Detection of drought-related human migration and population change on the North American Great Plains

EGU 2020 Session: Drought risk, vulnerability and impact assessment: achievements and future directions

Robert McLeman, Clara Grieg, George Heath, Francesca Fontanella
Department of Geography & Environmental Studies
Wilfrid Laurier University
Waterloo, Canada

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Research questions

- Does drought have an influence on contemporary rural migration & population patterns on the North American Great Plains?
- Do different methodological approaches generate similar results?
- Is there evidence for the "lessening hypothesis"?

Image: Highway in rural Nebraska.
All images from authors except where noted

Background

- Most contemporary research about population impacts of drought comes from low- and middle-income countries
- Relatively little evidence from high-income dryland regions such as the Great Plains
- Low-income vs high-income regions = very different agricultural systems in terms of land tenure, production methods, economic structure, technology, government engagement, etc

Drought & population change on Great Plains

- Since European settlement in late 1800s, severe drought episodes have occurred in approximately 20-30 year cycle
- These used to be accompanied by large fluctuations in rural population numbers, as subsistence farmers move in/out of affected areas
- Most infamous of these occurred in 1930s (aka "Dust Bowl" or "Dirt Thirties" migrations)

Image: abandoned farm, Kansas, 1930s. Photo from US Library Congress archives

Past papers on 1930s drought migration by authors

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GIS-based modeling of drought and historical population change on the Canadian Prairies

Robert McLeman [a], Sam Herold [a], Zoran Reljic [a], Mike Sawada [a], Daniel McKenney [b, †]
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https://doi.org/10.1016/j.jhg.2009.04.003

Abstract

This article describes the development of a GIS-based model of historical drought and population change in western Canada, designed to support qualitative field research into drought adaptation and migration. The model combines digitized census data and recently available modeled historical climate data at a 10 km^2 grid cell scale and can be used to generate maps of 'hotspots' where historical declines in rural populations may be associated with extended periods of heat and lack of precipitation. The results suggest a promising avenue for expanding and refining GIS-based modeling of historical human–climate interactions to support qualitative research and to potentially serve as a stepping stone toward forecasting future risk areas of drought-related migration in continental dryland areas.

Original Paper | Published: 26 June 2011

Soil and its influence on rural drought migration: insights from Depression-era Southwestern Saskatchewan, Canada

Robert A. McLeman & S. Kate Ploeger

Population and Environment 33, 304–332(2012) | Cite this article

Abstract

This article investigates linkages between soil conditions, farm-level vulnerability, adaptation, and rural migration during periods of drought. It begins by reviewing existing literature on climate adaptation in agricultural populations and on relationships between soil and rural migration. This is followed by a detailed case study of rural migration patterns that emerged in the Swift Current district of Saskatchewan, Canada, during a period of extended droughts and severe economic conditions in the 1930s. Using a combination of secondary literature, interviews with surviving first-hand observers and GIS modeling, the study shows how the interacting effects of household indebtedness, social capital, government relief programs, and farm-level soil quality helped stimulate population loss in many rural townships across the study area. The study focuses particularly on the role played by differential soil quality across the Swift Current district and how farms situated on sandier soils were typically more sensitive and vulnerable to drought than those situated on clay soils. Higher-than-average rates of population loss were associated with townships containing areas of poorer quality agricultural soils, an association replicable using GIS software and existing soil and population datasets.

“Lessening hypothesis”

- Since the 1950s, droughts no longer associated with obvious, large scale migrations
- “Lessening hypothesis”: a process of continuous innovation in technological adaptation and policy responses lessens the impacts of recurrent climatic events of similar magnitude on the exposed population (Warrick 1980)
- Therefore, potential for large scale population movements due to droughts diminishes over time as the population adapts in other ways

