



Participatory mapping; Vulnerabilities to hazards and the effects of technology use for creating socio-ecological resilience in America's Southern High Plains.

Brian Birchler¹, Austin Boardman¹, Jacqueline M. Vadjunec¹, Todd Fagin², Peter Kedron¹, Michael Larson¹

¹Oklahoma State University, ² University of Oklahoma - Oklahoma Biological Survey



Background

This poster examines community perceptions of environmental hazard vulnerabilities and the use of high technology for fostering social-ecological resilience in the grassland communities of Cimarron County, Oklahoma and Union County, New Mexico (Figure 1.0). The region has historically undergone severe weather events, including drought, most notably the 1930s Dust Bowl (Vadjunec and Sheehan 2010). As a result of extreme weather and land management the region is susceptible to invasive and nuisance species, particularly woody plant encroachment. Fagin (et al. 2016) notes common species such as One-seeded Juniper, Salt Cedar, Mesquite, Cholla Cactus, and Russian Thistle among the main invasives. Furthermore, due to periods of extreme dryness, followed by episodic heavy rains, some areas are subject to periodic flash flooding. To better adapt to these hazards, many ranchers and farmers rely on technologies such as Center Pivot Irrigation (CPI) or Precision Agriculture (Wenger et al. 2017). Using participatory sketch mapping this study's goal is to better understand how residents view the location, extent, and perception of environmental hazards, as well as the role of technology in fostering social-ecological resilience.

We seek to answer three research questions for this poster:

1. In what ways, including location, are residents in Cimarron County, OK and Union County, NM affected by natural hazards such as drought, invasive and nuisance species, and flooding?
2. In what ways, including location, are residents in Cimarron County, OK and Union County, NM adapting technology in their land management systems?
3. How and where do perceived natural hazards and technology usage differ from reality?

Methodology

To answer our research questions we performed *four* analyses using *three* principle data sources to triangulate information regarding drought, invasive/nuisance species, flooding, and technology.

Our three data sources included:

1. *Participatory Sketch Mapping*: Participating residents ($n=201$) identified areas of hazard and flooding risk, as well as technology use within the two-county study area
2. *Remotely Sensed Land-use*: Aerial and satellite imagery from the study area were obtained from USDA NAIP MrSID Mosaic 2015 and Landsat Mosaic 2011.
3. *Secondary Data*: Other forms of secondary hydrological and geographic data were collected from the USGS National Elevation Dataset, the USGS National Hydrography Dataset, and the WorldClim Global Climate Database.

Our triangulation efforts included four related methodologies:

1. *Participatory Map Fusion*: We aggregated participatory sketch maps into a single composite layer for further analysis. By counting overlapping areas of perceived environmental pressure (Figure 2), we compared participant perception with secondary ecological data (Figures 3b, 4b, 5, 6b).
2. *Statistical Centers of Perception*: We generated county weighted standard deviational ellipsoids (Scott and Janikas 2010) to determine perceived hotspots of alternative technology use and land use land cover change. These areas were then compared directly to location of center pivot irrigation and land cover change (Figures 4b, 5).
3. *Land Cover Change Detection*: Comparing NLCD data from 1992 and 2007 for the two counties, we detected areas of woody plant encroachment (Figure 5).
4. *Flooding Vulnerability*: Using USGS elevation and hydrography data we also calculated areas of flood risk throughout the study area as the product of slope and inverse distance to major rivers and streams (Figure 6b).

