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The association between drought conditions and increased occupational psychosocial stress among U.S. farmers: An occupational cohort study

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Abstract

Background—Drought represents a globally relevant natural disaster linked to adverse health. Evidence has shown agricultural communities to be particularly susceptible to drought, but there is a limited understanding of how drought may impact occupational stress in farmers.

Methods—We used repeated measures data collected in the *Musculoskeletal Symptoms among Agricultural Workers Cohort* study, including 498 Midwestern U.S. farmers surveyed with a Job Content Questionnaire (JCQ) at six-month intervals in 312 counties from 2012 through 2015. A longitudinal linear mixed effects model was used to estimate the change in job strain ratio, a continuous metric of occupational psychosocial stress, during drought conditions measured with a 12-month standardized precipitation index. We further evaluated associations between drought and psychological job demand and job decision latitude, the job strain components, and applied a stratified analysis to evaluate differences by participant sex, age, and geography.

Results—During the growing season, the job strain ratio increased by 0.031 (95% CI: 0.012, 0.05) during drought conditions, an amount equivalent to a one-half standard deviation change (Cohen's D = 0.5), compared to non-drought conditions. The association between drought and the

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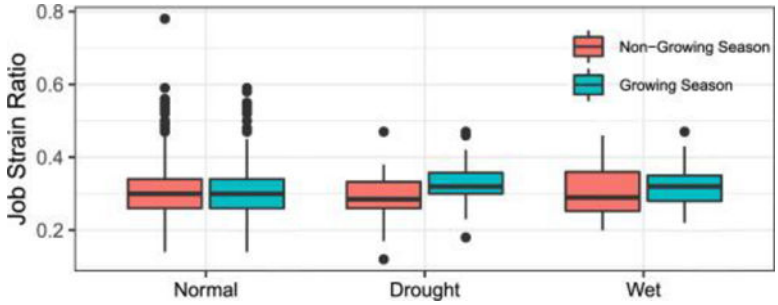
DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

job strain ratio was driven mostly by increases in the psychological job demand (2.09; 95% CI: 0.94, 3.24). No risk differences were observed by sex, age group, or geographic region.

Conclusions—Our results suggest a previously unidentified association between drought and increased occupational psychosocial stress among farmers. With North American climate anticipated to become hotter and drier, these findings could provide important health effects data for federal drought early warning systems and mitigation plans.

GRAPHICAL ABSTRACT



INTRODUCTION

Droughts are among the broadest and most impactful of all natural hazards. Over the past 40 years, the percentage of global land affected by drought nearly doubled and has affected more people than any other natural disaster (Food and Agriculture Organization of the United Nations, 2021). In the U.S., 28 recorded drought events occurred from 1980 to 2020 with estimated losses of $258.9 billion and in June of 2021, an estimated 39.8% of the U.S. is in moderate drought or worse with much of the American southwest experiencing extreme or exceptional drought (Smith, 2010-2019). While the financial costs of drought are behind only tropical cyclones and severe storms, its threat to public health remain understudied, particularly among vulnerable populations.

Drought has been associated with multiple adverse health outcomes, including increased mortality (Salvador et al., 2019; Berman et al., 2017; Lynch et al., 2020), respiratory-related disease (Salvador et al., 2019; Jagger et al., 2015; Smith et al., 2014a), water and vector borne infection (Stanke et al., 2013; Froelich et al., 2012; Hagan et al., 2018; Brown et al., 2014), and cardiovascular events (Berman et al., 2017). Evidence has correlated drought with worsening air quality and higher concentrations of ozone and fine particulate matter (Wang et al., 2017). This is driven by the exacerbation of secondary pollutant formation (Demetillo et al., 2019) or by elevating the conditions for wildfire spread and occurrence (Littell et al., 2016; Sutanto et al., 2020). Arid soils caused by drought can further increase dust-related fungal pathogens and drive incidence of pulmonary disease, such as Valley Fever (Tong et al., 2017; Zender and Talamantes, 2006). In developing nations, drought-induced water scarcity can directly affect disadvantaged populations, causing widespread famine, nutritional deficiencies, and community displacement (Ebi and Bowen, 2016). But among the health impacts of drought, the most well-studied are associations with poor mental health and psychological distress, particularly in regions with fewer freshwater resources.

Rural and farming communities are at heightened risk of drought-induced mental health impacts (Vins et al., 2015). A drought in agriculture regions can have disastrous effects, including crop and livestock loss, lower income, and subsequent harms on broader communities reliant upon agricultural enterprises. Australian studies have found that drought not only leads to increased mental distress among farmers (Austin et al., 2018; Edwards et al., 2015; O'Brien et al., 2014; Fennell et al., 2012), but can increase suicide mortality (Hanigan et al., 2012; Guiney, 2012). Similar associations have not been observed among urban populations during periods of drought (O'Brien et al., 2014; Hanigan et al., 2012). Several explanations for this disparity have been proposed. Among rural and farming populations, there is a heightened attitude of self-reliance and stoicism, which often impedes help-seeking behaviors (Vins et al., 2015; Fuller et al., 2000; Spleen et al., 2014). Rural areas are at a similar disadvantage in regards to those seeking mental health care with less infrastructure and providers, including psychiatrists, psychologists, counselors, and social workers, compared to the U.S. as a whole (Ellis et al., 2009). This combination of both perceived stigma and a lack of clinical resources for mental health care makes agricultural communities a highly vulnerable subpopulation for psychological distress.

In 2012, the U.S. experienced a pan-continental drought that covered 61.8% of the contiguous country, encompassing productive agricultural regions, including the Northern Plains and Midwestern states (Cook et al., 2013). Estimated agricultural losses exceeded $30 billion with a quarter of all corn, soybean, and sorghum harvests ruined, and moderate to severe drought conditions affecting 68% of livestock producing areas (Rippey, 2015; USDA Economic Research Service, 2013). In response to the drought, Midwestern states received economic assistance in the form of credit, crop insurance, and water conservation tools to rehabilitate impacted lands (Mallya et al., 2013). However, the influence of this drought event on farmers health, including occupational psychosocial stress, is unknown.