Studies on recent environment-population change linkages on Great Plains

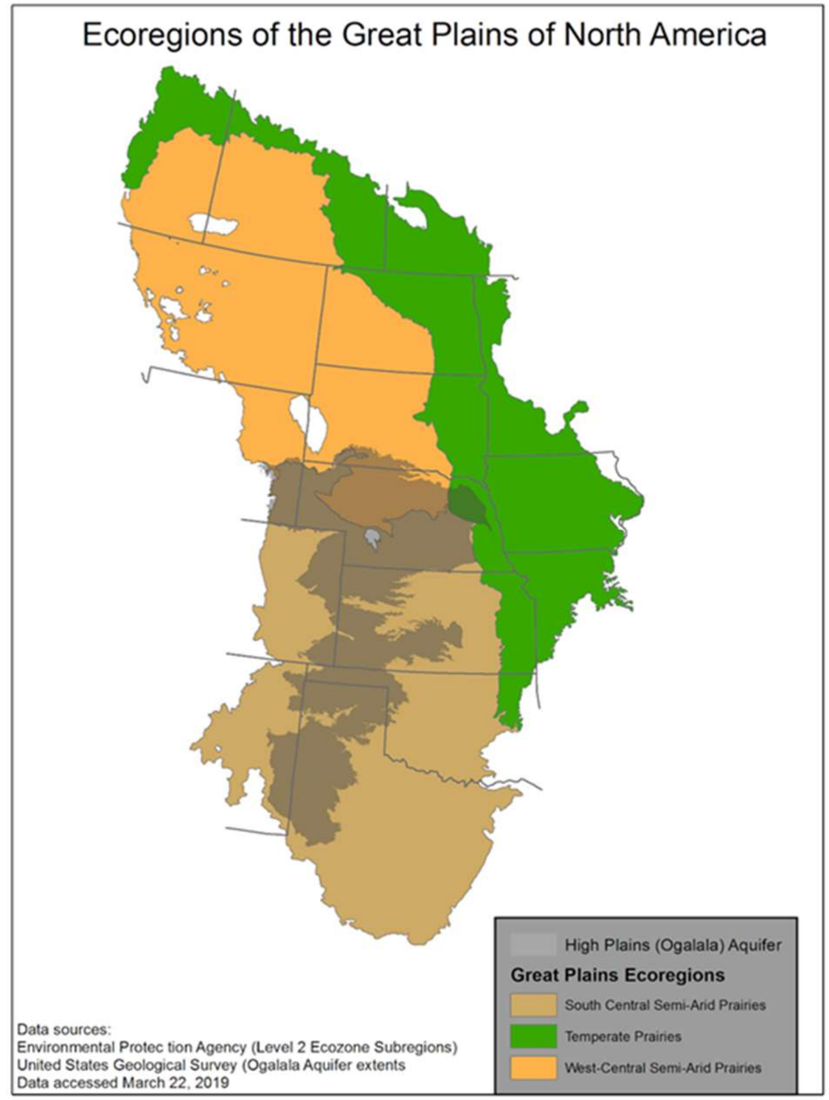
- Outmigration from rural counties in the 1970s showed some association with adverse weather conditions; since then, adverse weather has had minimal influence (Gutmann et al 2005)
- Since 1970, the rate of rural population decline has slowed in areas where farms are irrigated (Parton et al 2007)
- Drought-related yield shocks to corn crops stimulate a small but significant amount of rural employment-seeking outmigration by young adults (Feng et al 2012)

Approach in our project

- Use an exploratory, mixed-methods approach to identify possible associations between drought and population change since 1970s
- Sample <u>all</u> rural areas over that period, not just those where anecdotal or other evidence suggests there might be an association (i.e. avoid sampling on the dependent variable)
- Explore use of machine learning and geospatial regression techniques not previously used for this topic/region and compare results via GIS modelling
- Conduct qualitative field research in suspect locations to assess validity of model outputs

Study area

- Great Plains region includes parts of 3 Canadian provinces & 13 US states, from Alberta to Texas
- Contains 3 ecological sub-regions (temperate long-grass prairies, northern and southern semi-arid shortgrass prairies)
- Central and southern areas of Great Plains underlain by massive Ogallala aquifer



Data used

Population data, 1970-2010

- County-level population counts for 727 rural counties in USA (urban & suburban counties excluded)
- Rural census division population counts for Canadian regions of Plains (note Canadian census occurs on years ending in 1)