Figure 1 - Study Area

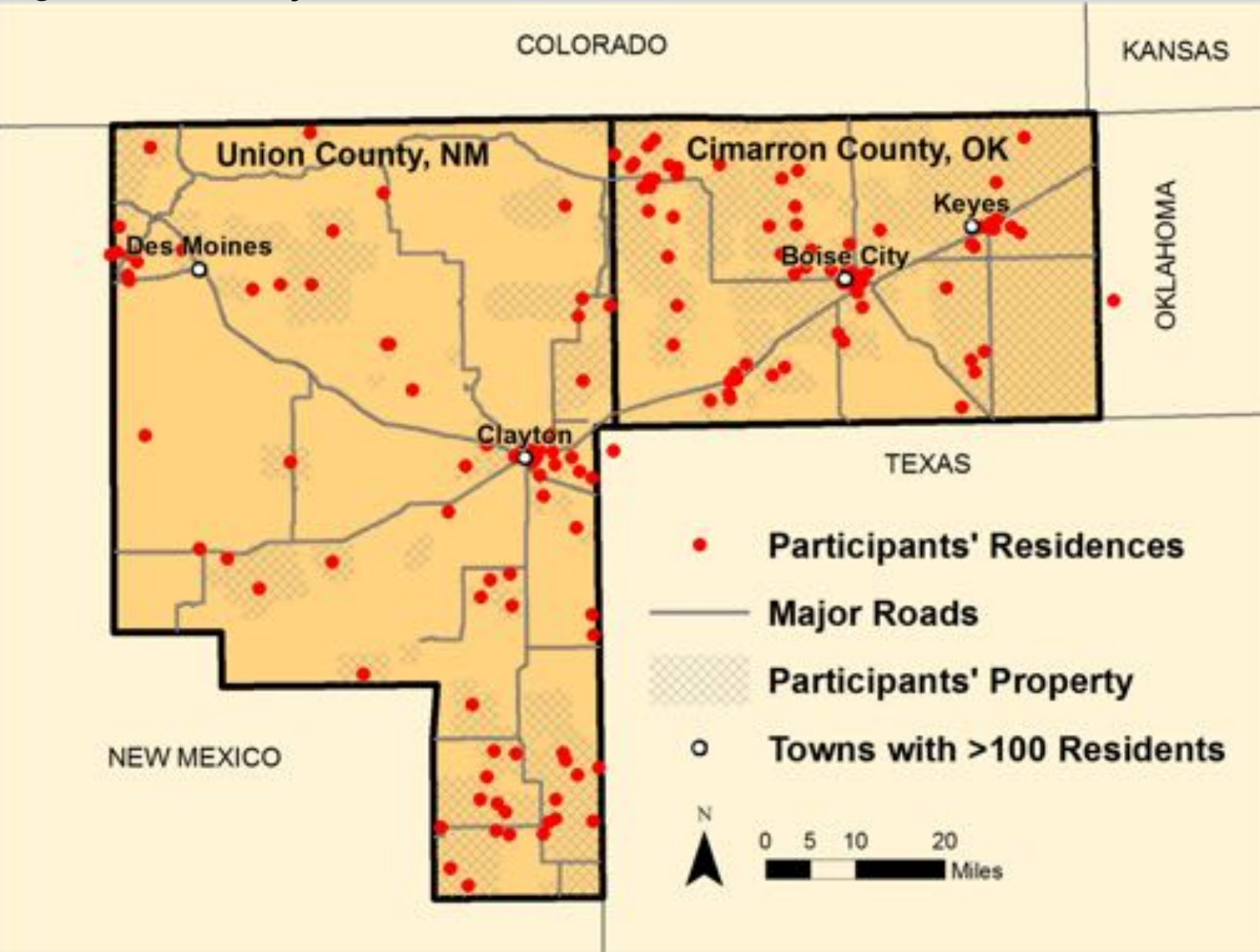