Increased job strain (a metric that combines measures of (i) psychological job demands and (ii) decision authority) is an established risk factor for worsening mental health, including psychological distress (Bourbonnais et al., 1996) and depressive symptoms (Daryl et al., 2000; Smith and Bielecky, 2012). We hypothesize that occupational psychosocial stress will be greater among U.S. farmers during drought, placing them at increased risk for adverse mental health outcomes. Identifying this association could provide important health effects data for drought mitigation plans and early warning systems. In 2006, the National Integrated Drought Information System (NIDIS) was formed by congressional mandate to create drought early warning systems that proactively manage drought-related risks. With an increased NIDIS focus on health risks associated with drought, the identification of populations vulnerable to drought are a necessity for state/local planning and strategies.

To test this relationship, we applied a longitudinal mixed-effects model to a Midwestern farmer cohort to estimate the association between occupational psychosocial stress and drought conditions that covered the historic 2012 event. We evaluated whether the season of drought occurrence and individual factors such as participant sex, age, and geography resulted in observed differences in reporting of occupational psychosocial stress. If an association between drought and occupational psychosocial stress were observed, it would represent the first time that drought impacts on the worker stress would have been evaluated

in North America. A specific focus on farmers allows us to confirm if their vulnerability to drought observed in other parts of the globe remains a risk factor in the United States. Furthermore, our findings would provide important clues regarding extreme weather impacts on agricultural populations, who are at greater risk in a changing climate, and inform mitigation and preparedness policy.

2. METHODS

2.1. Study region, timeframe, and design

We examined occupational psychosocial stress among farmers residing in 312 counties across nine midwestern states (Illinois, Iowa, Kansas, Minnesota, Missouri, Nebraska, North and South Dakota, and Wisconsin). Farmer data were collected from 2012 through 2015. Drought measures were spatially and temporally linked to farmer county of residence both during and prior to survey response periods and a linear mixed-effects model was used to estimate the association between exposure to drought conditions and occupational psychosocial stress.

2.2. Farmers cohort data

We used previously collected and de-identified longitudinal data from 518 agricultural workers, 95% self-described as farm owners or operators (e.g., the individual running the farm and making day-to-day management decision), who were surveyed across a 3-year period. The purpose of the original study (Fethke et al., 2015) was to estimate associations between the physical demands of agricultural work and musculoskeletal pain. All participants, even if reporting secondary employment, specified that they perform the majority of work on their farm. Participants completed a baseline survey in March 2012 with follow-up surveys at 6-month intervals until May 2015. Questions included survey response date, personal demographics such as age, sex, and education, a description of farm characteristics (commodities, size, tasks performed and task hours, among others), and items from the psychological job demands and decision latitude subscales of the Job Content Questionnaire (JCQ) to measure occupational psychosocial stress (Karasek et al., 1998). Additional questions included the Positive and Negative Affect Schedule (PANAS) to measure negative affect, a personality trait involving the experience of negative emotions, a potential confounder of the JCQ and drought association (Watson et al., 1988). Participants also reported the experience of musculoskeletal pain of the low back, neck/shoulder, and elbow/wrist/hand regions during the three-month period immediately preceding survey administration. We created a new variable – seasonal pain – which was classified as positive if participants reported pain for any of the three body regions and negative if they reported no pain for all three body regions. A second variable was created to evaluate participants reporting seasonal pain in 2 or more body regions simultaneously.

2.3. Estimation of job strain

A widely-accepted model is that occupational psychosocial stress (sometimes called “job strain”) increases with increased psychological job demands and decreased decision latitude (Schnall et al., 1994). The JCQ is a self-completed survey designed to quantify psychological job demands and decision latitude. A continuous measure of job strain was

calculated as the ratio of the psychological job demands subscale score to the decision latitude subscale score. The job strain ratio was the primary dependent variable in the current study, with greater values indicating greater occupational psychosocial stress. Additional analyses explored the psychological job demands and decision latitude subscale scores as separate dependent variables. We created an additional variable to designate whether surveys were completed during the growing season (May-October) or the non-growing season (November-April). Months were selected based on average planting and harvest times of major crops (e.g., soy, corn, wheat) grown in the Midwest. This variable allowed us to evaluate whether JCQ responses changed when farmers were actively planting or growing crops in comparison to periods of lower activity during the non-growing season.

2.4. Drought exposure assessment

We used the publicly available nClimGrid standardized precipitation index (SPI) to assess drought conditions for each participant across the study observation period (NOAA National Centers for Environmental Information, n.d.). The SPI uses precipitation to characterize abnormal dryness or wetness across different timescales. SPI values were interpreted as the number of standard deviations that observed precipitation departs from long-term average conditions (Keyantash, 2018). Our study focused on the 12-month SPI, which is a timescale indicative of a long-term drought event. The SPI is initially estimated as a geographically gridded continuous U.S. output for each month, which we aggregated to the county-level. Furthermore, since we were linking drought to occupational psychosocial stress, we estimated a 3-month rolling mean of county-level SPI to capture average conditions prior to the date of survey responses.

We re-classified the continuous SPI value into a categorical variable, representing drought, normal, and wet conditions, using U.S. Drought Monitor scales (National Drought Mitigation Center, 2020). SPI values ≤−1.5 were classified as drought conditions, values between −1.5 and 1.5 were classified as normal conditions, and values ≥1.5 were classified as wet conditions. An SPI value of ≤−1.5 was considered an ‘extreme’ or ‘exceptional’ drought event associated with major or exceptional widespread crop or pasture losses (National Drought Mitigation Center, 2020).

2.5. Statistical analysis

To estimate the association between drought and occupational psychosocial stress, we applied a linear mixed-effects longitudinal model with repeated measures of job strain ratio as the dependent variable and the categorized drought variable according to the survey date as the primary independent variable. We fit the following model using restricted maximum likelihood, $Y_{ij} = \beta_0 + \beta_1 Drought_{ij} + \beta_2 SurveySeason_{ij} + \beta_3 Drought_{ij} SurveySeason_{ij} + \beta_4 Pain_{ij} + \beta_5 Occupation_{ij} + \beta_6 NegAffec_{ij} + \beta_7 Age_{7\,ij} + \beta_8 Time_{ij} + b_i \varphi_i + \varepsilon_{ij}$ where Y_{ij} is the continuous job strain ratio for the j^{th} observation on participant i, $\beta_{1,\ldots,n}$ are the fixed effect regression coefficients and $Drought_{ij}$ is the categorical drought condition (normal, drought, or wet) for the j^{th} survey response on participant i. To evaluate whether job strain ratio varies by growing season and drought, we included a categorical variable for the survey response season, where $SurveySeason_{ij}$ is an indicator of whether the survey represents the growing season or the non-growing season and $Drought_{ij} SurveySeason_{ij}$ represents the

interaction between drought and survey season. We adjusted for individual characteristics that can influence stress, where $Pain_{ij}$ is the categorical presence or absence of seasonal pain, $Occupation_{ij}$ is a binary variable of whether farming is the primary occupation, $NegAffec_{ij}$ is a binary category of whether a person has low or high negative affectivity, and Age_{ij} is the age of participant i on the date of the j^{th} survey response. We adjusted for potential changes in job strain ratio over time by including $Time_{ij}$, which represents the date (month and year) when a survey was completed. We further included a random person effect, φ_i, to account for within-person variability. In a sensitivity test, we adjusted our model for inclusion of 1) sex, 2) farm size, 3) the type of farm (e.g. grain only, livestock, multiple commodity), and 4) seasonal pain in multiple body regions.