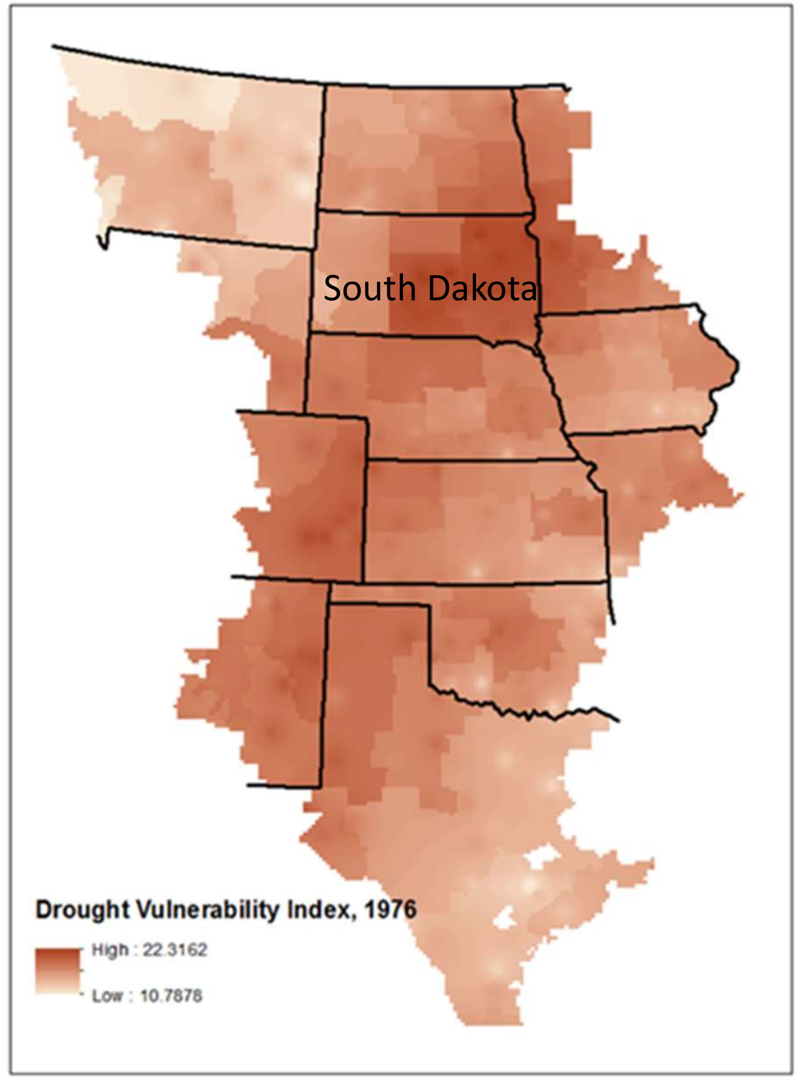
Climate data, 1970-2010

40 different climate variables, including:

- Monthly Palmer Drought Severity Index (PDSI scores)
- Number of degree days/year where max daily temperature >30^{o}C
- Annual precipitation received April to August

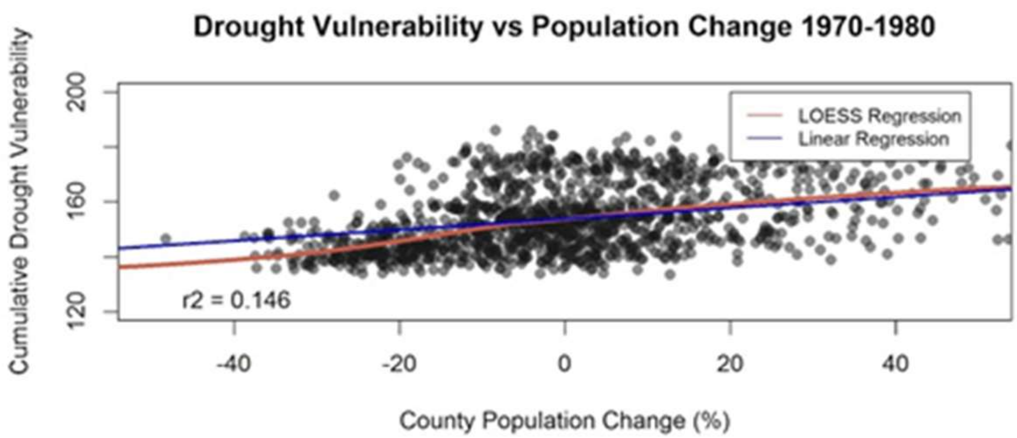
GIS model

- Data adjusted, rasterized, rescaled, and added to ArcGIS model gridded at 10km x 10 km scale
- A “drought potential” score generated for each year for each grid pixel
- Example to right: ranked drought potential score for year 1976, darker = higher likelihood
- Note concentration over eastern south Dakota