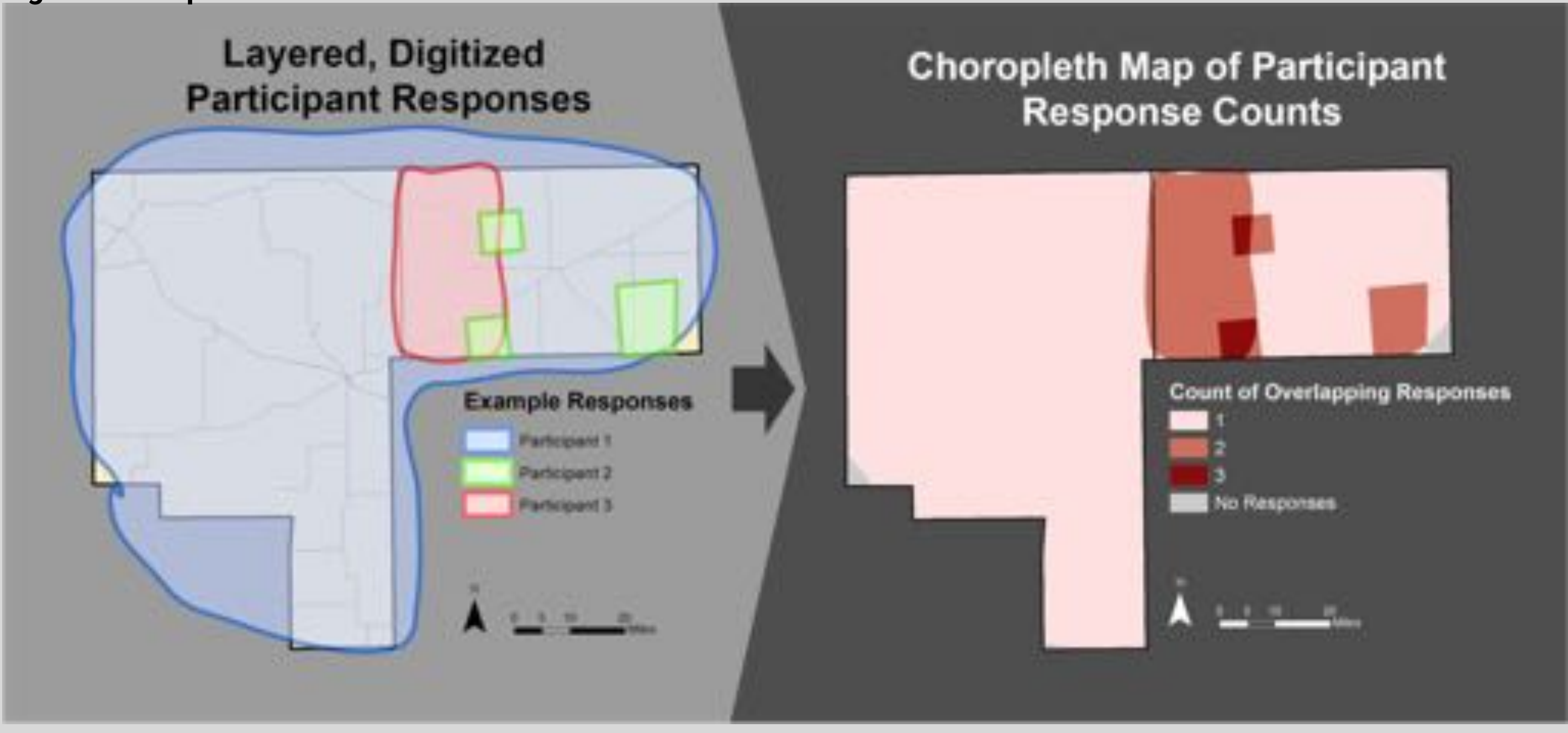


