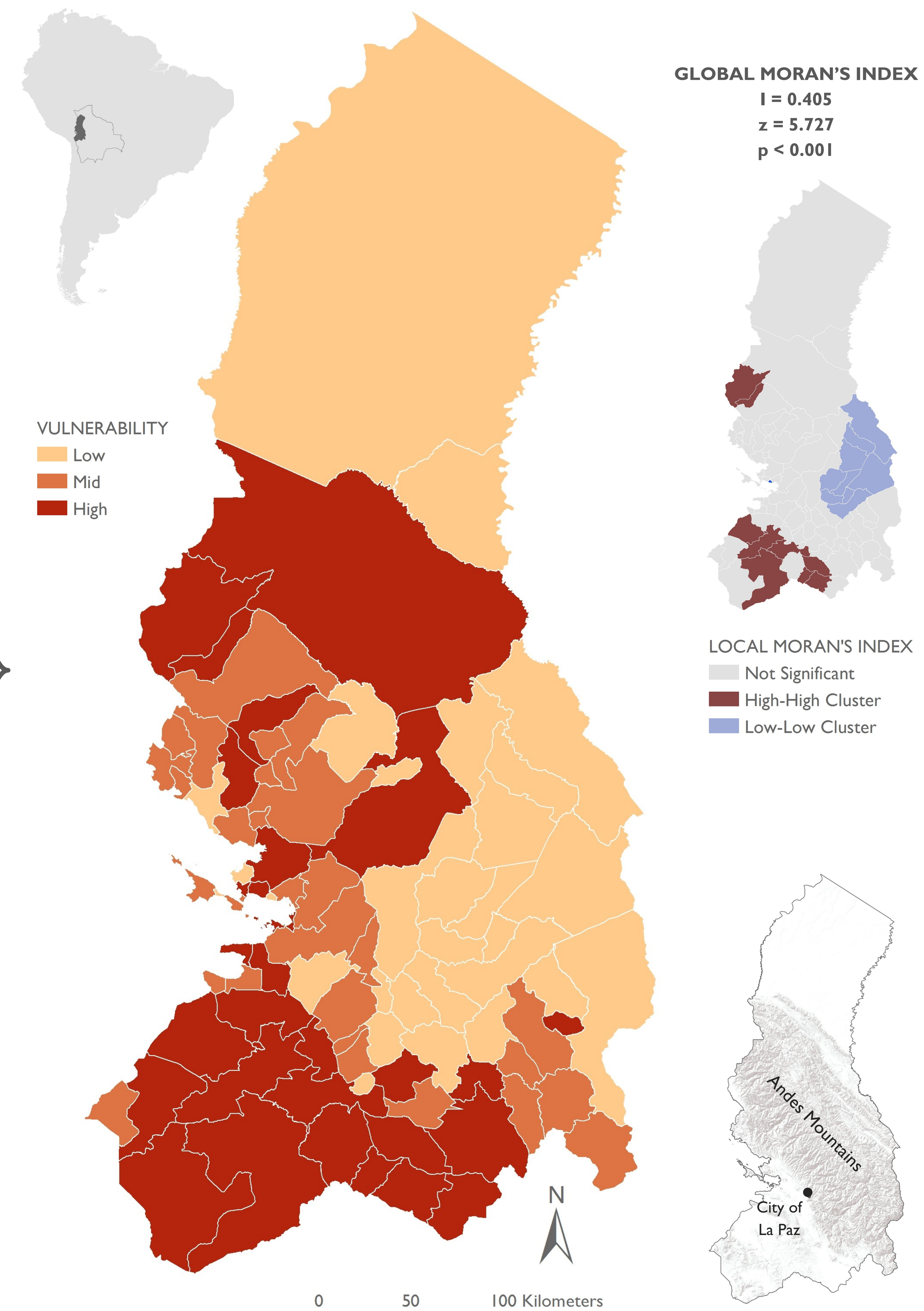
Infrastructural assets

DISTANCE TO ROADS (+)
DISTANCE TO URBAN CENTERS (+)
IRRIGATED CROPLAND (–)