Data analyses: regression methods

- Multiple techniques used, including Loess & linear regression, Moran's I test for spatial auto-correlation, Cook's Distance measure to test residuals
- All done using customized r-program scripts
- Decadal data comparisons done at multiple spatial scales, including all region, sub-region, national, province/state levels and R-squared significance calculated



Sample output: comparison of regression scores for drought probability vs county-level population change in US rural Great Plains counties, 1970-1980s

Findings using regression analyses

- Drought & rural population change exhibits strongest association in temperate regions in 1970s, with strength declining each successive decade
- Rural US counties show strongest associations generally
- State-level comparisons show strongest associations in arid Southwestern region, with irrigation access a possible mitigating variable
- Intrastate variations exhibit possible neighbourhood effects”, but also strong influence of exogenous factors

	1970s		1980s		1990s		2000s	
All Rural	0.025***	10.83	0.001	7.75	0	8.91	0	8.27
Rural USA	__0.097***__	4.49	__0.092***__	3.59	__0.305***__	3.49	__0.050***__	3.86
Rural CAN	0	6.47	0.002	4.61	0.017*	5.11	__0.030__	5.88
Rural Temperate	0.083***	4.78	__0.072***__	3.38	__0.138***__	4.04	__0.030**__	4.18
Temperate CAN	0	5.74	0.002	4.45	0	4.94	0.001	4.99
Temperate USA	0	2.68	0.030**	2.35	0.136***	2.36	__0.051*__	3.07
Rural NW Semi Arid	0.062***	6.43	__0.042**__	4.44	__0.033*__	4.86	0.001	5.78
NW Semi Arid CAN	0.006	7.47	0.019	4.92	__0.094__	5.23	0	6.80
NW Semi Arid USA	0.131**	4.17	__0.041*__	3.90	0	3.63	0.026	4.02
Rural S. Semi Arid	__0.147***__	5.18	__0.154***__	4.25	__0.317***__	4.07	0.005	4.41

Table = Selected Model Results (R-Squared, MAE, Independent Variable Significance ((= 0.05, **=0.01, ***=0.001) for Area Difference Population Estimator)*

Data analyses: machine learning

- Random forest & regression tree methods used
- = Automated approach to detect if specific climatic variables in given year(s) are associated to population decline in particular periods
- Requires establishing selection criteria & rules for splitting data
- 42 runs done, at regional, sub-regional and national scales

Sample output:

- *For decade 1971-1981, following variables show possible association to rural population changes in temperate US region:*
- *Precipitation in 1973 and1974 (potential contribution to overall change 18% and 39% respectively); combined drought index variables 1974 (15%) and 1975 (10%); PDSI in 1976 (10%); summer precipitation in 1975 (10%)*

Findings using machine learning

- Outputs simply show where you might wish to look more closely; does not “prove” cause/effect
- Shows overall declining association between climate variable & population change by decade
- Generally similar outputs to regression analyses, but points more strongly to particular clusters of counties