Figure 1 details the extent of participants and their property within the study counties of Cimarron, OK and Union, NM. These agricultural communities are located in a five-state region between Colorado, Kansas, and Texas in the Western High Plains of the United States. This region is known for its rolling grasslands, biodiverse prairie landscapes, and the small communities who steward the land.

Figure 2 – Map Fusion



Drought Responses & Precipitation

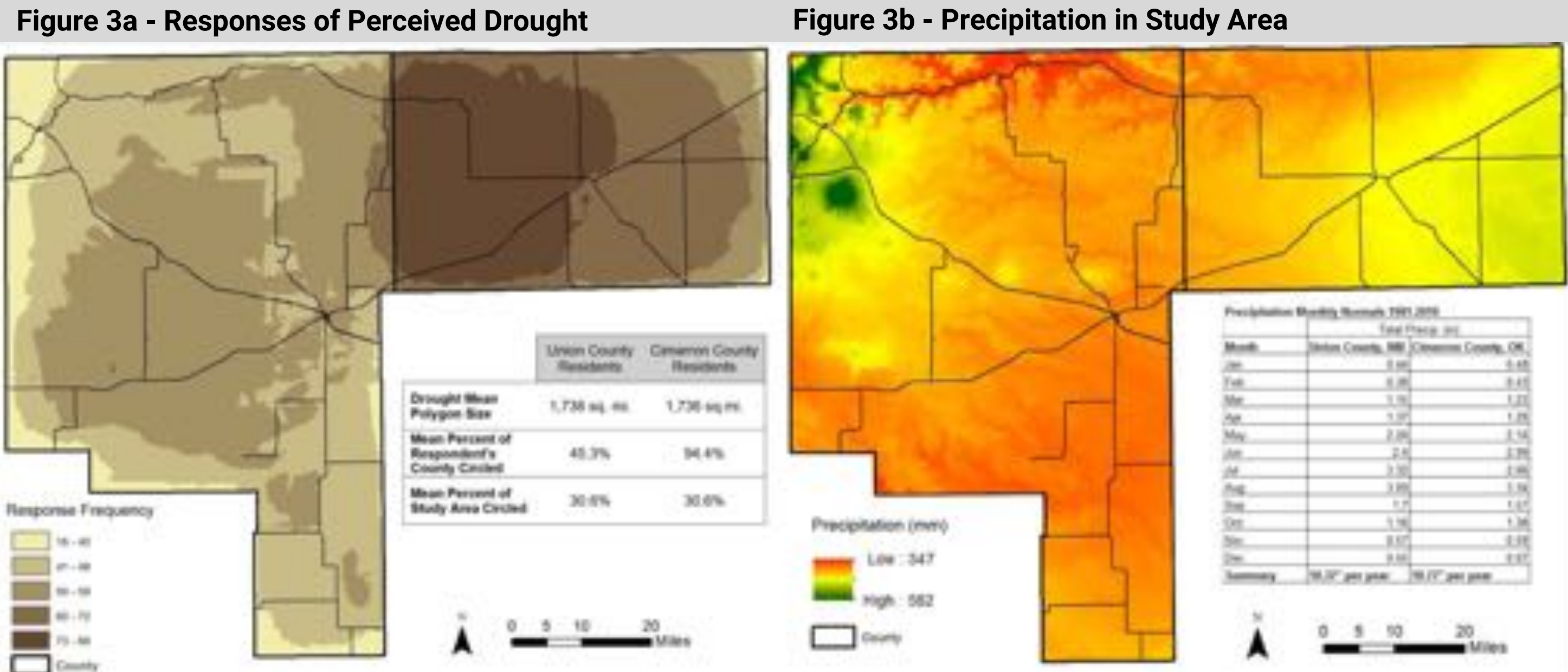


Figure 3a depicts aggregate participant perceptions in the two-county study area. The most frequent of the 245 drought sketches depicted either one or both counties as completely vulnerable to drought. Many informants also identified susceptible land parcels as those they owned.

Figure 3b represents recorded annual precipitation in both counties. (Precipitation data adapted from WorldClim Global Climate Database, Hijmans et al., 2005, NOAA 1981-2010 Monthly Normals (2016)).

Analysis: Participants highlighted drought-vulnerable landscapes in the North-South central regions of the study area with the most concentrated area being in Western Cimarron County, OK. The lowest precipitation rates are concentrated in the Southern parts of Union County, NM while fairer climates are East of Cimarron County, OK and West of Union County, NM. Western regions of Union County approach the higher elevation Raton-Clayton Volcanic Field, possibly leading to higher precipitation rates and cooler weather patterns.