We also constructed separate models using the psychological job demands and decision latitude subscale scores as the dependent variable to explore the effect of drought conditions on these distinct dimensions of occupational psychosocial stress. We used the primary model described above to perform this evaluation. We additionally performed stratified analyses to examine potential heterogeneity of effect by sex (male, female), age (<60 years, 60-75 years, 75+ years), and geographic location based on state of residence (East = Illinois, Wisconsin; North = Minnesota, North Dakota, South Dakota; South = Iowa, Nebraska, Kansas, Missouri). Results could not be stratified by ethnicity as over 98% of participants reported as Caucasian.

Analyses were performed using R Statistical Software (v. 4.0.2) and the ‘nlme’ package (Pinheiro et al., 2021). The study was reviewed and approved by the University of Minnesota Institutional Review Board (STUDY 00007664).

3. RESULTS

The cohort initially included 518 farmers, but missing JCQ and PANAS information reduced our dataset to 498 unique participants with 2074 survey responses and a median number of observations of 4 out of 7 survey data collection rounds (Table 1). Participants were primarily male with a mean age of 61.7 (sd = 12.0) years, which is slightly higher than the U.S. average farmer age of 58.3 years (USDA National Agricultural Statistics Service, 2014). About 72% of the participants reported farming as the primary occupation, whereas 48% of U.S. farmers consider farming to be their primary occupation (USDA National Agricultural Statistics Service, 2014). Averaged across all participants the mean job strain ratio was 0.31 (standard deviation of 0.06) with a within person standard deviation of 0.03.

Drought conditions were normally distributed across our study period with an average SPI of −0.03 (range −2.78 to 2.46) and normal conditions constituted 93.2% of our total data days (Table 2). We had 82 survey responses (4.0%) during drought conditions and 59 (2.8%) responses during wet conditions. When stratified by growing season, the average SPI was similar across both growing and non-growing seasons.

No clear relationship was observed on a scatterplot of SPI and job strain ratio (Fig. 1). A fitted loess curve suggested that job strain ratio may be slightly higher during both wet (SPI ≥ 1.5) and drought conditions (SPI ≤ −1.5) compared to normal conditions, but this trend

was weak (Pearson correlation rho = 0.04 (95% CI: −0.003, 0.082). Boxplots suggested no meaningful differences in the distributions of job strain ratio across the SPI categories (Fig. 2A). Likewise, we observed similar job strain ratio distributions by growing and non-growing seasons (Fig. 2B). However, when stratified by both SPI category and season, we observed that the job strain ratio was significantly higher during drought conditions that occurred during the growing compared to the non-growing season ($P < 0.01$, Welch's 2-sided t-test) (Fig. 2C).

Stratified analyses for sex, age, and geographic location found that drought during the growing season is positively associated with increased job strain ratio and psychological job demand regardless of subgroup, although statistical significance is lost in many subgroups (Fig. 3). There is some evidence that males and younger farmers showed a weaker increase in job strain ratio associated with drought, while the association between drought and psychological job demands increased more in northern states of Minnesota and the Dakotas. However, these differences may be attributable to smaller sample sizes as a consequence of stratification and may not reflect true associations between drought and occupational psychosocial stress.

The magnitudes of the observed associations between drought conditions and occupational psychosocial stress (i.e., job strain, psychological job demands, and decision latitude) did not meaningfully change when adjusting for sex, farm size, farm commodity type, or seasonal pain and models were robust to their exclusion based on AIC and log-likelihood. When replacing the any seasonal pain variable with seasonal pain in multiple body parts, we observed multiple body part pain increased participant job strain ratio by 0.007 (95% CI: 0.002, 0.013) and increased the psychological job demand by 0.40 (95% CI: 0.06, 0.74). There was no significant association with job decision latitude. However, the association between drought and occupational psychosocial stress remained consistent for all models, which indicates that their role in exacerbating occupational stress likely remains independent.

4. DISCUSSION

Occupational psychosocial stress has been associated with mental health outcomes in some populations (Daryl et al., 2000; Smith and Bielecky, 2012; Mark and Smith, 2012). In comparison to many occupations, drought may uniquely impact the experience of occupational psychosocial stress in an agriculture setting. Drought, therefore, is a plausible yet understudied etiology of the burden of mental health outcomes among farmers. We found that among a cohort of Midwestern farmers longitudinally surveyed for occupational psychosocial stress, drought condition during the growing season increased job strain ratio by about 50% of its standard deviation; the equivalent of a medium difference in effect size. Furthermore, the magnitude of increased job strain ratio during drought was four-fold larger than the increase from other stressors, such as pain in multiple body parts (0.03 vs. 0.007, respectively). Our findings will provide new information for drought early warning plans and potential targeted care plans for agricultural workers during periods of increased risk.

The use of a longitudinal dataset to examine within-person associations between drought and occupational psychosocial stress is a strength of this study. As far as the authors are aware, no other study of associations between drought and job strain has collected within-person evaluations of job strain for more than two repeated measures. In fact, nearly all other research on the psychological impacts of drought was conducted with cross-sectional population-based surveys (Hanigan et al., 2018; Edwards et al., 2015; O'Brien et al., 2014; Fennell et al., 2012), which cannot capture the time-varying effect of drought at the individual level. Additionally, prior studies almost entirely focus on Australian populations with a near absence of North American study samples, except for an analysis of acute stress in the general population of California during the 2015 drought (Barreau et al., 2017). This dearth of research makes it difficult to perform comparative evaluations and determine global variation of drought impacts. Furthermore, our study was designed to examine the association between drought and occupational psychosocial stress in a farming cohort. Other outcomes, such as the Kessler Psychological Distress Index or suicide deaths, capture broader measures of distress that could be unrelated to occupational stressors (O'Brien et al., 2014; Fennell et al., 2012; Guiney, 2012; Hanigan et al., 2018).