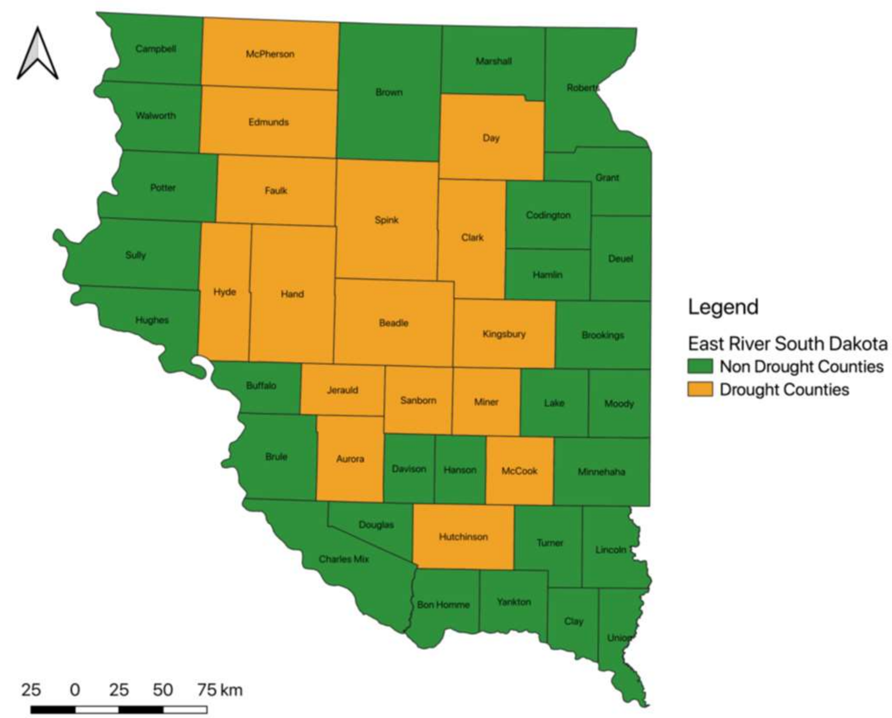


Image: Counties in eastern South Dakota where 1970s drought conditions & pop change show strong association are shaded in yellow

Qualitative field research

- Population data = 10 year intervals, much coarser than climate data
- Models simply show associations, cannot provide causation
- Qualitative research allows to assess potential causation; possible of lag effects between drought event and population change; exogenous factors; refine models

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Current Directions in Water Scarcity Research
Volume 2, 2019, Pages 311-323

Chapter 21 - Drought adaptation when irrigation is not an option: the case of Lincoln Co., Colorado, USA

Robert McLeman

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https://doi.org/10.1016/B978-0-12-814820-4.00021-3

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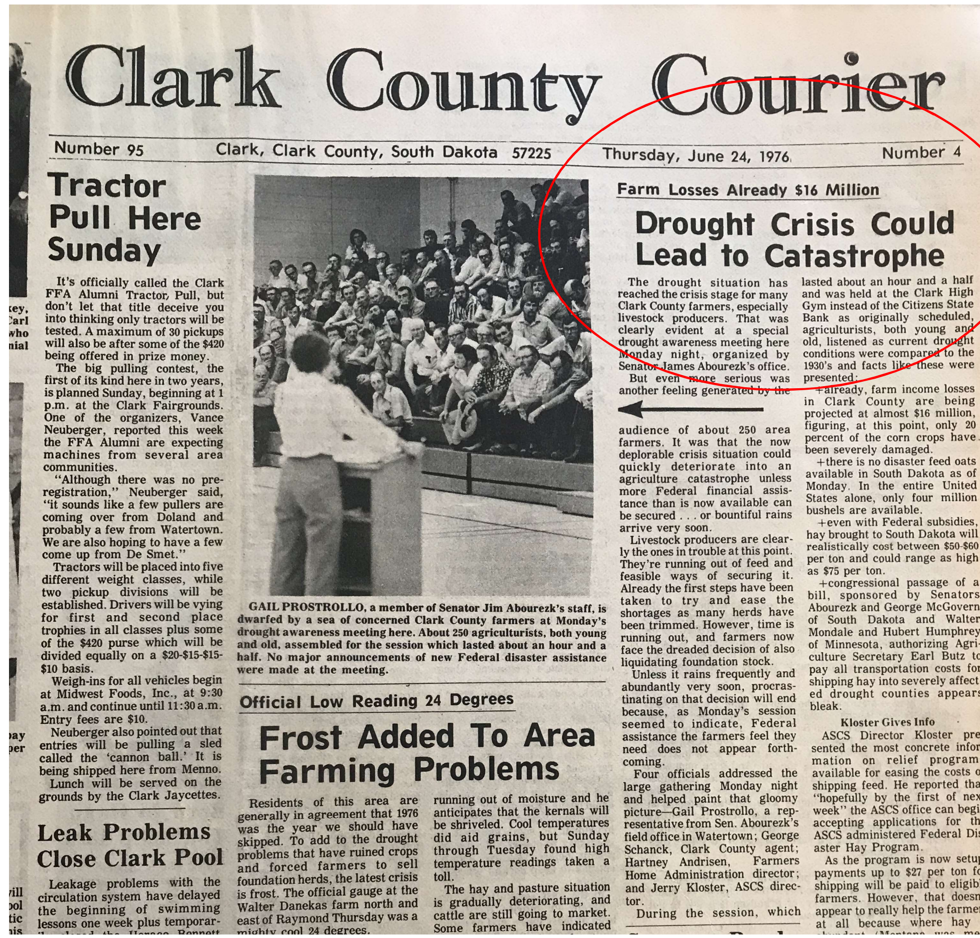
Abstract

This chapter describes drought impacts and adaptation in a dryland agricultural county in Colorado, USA, where there is insufficient ground and surface water to support crop irrigation. Water scarcity is an ongoing challenge for farmers, ranchers, and small urban centers in the county, with periodic droughts testing the limits of local adaptive capacity. Important factors in adaptation include crop insurance, government subsidies, and flexible agricultural practices. In Colorado, water is a shared common resource administered by the state, creating an added layer of complexity in water management and use. The experiences documented here are ones that many dryland agricultural regions in other parts of the world can expect to encounter in coming decades as changing climate, demographic characteristics, and socioeconomic factors take hold.