Technology Applications & Use

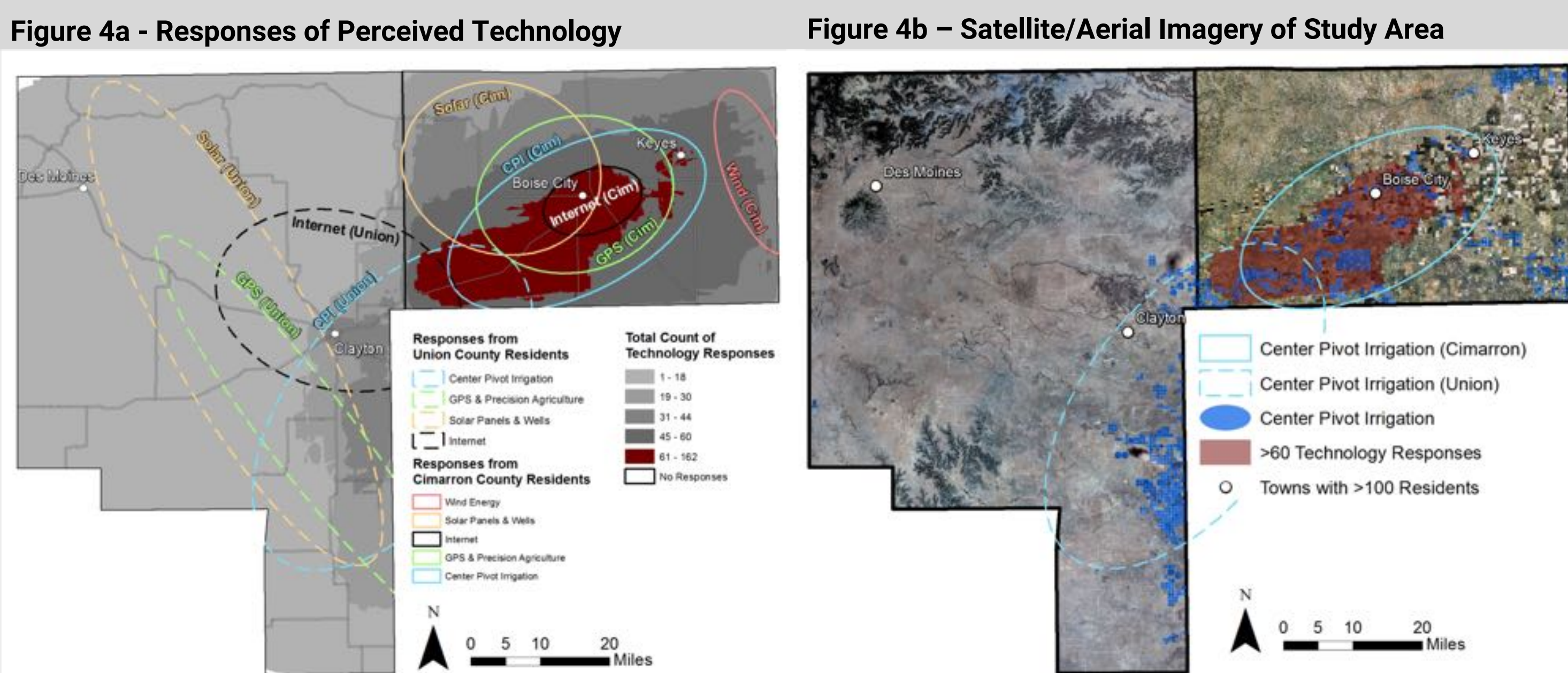


Figure 4a illustrates the concentration of technology 'hot spots' around Boise City, OK and Clayton, NM.

Figure 4b depicts CPI locations which line up well with participant responses of CPI and GPS SDEs.

Analysis: Figure 4 uses SDEs to represent the frequency of participant technology use by type and location. Main technology adaptations include CPI, solar energy, precision agriculture (GPS), and internet usage. CPI occurs in predominantly farming areas, and solar power technologies in predominantly ranching areas. Using aerial photography and data by Wenger et al. (2017), Figure 4b compares perceived CPI usage (Figure 4a) with actual CPI usage. Overall, participant maps show diverse, yet geographically distinct technological adaptations.