Uniquely, this study demonstrated that the association between job strain and drought was driven by the effect of drought on psychological job demands as opposed to decision latitude. Karasek (1979) stated that the job demand scale quantifies psychological pressures related to accomplishing your workload, stress from unexpected tasks, and job-related personal conflict, including fear of career or unemployment (Karasek, 1979). Alternatively, job decision latitude measures the workers intellectual discretion and decision authority in completing their tasks. It is likely that mental and physical demands related to farming are more sensitive to an external perturbation, such as drought, whereas the fundamental decision execution and required tasks are unlikely to change, making the observed results plausible. Elevated job strain ratios and psychological job demand have also been associated with non-mental health outcomes, including increased risk for cardiovascular disease (Chikani et al., 2005; Collins et al., 2005). Berman et al. (2017) observed drought conditions to be associated with cardiovascular hospitalization risk among older adults, while Salvador et al. (2021) identified increased risk for cardiovascular-related mortality. These findings indicate a potentially broader range of adverse health risks for farmers caused by increased occupational psychosocial stress during drought.

Other research suggests that psychological distress associated with drought show sex- and age-based heterogeneities. One hypothesis is that population subgroups have different coping mechanisms and strategies. South Australian studies found younger farmers and spouses to have higher levels of drought induced distress compared to older adults, with no differences by sex (Austin et al., 2018; Fennell et al., 2012). In a separate rural Australian study, younger and middle-aged female farmers showed greater psychological distress during drought conditions (Hanigan et al., 2018). When examining suicide-related deaths, males had much greater risk of suicide deaths during extreme drought compared to females (Hanigan et al., 2012), but for all-cause mortality in Spain, older adults were most vulnerable (Salvador et al., 2021). Our analyses did not reveal significant effect modification of drought on occupational psychosocial stress by sex, age, or geography. This might be attributable to true differences between U.S. farmers compared to other populations or to

our specific focus on occupational psychosocial stress as opposed broader constructs of mental health and/or distress. It is further possible that our sample lacked statistical power to detect statistically significant across-population differences. This is likely the case for our estimated changes in stress for male and female populations, since our study population was overwhelmingly (94.6%) male. Regardless, this is still an area of interest since mental health services might tailor outreach to target vulnerable populations as drought risks become severe over time.

Projections of future climate for central North America indicate that conditions will become drier and hotter than present conditions, and will lead to increased challenges for rural and agricultural populations (Cook et al., 2015; Dai, 2013). Geographic and technological advantages that buffer effects of drought, such as widescale irrigation and groundwater pumping, will diminish as non-renewable aquifers and river flows are depleted (Scanlon et al., 2012). As a consequence, the threat of increased psychological job demands related to drought may become more severe among farming populations in the future with consequent adverse effects on mental health. As an occupational cohort, farmers tend to be older than traditional workers and live in regions with fewer medical resources, which leaves them as a more vulnerable subgroup to work-related stress. Investment in primary, secondary, and tertiary mental health prevention and targeted intervention efforts will be crucial for building resilience among farming communities, which are already at a structural care disadvantage (Ellis et al., 2009).

Our findings should be interpreted in the context of several limitations. First, Fethke et al. (2015) reported an 8.1% participation rate for the sample included in this study (518 out of 6415 randomly selected farm operators), which was reduced to 498 participants in this study. Our findings may not be generalizable to a larger farming population, especially since drought vulnerability and adaptation approaches may vary by region (Smith et al., 2014b). However, in the nine-state study area, the demographic characteristics of participants and the distribution of produced commodities were not meaningfully different from regional statistics generated by the National Agricultural Statistics Service (USDA National Agricultural Statistics Service, 2014). Thus, we cannot conclude the observed relationship between drought and occupational psychosocial stress is different among study participants compared to the general Midwest farming population.

Second, the original study was not designed to address potential health effects from drought. The questionnaire was developed to evaluate agricultural tasks and musculoskeletal pain, so its application to study environmental exposures represents a novel use. Questions to identify a causal relationship between drought and occupational psychosocial stress, such as perceptions of drought or crop and livestock loss specifically from drought, were not included. Similarly, information regarding the availability and use of irrigation or crop insurance over the duration of observation was not collected.

Third, we quantified drought using the SPI, which is a commonly used international metric for monitoring drought. However, it is possible that health effects from drought would show variability if alternative indices had been applied. In heat wave studies, it has been argued that heat measures should vary regionally to best capture local effects (Kent et al.,

2014; Dong et al., 2016). A similar regional exposure definition may result in different estimated drought and stress effects. Fourth, surveys were completed at 6-month intervals, so perceptions of job strain may be biased toward more recent events. However, it is unlikely that error in the ascertainment of occupational psychosocial stress was dependent on drought conditions. Finally, our 3-month rolling mean of a 12-month SPI represents a long-term drought variable that will not rapidly change from month to month, reducing the likelihood of exposure misclassification for any one participant at any one observation during the study period.

5. CONCLUSIONS

An association between drought conditions and increased occupational psychosocial stress among a cohort of U.S. farmers was observed in the current analyses. This relationship was observed only when a drought occurred during the growing season, indicating a seasonal relationship directly linked to the psychological job demand of the farming occupation. Given associations between occupational psychosocial stress and adverse mental health outcomes in non-agricultural populations, our observations are consistent with the hypothesis that the elevated burden of adverse mental health outcomes among farmers may, in part, be a consequence of drought conditions. Should drought become more common, as expected with global climate change, then prevention efforts to address its impact on farmer mental health may be warranted. Health risks to farmers may be incorporated into drought early warning plans and local mitigation strategies that address impacts of drought and reduce burdens on populations.