Image: publication from field research in eastern Colorado, location identified by spatial regression methods

Case study: eastern South Dakota drought, 1976

- Unusually localized drought, worst in century
- Farming system = family operated 500 acre cattle farms, fields used to pasture or grow feed for cattle
- No irrigation
- Government assistance consisted primarily of loans
- Farmers sold off herds to generate short-term income



Clark County Courier

Number 95 | Clark, Clark County, South Dakota 57225 | Thursday, June 24, 1976 | Number 4

Tractor Pull Here Sunday

It's officially called the Clark FFA Alumni Tractor Pull, but don't let that title deceive you into thinking only tractors will be tested. A maximum of 30 pickups will also be after some of the $420 being offered in prize money.

The big pulling contest, the first of its kind here in two years, is planned Sunday, beginning at 1 p.m. at the Clark Fairgrounds. One of the organizers, Vance Neuberger, reported this week the FFA Alumni are expecting machines from several area communities.

"Although there was no pre-registration," Neuberger said, "it sounds like a few pullers are coming over from Doland and probably a few from Watertown. We are also hoping to have a few come up from De Smet."

Tractors will be placed into five different weight classes, while two pickup divisions will be established. Drivers will be vying for first and second place trophies in all classes plus some of the $420 purse which will be divided equally on a $20-$15-$15-$10 basis.

Weigh-ins for all vehicles begin at Midwest Foods, Inc., at 9:30 a.m. and continue until 11:30 a.m. Entry fees are $10.

Neuberger also pointed out that entries will be pulling a sled called the 'cannon ball.' It is being shipped here from Menno.

Lunch will be served on the grounds by the Clark Jaycettes.

Leak Problems Close Clark Pool

Leakage problems with the circulation system have delayed the beginning of swimming lessons one week plus temporar-

GAIL PROSTROLLO, a member of Senator Jim Abourezk's staff, is dwarfed by a sea of concerned Clark County farmers at Monday's drought awareness meeting here. About 250 agriculturists, both young and old, assembled for the session which lasted about an hour and a half. No major announcements of new Federal disaster assistance were made at the meeting.

Official Low Reading 24 Degrees

Frost Added To Area Farming Problems

Residents of this area are generally in agreement that 1976 was the year we should have skipped. To add to the drought problems that have ruined crops and forced farmers to sell foundation herds, the latest crisis is frost. The official gauge at the Walter Danekas farm north and east of Raymond Thursday was a mighty cool 24 degrees.

running out of moisture and he anticipates that the kernals will be shriveled. Cool temperatures did aid grains, but Sunday through Tuesday found high temperature readings taken a toll.

The hay and pasture situation is gradually deteriorating, and cattle are still going to market. Some farmers have indicated

Farm Losses Already $16 Million

Drought Crisis Could Lead to Catastrophe

The drought situation has reached the crisis stage for many Clark County farmers, especially livestock producers. That was clearly evident at a special drought awareness meeting here Monday night, organized by Senator James Abourezk's office.

But even more serious was another feeling generated by the audience of about 250 area farmers. It was that the now deplorable crisis situation could quickly deteriorate into an agriculture catastrophe unless more Federal financial assistance than is now available can be secured . . . or bountiful rains arrive very soon.

Livestock producers are clearly the ones in trouble at this point. They're running out of feed and feasible ways of securing it. Already the first steps have been taken to try and ease the shortages as many herds have been trimmed. However, time is running out, and farmers now face the dreaded decision of also liquidating foundation stock.

Unless it rains frequently and abundantly very soon, procrastinating on that decision will end because, as Monday's session seemed to indicate, Federal assistance the farmers feel they need does not appear forthcoming.