Scope & Limitations

Our sampling method, although intensive and geographically stratified by county, was purposive, not random. Consequently, care should be taken with generalizing results. Our study is confined to only two counties even though there is evidence of similar hazardous events and technology use in adjacent counties of Colorado, New Mexico, Kansas, Oklahoma, and Texas. We believe that similar perceptions and vulnerabilities exists in neighboring counties and have plans to carry out further research. Lastly, maps are based on perceptions. Some mapping categories such as technology and invasive/nuisance species have been divided into multiple subtypes which were not consistently labeled by each participant.

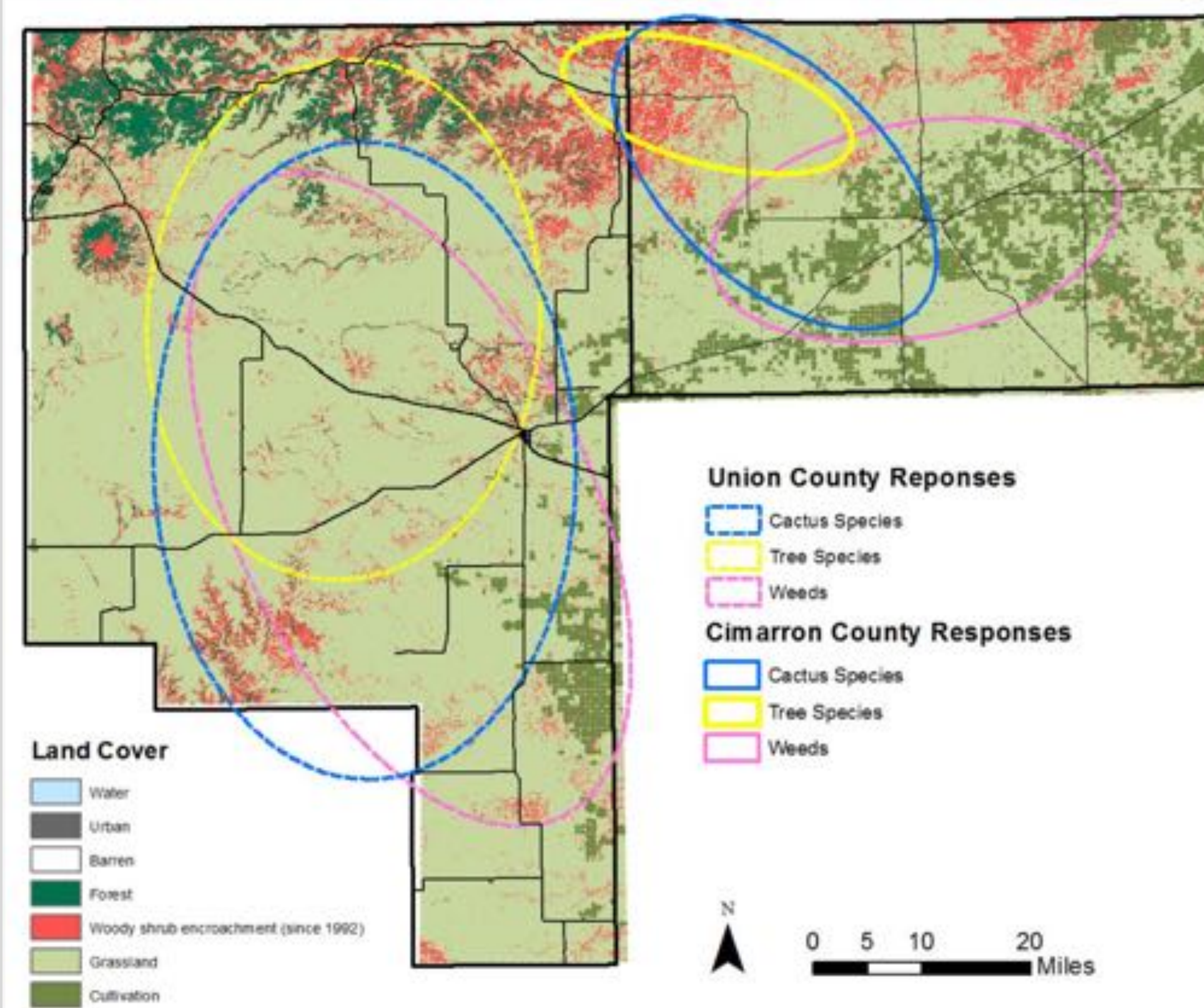
Acknowledgements

The authors would like to lend a special thanks to the following:
The residents of Cimarron County, OK and Union County, NM.
Jaryd Hinch and Jackson Nail (students from GEOG 4313) for their assistance in the field with sketch map collection.
This research has been funded by a National Science Foundation (NSF) research grant (#CMMI-1266381: Vadjunec, Phillips, & Fagin). Any opinions, findings, and conclusions or recommendations expressed here are those of the authors and do not necessarily reflect the views of our funders.

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Invasive/Nuisance Species Response & Land Cover



Analysis: Three participant categories are mapped; 1) Cactus species, 2) Woody tree/shrub species, and 3) weeds. The cactus category includes invasive/nuisance species such as Cholla and Yucca cactus. Within the tree species layer, participants would often mark species such as One-seeded Juniper, Mesquite, and or Salt Cedar as invasive or nuisance plants. The weeds category is by far the largest category with responses ranging from Russian Thistle, locoweed, snakeweed, sheep's head, bindweed, and or other locally termed weeds.

Of particular note is the tree species SDE for Cimarron county. This SDE accurately highlights encroaching species when compared to the land use raster. The weeds response category, as expected, encloses around the main population centers of both counties and thus is the broadest ellipse of the three categories.

Figure 5 displays the perceived extent of invasive/nuisance species in both counties. The map is comprised of six standard deviational ellipses (SDE) overlaid on a map of actual land-use/land-cover change showing vegetation change from 1992-2011 (Fagin et al. 2016). Of particular note, all cells highlighted red depict new shrubland encroachment.