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REFERENCES

Austin EK, Handley T, Kiem AS, et al. , 2018. Drought-related stress among farmers: findings from the Australian rural mental health study. Med. J. Aust 209 (4), 159–165. 10.5694/mja17.01200. [PubMed: 30041594]

Barreau T, Conway D, Haught K, et al. , 2017. Physical, mental, and financial impacts from drought in two California counties, 2015. Am. J. Public Health 107 (5), 783–790. 10.2105/AJPH.2017.303695. [PubMed: 28323464]

Berman JD, Ebisu K, Peng RD, Dominici F, Bell ML, 2017. Drought and the risk of hospital admissions and mortality in older adults in western USA from 2000 to 2013: a retrospective study. The Lancet Planetary Health 1 (1), e17–e25. 10.1016/S2542-5196(17)30002-5. [PubMed: 29057392]

Bourbonnais R, Brisson C, Moisan J, Vézina M, 1996. Job strain and psychological distress in white-collar workers. Scand. J. Work Environ. Health 22 (2), 139–145. [PubMed: 8738893]

Brown L, Medlock J, Murray V, 2014. Impact of drought on vector-borne diseases –how does one manage the risk? Public Health 128 (1), 29–37. 10.1016/j.puhe.2013.09.006. [PubMed: 24342133]

Chikani V, Reding D, Gunderson P, McCarty CA, 2005. Psychosocial work characteristics predict cardiovascular disease risk factors and health functioning in rural women: the Wisconsin rural

Women's health study. J. Rural. Health 21 (4), 295–302. 10.1111/j.1748-0361.2005.tb00098.x. [PubMed: 16294651]

Collins SM, Karasek RA, Costas K, 2005. Job strain and autonomic indices of cardiovascular disease risk. Am. J. Ind. Med 48 (3), 182–193. 10.1002/ajim.20204. [PubMed: 16094616]

Cook BI, Smerdon JE, Seager R, Cook ER, 2013. Pan-continental droughts in North America over the last millennium. J. Clim 27 (1), 383–397. 10.1175/JCLI-D-13-00100.1.

Cook BI, Ault TR, Smerdon JE, 2015. Unprecedented 21st century drought risk in the American southwest and Central Plains. Sci. Adv 1 (1), e1400082. 10.1126/sciadv.1400082. [PubMed: 26601131]

Dai A, 2013. Increasing drought under global warming in observations and models. Nat. Clim. Chang 3 (1), 52. 10.1038/nclimate1633.

Daryl B, O'Connor PEB, Rory C, O'Connor Barbara L., White., 2000. The effect of job strain on British general practitioners' mental health. J. Ment. Health 9 (6), 637–654. 10.1080/jmh.9.6.637.654.

Demetillo MAG, Anderson JF, Geddes JA, et al. , 2019. Observing severe drought influences on ozone air pollution in California. Environ Sci Technol 53 (9), 4695–4706. 10.1021/acs.est.8b04852. [PubMed: 30968688]

Dong W, Zeng Q, Ma Y, Li G, Pan X, 2016. Impact of heat wave definitions on the added effect of heat waves on cardiovascular mortality in Beijing, China. Int. J. Environ. Res. Public Health 13 (9), 933. 10.3390/ijerph13090933. [PubMed: 27657103]

Ebi KL, Bowen K, 2016. Extreme events as sources of health vulnerability: drought as an example. Weather and Climate Extremes 11, pp. 95–102. 10.1016/j.wace.2015.10.001.

Edwards B, Gray M, Hunter B, 2015. The impact of drought on mental health in rural and regional Australia. Soc. Indic. Res 121 (1), 177–194. 10.1007/s11205-014-0638-2.

Ellis AR, Konrad TR, Thomas KC, Morrissey JP, 2009. County-level estimates of mental health professional supply in the United States. PS 60 (10), 1315–1322. 10.1176/ps.2009.60.10.1315.

Fennell KM, Kettler LJ, Skaczkowski G, Turnbull DA, 2012. Farmers' stress and coping in a time of drought. Rural Remote Health 2071 (12). 10.22605/RRH2071.

Fethke NB, Merlino LA, Gerr F, Schall MC, Branch CA, 2015. Musculoskeletal pain among Midwest farmers and associations with agricultural activities. Am. J. Ind. Med 58 (3), 319–330. 10.1002/ajim.22398. [PubMed: 25345841]

Berman JD, Ramirez MR, Bell JE et al. Science of the Total Environment 798 (2021) 149245. [PubMed: 34320456]

Food and Agriculture Organization of the United Nations, 2021. Land & Water - Drought http://www.fao.org/land-water/home/en/. (Accessed 26 January 2021).

Froelich BA, Williams TC, Noble RT, Oliver JD, 2012. Apparent loss of Vibrio vulnificus from North Carolina oysters coincides with a drought-induced increase in salinity. Appl. Environ. Microbiol 78 (11), 3885–3889. 10.1128/AEM.07855-11. [PubMed: 22447591]

Fuller J, Edwards J, Procter N, Moss J, 2000. How definition of mental health problems can influence help seeking in rural and remote communities. Aust. J. Rural Health 8 (3), 148–153. 10.1046/j.1440-1584.2000.00303.x. [PubMed: 11249402]

Guiney R, 2012. Farming suicides during the Victorian drought: 2001-2007. Aust. J. Rural Health 20 (1), 11–15. 10.1111/j.1440-1584.2011.01244.x. [PubMed: 22250871]

Hagan RW, Didion EM, Rosselot AE, et al. , 2018. Dehydration prompts increased activity and blood feeding by mosquitoes. Sci. Rep 8 (1), 1–12. 10.1038/s41598-018-24893-z. [PubMed: 29311619]

Hanigan IC, Butler CD, Kokic PN, Hutchinson MF, 2012. Suicide and drought in New South Wales, Australia, 1970-2007. PNAS 109 (35), 13950–13955. 10.1073/pnas.1112965109. [PubMed: 22891347]

Hanigan IC, Schirmer J, Niyonsenga T, 2018. Drought and distress in southeastern Australia. EcoHealth 15 (3), 642–655. 10.1007/s10393-018-1339-0. [PubMed: 29797158]

Jagger M, Kintziger K, Stockdale E, Watkins S, 2015. Health Effects of Precipitation Abundance and Deficits in Florida 10.13140/RG.2.1.3326.4487.

Karasek RA, 1979. Job demands, job decision latitude, and mental strain: implications for job redesign. Adm. Sci. Q 24 (2), 285. 10.2307/2392498.