Four officials addressed the large gathering Monday night and helped paint that gloomy picture—Gail Prostrollo, a representative from Sen. Abourezk's field office in Watertown; George Schanck, Clark County agent; Hartney Andrisen, Farmers Home Administration director; and Jerry Kloster, ASCS director.

During the session, which lasted about an hour and a half and was held at the Clark High Gym instead of the Citizens State Bank as originally scheduled, agriculturists, both young and old, listened as current drought conditions were compared to the 1930's and facts like these were presented:

+already, farm income losses in Clark County are being projected at almost $16 million, figuring, at this point, only 20 percent of the corn crops have been severely damaged.

+there is no disaster feed oats available in South Dakota as of Monday. In the entire United States alone, only four million bushels are available.

+even with Federal subsidies, hay brought to South Dakota will realistically cost between $50-$60 per ton and could range as high as $75 per ton.

+congressional passage of a bill, sponsored by Senators Abourezk and George McGovern of South Dakota and Walter Mondale and Hubert Humphrey of Minnesota, authorizing Agriculture Secretary Earl Butz to pay all transportation costs for shipping hay into severely affected drought counties appears bleak.

Kloster Gives Info

ASCS Director Kloster presented the most concrete information on relief programs available for easing the costs of shipping feed. He reported that "hopefully by the first of next week" the ASCS office can begin accepting applications for the ASCS administered Federal Disaster Hay Program.

As the program is now setup, payments up to $27 per ton for shipping will be paid to eligible farmers. However, that doesn't appear to really help the farmers at all because where hay is

How farmers explained population impact of drought

- Interviews with retired farmers suggest few people left area during the drought
- However, heavier debt loads & reduced herd size made farmers more vulnerable to interest rates rising from 5% to 20% over next 3 years
- Thousands of area farmers went into financial distress, bankruptcy and this caused outmigration

Image: Abandoned main street businesses in Ipswich, SD

In-migration during drought

- Qualitative research suggested re-analysis of population data by age cohort
- This revealed in-migration of men aged 30-34 to drought counties in 1970s
- Is likely return migration to help perform labour on farms during drought, when farmers had extra work to do but had no $ to hire labour

Outlier: net inflow of male migrants aged 30-34 to drought counties in 1970s

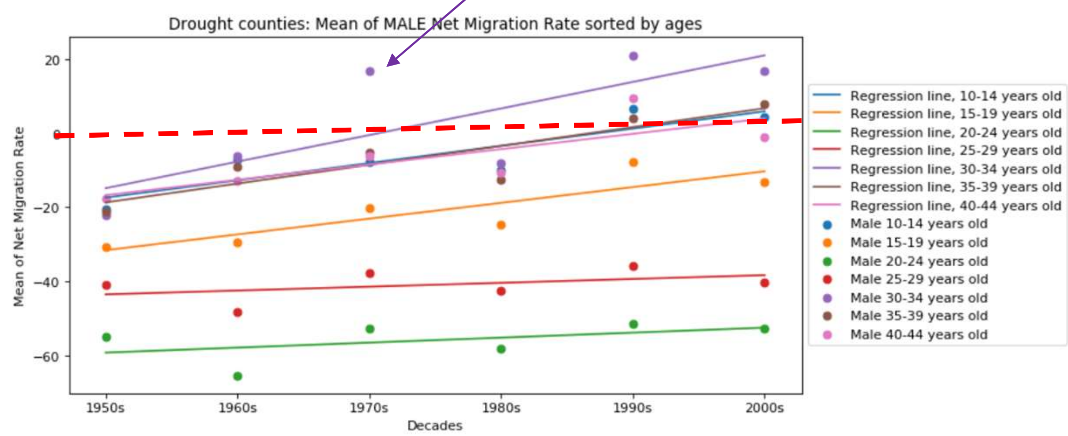


Image: net male migration rates for drought counties, 1950-2010. Dotted red line shows net rate = zero; anything below it = net out-migration. Colours = various age cohorts.

Findings (so far)

- Different modeling methods highlight similar potential associations, but emphasize some areas over others
- Mixed methods approach is important; need for qualitative research to "ground truth" evidence, assess potential causation and refine models is essential
- Evidence for lessening hypothesis is strong
- Temporal coarseness of population data = a key limit on predictive power of models, not climate data

Thanks!

Contact:

Professor Robert McLeman

Department of Geography & Environmental Studies

Wilfrid Laurier University

Waterloo, Ontario, Canada

rmcleman@wlu.ca