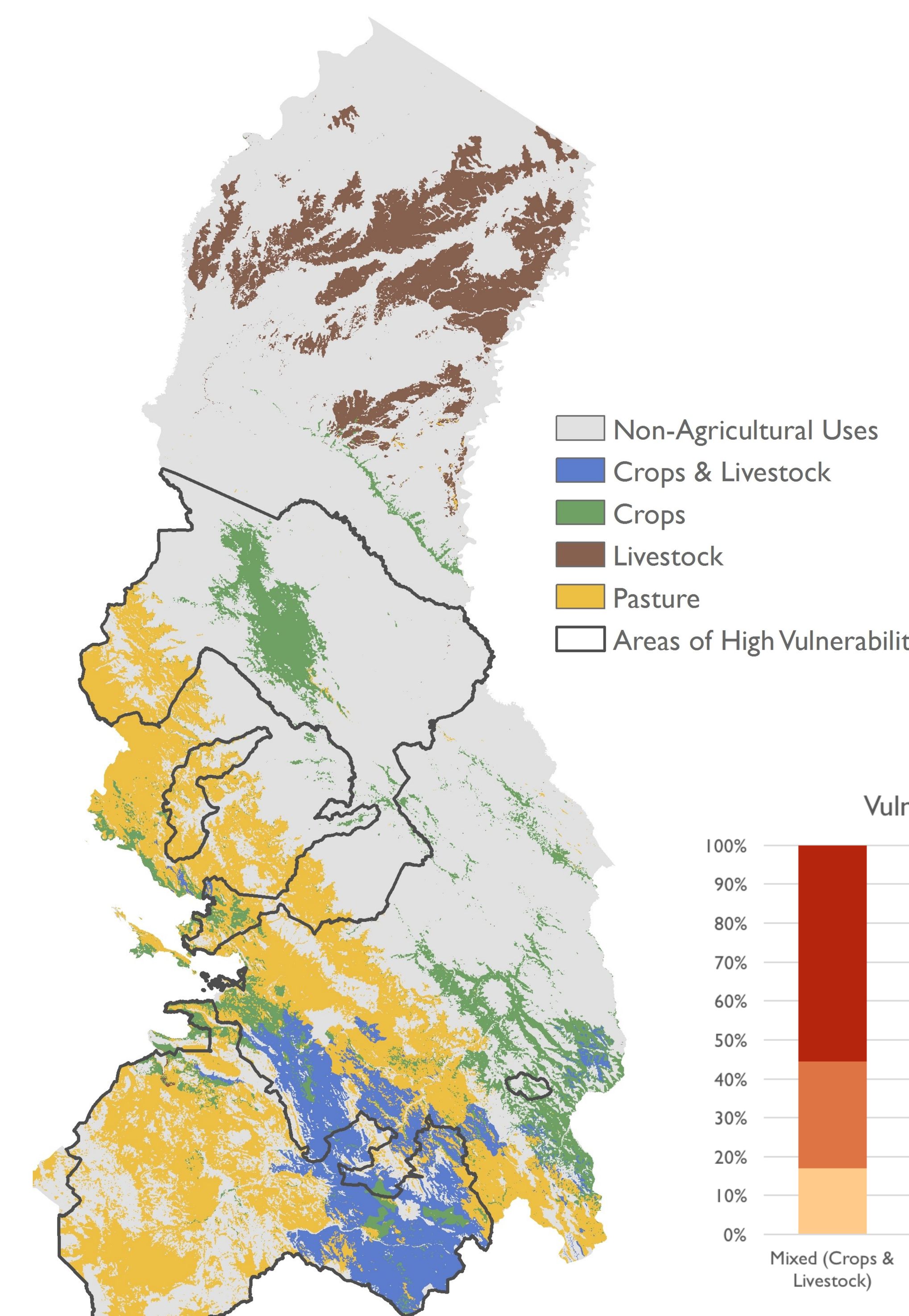


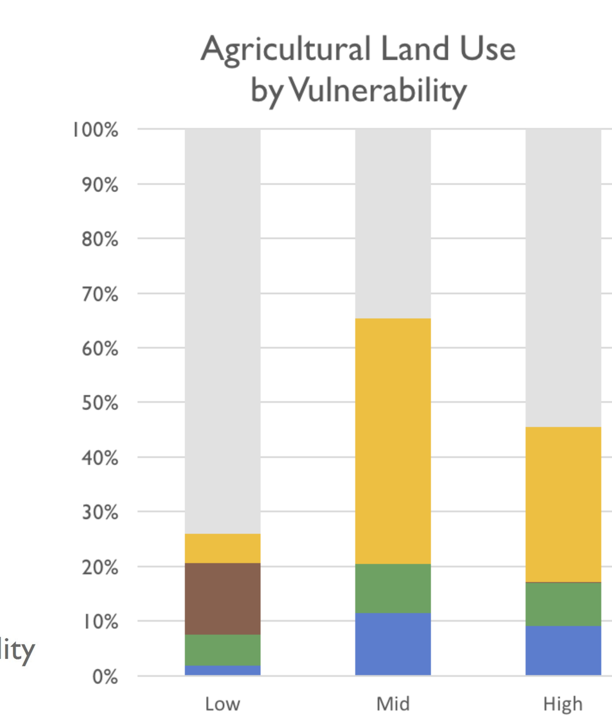
Relationship to Vulnerability
(+) Increases vulnerability
(–) Decreases vulnerability