Karasek R, Brisson C, Kawakami N, Houtman I, Bongers P, Amick B, 1998. The jobcontent questionnaire (JCQ): an instrument for internationally comparative assessments of psychosocial job characteristics. J. Occup. Health Psychol 3 (4), 322.10.1037/1076-8998.3.4.322. [PubMed: 9805280]

Kent ST, McClure LA, Zaitchik BF, Smith TT, Gohlke JM, 2014. Heat waves and health outcomes in Alabama (USA): the importance of heat wave definition. Environ. Health Perspect 122 (2), 151–158. 10.1289/ehp.1307262. [PubMed: 24273236]

Keyantash J, 2018. National Center for Atmospheric Research Staff. The Climate Data Guide: Standardized Precipitation Index (SPI) August 7. https://climatedataguide.ucar.edu/climate-data/standardized-precipitation-index-spi. (Accessed 10 November 2020).

Littell JS, Peterson DL, Riley KL, Liu Y, Luce CH, 2016. A review of the relationships between drought and forest fire in the United States. Glob. Chang. Biol 22 (7),2353–2369. 10.1111/gcb.13275. [PubMed: 27090489]

Lynch KM, Lyles RH, Waller LA, Abadi AM, Bell JE, Gribble MO, 2020. Drought severity and all-cause mortality rates among adults in the United States: 1968-2014. Environ. Health 19 (1), 52. 10.1186/s12940-020-00597-8. [PubMed: 32423443]

Mallya G, Zhao L, Song XC, Niyogi D, Govindaraju RS, 2013. 2012 Midwest droughtin the United States. J. Hydrol. Eng 18 (7), 737–745. 10.1061/(ASCE)HE.1943-5584.0000786.

Mark G, Smith AP, 2012. Occupational stress, job characteristics, coping, and the mental health of nurses. Br. J. Health Psychol 17 (3), 505–521. 10.1111/j.2044-8287.2011.02051.x. [PubMed: 22107162]

National Drought Mitigation Center, 2020. Drought Classification https://droughtmonitor.unl.edu/About/AbouttheData/DroughtClassification.aspx. (Accessed 24 September 2020).

NOAA National Centers for Environmental Information, .. U.S. Gridded Standardized Precipitation Index (SPI) from nClimGrid-Monthly Drought.gov. https://www.drought.gov/data-maps-tools/us-gridded-standardized-precipitation-index-spinclimgrid-monthly. (Accessed 25 February 2021).

O'Brien LV, Berry HL, Coleman C, Hanigan IC, 2014. Drought as a mental health exposure. Environ. Res 131, 181–187. 10.1016/j.envres.2014.03.014. [PubMed: 24727641]

Pinheiro J, Bates D, DebRoy S, Nlme, Sarkar D, 2021. nlme: Linear and Nonlinear Mixed Effects Models R package version 31–152. https://CRAN.R-project.org/package=nlme.

Rippey BR, 2015. The U.S. drought of 2012. Weather and Climate Extremes 10, pp. 57–64. 10.1016/j.wace.2015.10.004.

Salvador C, Nieto R, Linares C, Diaz J, Gimeno L, 2019. Effects on daily mortality of droughts in Galicia (NW Spain) from 1983 to 2013. Sci. Total Environ 662, 121–133. 10.1016/j.scitotenv.2019.01.217. [PubMed: 30690347]

Salvador C, Nieto R, Linares C, Díaz J, Alves CA, Gimeno L, 2021. Drought effects on specific-cause mortality in Lisbon from 1983 to 2016: risks assessment by gender and age groups. Sci. Total Environ 751, 142332. 10.1016/j.scitotenv.2020.142332. [PubMed: 33182008]

Scanlon BR, Faunt CC, Longuevergne L, et al. , 2012. Groundwater depletion and sustainability of irrigation in the US High Plains and Central Valley. PNAS 109 (24), 9320–9325. 10.1073/pnas.1200311109. [PubMed: 22645352]

Schnall PL, Landsbergis PA, Baker D, 1994. Job strain and cardiovascular disease. Annu.Rev. Public Health 15, 381–411.

Smith A, 2010-2019. A landmark decade of U.S. billion-dollar weather and climate disasters. ClimateWatch Magazine https://www.climate.gov/news-features/blogs/beyond-data/2010-2019-landmark-decade-us-billion-dollar-weather-and-climate. (Accessed 4 February 2021).

Smith PM, Bielecky A, 2012. The impact of changes in job strain and its components on the risk of depression. Am. J. Public Health 102 (2), 352–358. 10.2105/AJPH.2011.300376. [PubMed: 22390450]

Smith LT, Aragão LEOC, Sabel CE, Nakaya T, 2014. Drought impacts on children's respiratory health in the Brazilian Amazon. Sci. Rep 4. 10.1038/srep03726.

Smith K, Woodward A, Campbell-Lendrum D, et al., 2014. Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change Cambridge University Press.

Spleen AM, Lengerich EJ, Camacho FT, Vanderpool RC, 2014. Health care avoidance among rural populations: results from a nationally representative survey. J. Rural Health 30 (1), 79–88. 10.1111/jrh.12032. [PubMed: 24383487]

Stanke C, Kerac M, Prudhomme C, Medlock J, Murray V, 2013. Health effects of drought: a systematic review of the evidence. PLoS Currents 10.1371/currents.dis.7a2cee9e980f91ad7697b570bcc4b004.

Sutanto SJ, Vitolo C, Di Napoli C, D'Andrea M, Van Lanen HAJ, 2020. Heatwaves, droughts, and fires: exploring compound and cascading dry hazards at the Pan-European scale. Environ. Int 134, 105276. 10.1016/j.envint.2019.105276. [PubMed: 31726364]

Tong DQ, JXL, Wang, Gill TE, Lei H, Wang B, 2017. Intensified dust storm activity and Valley fever infection in the southwestern United States. Geophys. Res. Lett 44 (9). 10.1002/2017GL0735242017GL073524.

USDA Economic Research Service, January 16, 2013. U.S. Drought 2012: Farm and Food Impacts https://web.archive.org/web/20130116030109/http://www.ers.usda.gov/topics/in-the-news/us-drought-2012-farm-and-food-impacts.aspx. (Accessed 26 January 2021).

USDA National Agricultural Statistics Service, 2014. Farm Demographics: US Farmers by Gender, Age, Race Ethnicity, and More. 4. U.S. Department of Agriculture www.agcensus.usda.gov.