Flooding and Vulnerability

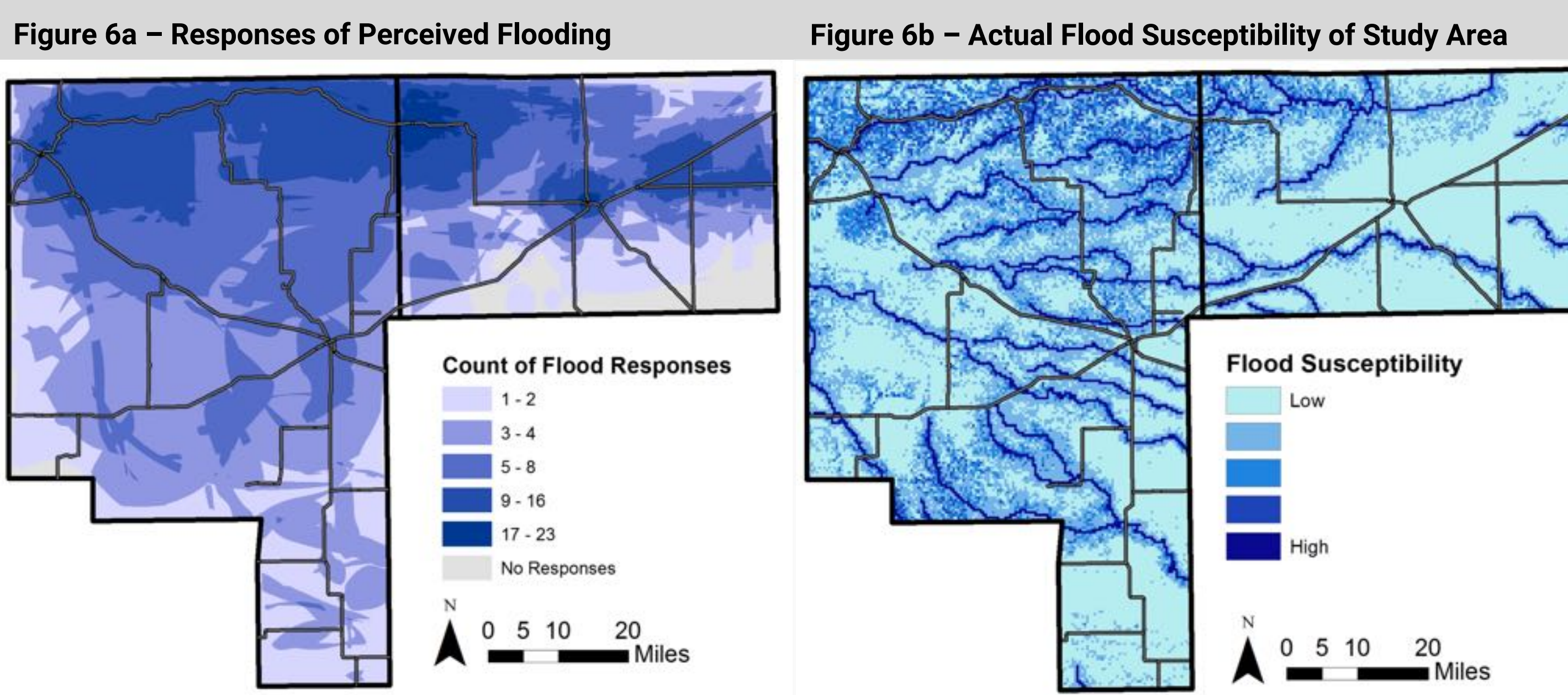


Figure 6a showcases the perceived response frequency of flash flooding, which occurred primarily along the dry Cimarron River drainage in the northern portion of the study area, as well as near the Highway 412 corridor in eastern Cimarron County. Figure 6b shows flood susceptibility throughout the two counties and indicates a high chance of flooding near the Cimarron River, especially in the Northern boundaries.

Analysis: Within Union County, participants circled larger areas of flood compared to Cimarron County. Overall, residents' flooding perception maps closely overlap with our actual flood susceptibility maps, indicating respondents are keenly aware of environmental hazards on the landscape.

Conclusions

The maps displayed here represent the perceptions of residents to hazards in both Cimarron County, Oklahoma and Union County, New Mexico. The people here have a long history of land use in the region, as well as a long history of struggles against this harsh, semi-arid environment. As a result, they appear to have generated comprehensive knowledge about their landscapes. They have also adapted their land use and technologies as needed. A goal of this poster, as well as the larger NSF project in general, is find ways to co-produce knowledge together as scientists and residents. With this in mind, we created "A Map of the People" that showcases their opinions about the land they care for. The sketch mapping methodology allowed residents to freely express their perceptions within their community boundaries. As a result, we now have a set of maps created by the people where their concerns about drought, flooding, plant species, as well as their perceived extents of technology can now be viewed and studied on a larger scale. Below are some of our key findings:

1. Perceived residential knowledge about drought is valuable and credible as most of the responses visually correlate with precipitation maps indicating drought.
2. Technology responses are geographically focused and highly accurate depending on which county responses are from.
3. Invasive and nuisance species are generally well understood by residents, responses vary depending on occupation and location of participants. Tree species have the highest visual correlation to new encroaching shrubland as shown in the land cover map (Figure 5.0). Participants identified numerous weed species encroaching around areas of mainly farm and ranch land. Perceived cactus responses are varied, but carry a generally accurate dispersion from North to South within both counties.
4. Landscapes are more prone to flooding in Union County, New Mexico than Cimarron County, Oklahoma. Participants in Union County appear to know more about the geographical extent of flooding vulnerability than Cimarron County residents, perhaps due to slightly greater rainfall averages in Western regions.

Participatory sketch mapping has lead to an abundance of spatial knowledge over the two study area counties. This approach, combined with other methodologies, shows academic promise in finding new ways to communicate vulnerability spatially across various scales. In a rural study area such as Cimarron County and Union County, participatory mapping provides a critical inlet to the concerned and knowledgeable voices found in the High Plains.