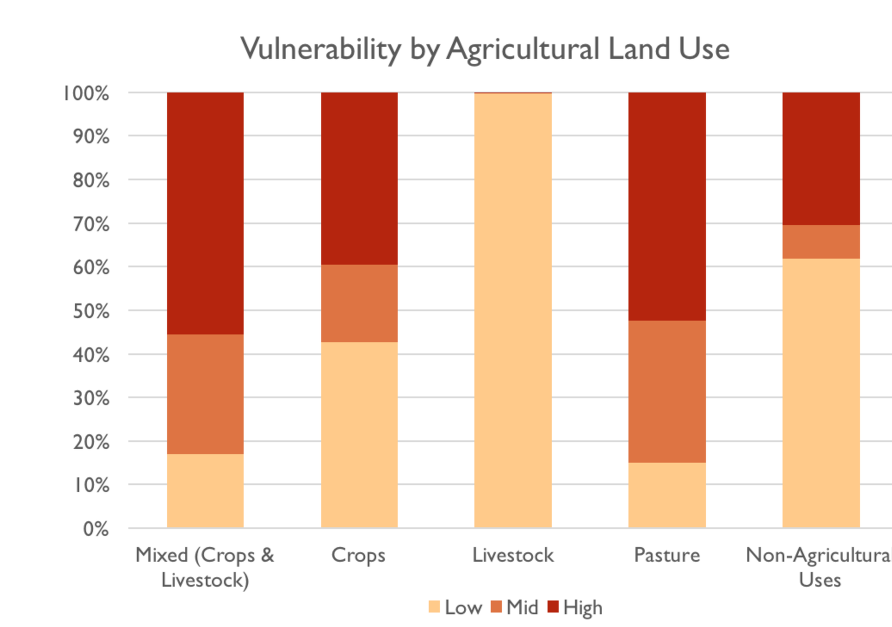
VULNERABILITY INDEX



AGRICULTURAL LAND USES







Cartographer Caitlin Matthews
Course Advanced GIS, April 2017

Data Sources GeoBolivia, Instituto Nacional de Estadística de Bolivia, Unidad de Análisis de Políticas Sociales y Económicas

Projection WGS_1984_UTM_Zone_19S

CITATIONS

Brooks, N., Adger, W. N., & Kelly, P. M. (2005). The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. *Global Environmental Change, 15*(2), 151–163.

Gizachew, L., & Shimelis, A. (2014). Analysis and mapping of climate change risk and vulnerability in Central Rift Valley of Ethiopia. *African Crop Science Journal, 22*(0), 807–818.

Li, Y., Xiong, W., Hu, W., Berry, P., Ju, H., Lin, E., Wang, W., Li, K., & Pan, J. (2015). Integrated assessment of China's agricultural vulnerability to climate change: a multi-indicator approach. *Climatic Change, 128*(3–4), 355–366.

McDowell, J. Z., & Hess, J. J. (2012). Accessing adaptation: Multiple stressors on livelihoods in the Bolivian highlands under a changing climate. *Global Environmental Change, 22*(2), 342–352.

Metternicht, G., Sabelli, A., & Spensley, J. (2014). Climate change vulnerability, impact and adaptation assessment: Lessons from Latin America. *International Journal of Climate Change Strategies and Management, 6*(4), 476–442.

Miranda, M. L., Hastings, D. A., Aldy, J. E., & Schlesinger, W. H. (2011). The Environmental Justice Dimensions of Climate Change. *Environmental Justice, 4*(1), 17–25. h

Pachauri, R. K., & IPCC (Eds.). (2008). *Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II, and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Geneva: IPCC.

Rangecroft, S., Harrison, S., Anderson, K., Magrath, J., Castel, A. P., & Pacheco, P. (2013). Climate Change and Water Resources in Arid Mountains: An Example from the Bolivian Andes. *AMBIO, 42*(7), 852–863.

Seiler, C., Hutjes, R. W. A., & Kabat, P. (2013). Climate Variability and Trends in Bolivia. *Journal of Applied Meteorology and Climatology, 52*(1), 130–146.

Thibeault, J. M., Seth, A., & Garcia, M. (2010). Changing climate in the Bolivian Altiplano: CMIP3 projections for temperature and precipitation extremes. *Journal of Geophysical Research. Atmospheres, 115*(8).

Valdivia, C., Seth, A., Gilles, J. L., García, M., Jiménez, E., Cusicanqui, J., … Yucra, E. (2010). Adapting to Climate Change in Andean Ecosystems: Landscapes, Capitals, and Perceptions Shaping Rural Livelihood Strategies and Linking Knowledge Systems. *Annals of the Association of American Geographers, 100*(4), 818–834.

Wheeler, T., & von Braun, J. (2013). Climate Change Impacts on Global Food Security. *Science, 341*(6145), 508–513.

PHOTO SOURCE Sebastian Leal. (2013). "En algún lugar desértico de Bolivia." Flickr Creative Commons.