Vins H, Bell J, Saha S, Hess JJ, 2015. The mental health outcomes of drought: a systematic review and causal process diagram. Int. J. Environ. Res. Public Health 12 (10), 13251–13275. 10.3390/ijerph121013251. [PubMed: 26506367]

Wang Y, Xie Y, Dong W, Ming Y, Wang J, Shen L, 2017. Adverse effects of increasing drought on air quality via natural processes. Atmos. Chem. Phys 17 (20), 12827–12843. 10.5194/acp-17-12827-2017.

Watson D, Clark LA, Tellegen A, 1988. Development and validation of brief measures of positive and negative affect: the PANAS scales. J. Pers. Soc. Psychol 54 (6), 1063–1070. 10.1037/0022-3514.54.6.1063. [PubMed: 3397865]

Zender CS, Talamantes J, 2006. Climate controls on valley fever incidence in Kern County, California. Int. J. Biometeorol 50 (3), 174–182. 10.1007/s00484-005-0007-6. [PubMed: 16249922]

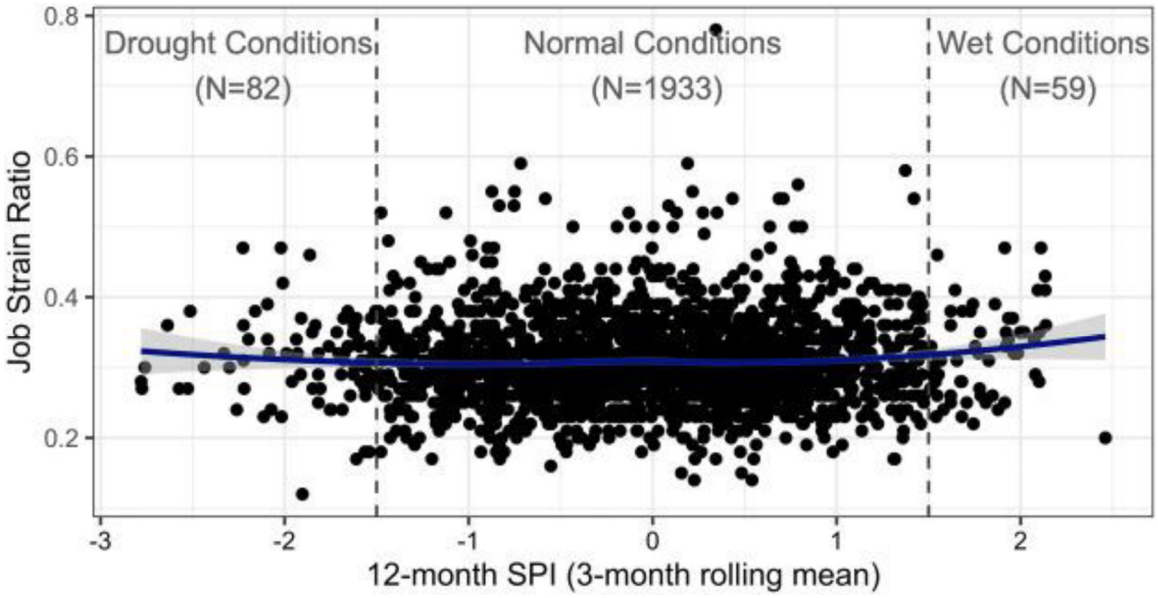

Figure 1. Individual job strain ratios and the associated drought conditions using a 3-month rolling mean of the 12-month standardized precipitation index (SPI).

SPI is stratified as categories for drought conditions (≤−1.5 SPI), normal conditions (−1.5 to <1.5 SPI), and wet conditions (≥1.5 SPI). N values represent the job strain measures reported during each category. The solid line represents a fitted loess curve with a 95% confidence band.

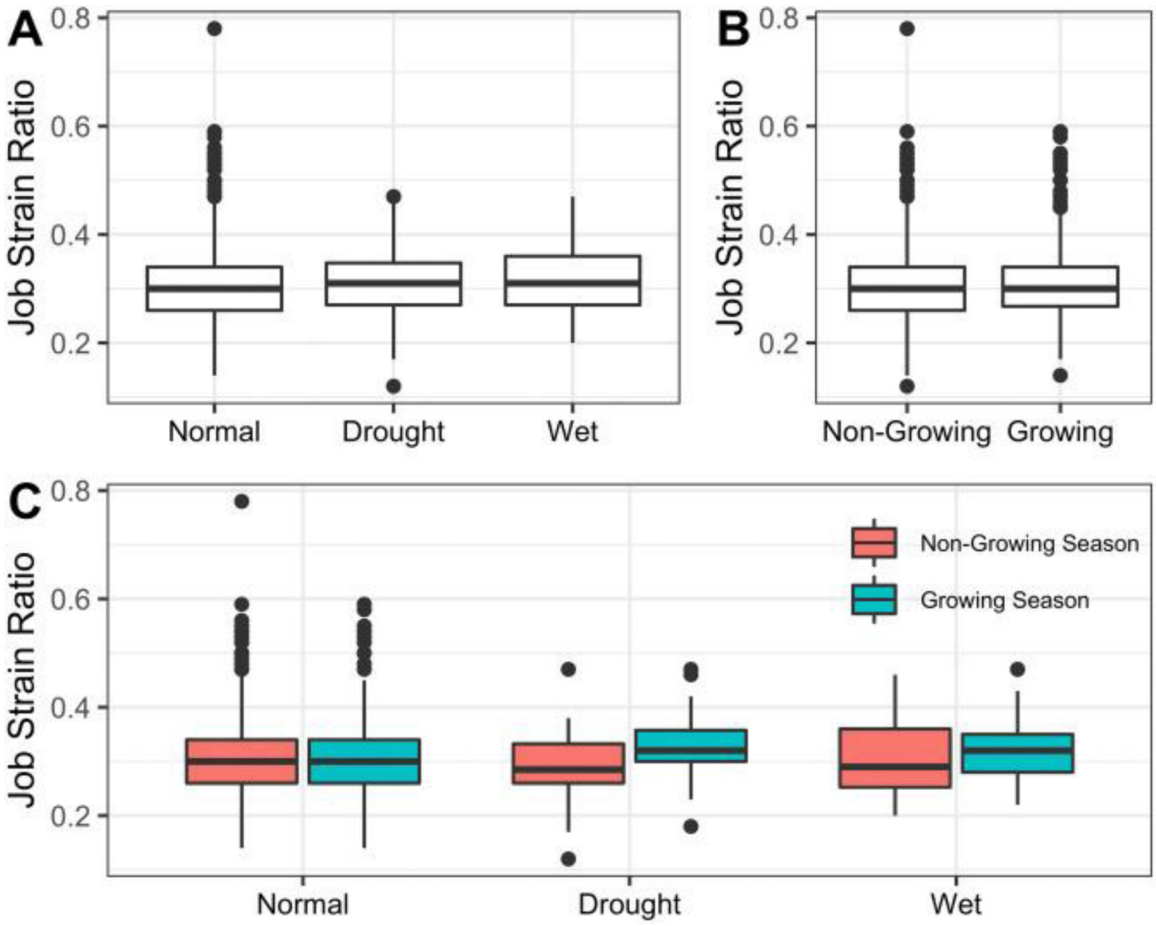

Figure 2.

Distribution of estimated job strain ratios among the farmers cohort stratified by A) drought conditions, B) season of response (non-growing season = November to April; growing season = May to October), and C) drought and season of response.

The mixed effects regression model showed that job strain ratio increased by 0.03 (95% CI: 0.01, 0.05) during drought conditions in the growing season (i.e., the drought and season interaction reported in Table 3). This magnitude of a 0.03 increase in job strain ratio represents nearly one-half of the cohort wide standard deviation of job strain ratio (0.06; Table 1), indicating a fairly large increase in job-related stress during drought conditions. A drought during the non-growing season was associated with a −0.03 (95% CI: −0.04, −0.01) change in the job strain ratio. In models examining psychological job demands and decision latitude as outcomes, we identified no association between drought conditions and decision latitude. However, psychological job demands increased by 2.09 (95% CI: 0.94, 3.24) during drought that occurred during the growing season with a decline of −1.49 (95% CI: −2.27, −0.7) during drought in a non-growing season. This finding suggests that the association between occupational psychosocial stress and drought conditions is being driven by effects on psychological job demands as opposed to decision latitude.

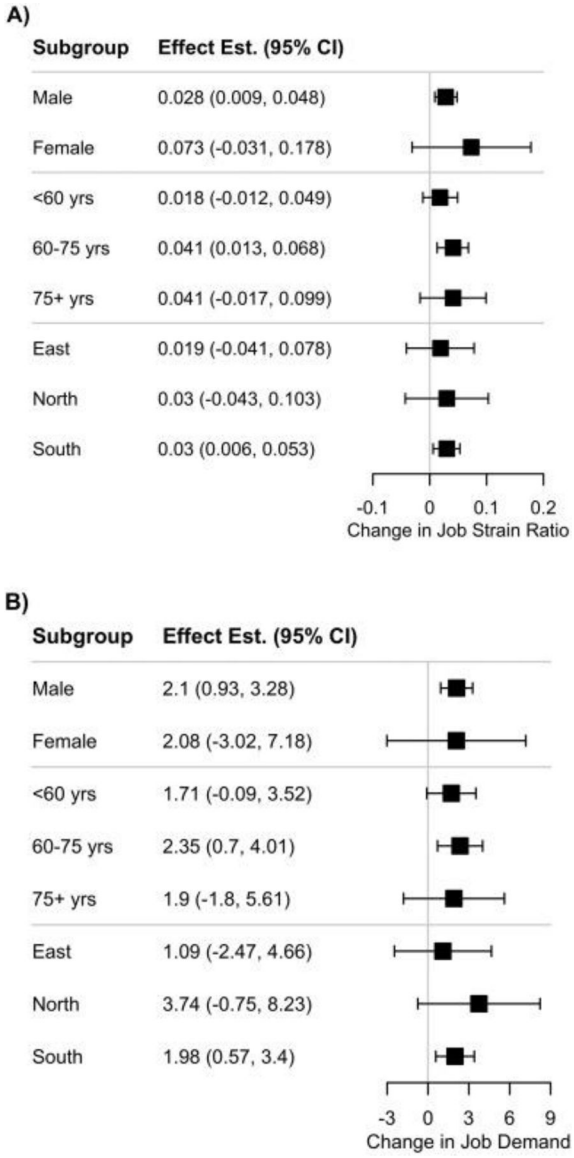

Figure 3.

Estimated change in A) job strain ratio and B) psychological job demand from drought conditions during the growing season when stratified by sex, age, and geographic location. East denotes farmers from Wisconsin, Illinois; North denotes Minnesota, North Dakota, South Dakota; South denotes Iowa, Nebraska, Kansas, Missouri.

Table 1.

Descriptive statistics of all responses from the Agricultural Worker's Cohort.

Characteristics	Total Responses (%)	Mean (SD)	Range
Survey responses[A]	2074 (100)	5.40 (2.14)	1 to 7
Sex - male	1962 (94.6)	–	–
Age (yrs)	–	61.69 (11.99)	21 to 93
Primary job - farming	1488 (71.7)	–	–
Negative affect - high	1162 (56.0)	–	–
Job strain ratio	–	0.31 (0.06)	0.12 to 0.78
Psychological job demand		23.11 (4.11)	9 to 36
Psychological job control		75.88 (8.67)	36 to 94
Report seasonal pain - yes	1115 (53.8)	–	–

[A]Values represent the distribution of survey responses per participant.

Table 2.

Summary of standardized precipitation index (SPI)[a] drought conditions at the time of survey responses, stratified by overall SPI, categories of drought, and SPI during growing and non-growing season.

Empty Cell	n (%)	Mean (SD)	Range
Drought characteristics			
SPI	2074 (100)	−0.03 (0.87)	−2.78 to 2.46
Drought categories			
Wet (≥1.5 SPI)	59 (2.8)	1.80 (0.22)	1.51 to 2.46
Normal (>−1.5 to <1.5 SPI)	1933 (93.2)	0.00 (0.74)	−1.49 to 1.47
Drought (≤−1.5 SPI)	82 (4.0)	−1.89 (0.34)	−1.50 to −2.78
Season			
Non-growing season	1182 (57.0)	0.04 (0.84)	−2.78 to 2.46
Growing season	892 (43.0)	−0.11 (0.90)	−2.51 to 2.13

[A]Represents the 3-month rolling mean of the 12-month standardized precipitation index (SPI) value when participants responded to surveys.

Table 3.

Estimates of the effects of drought, season, drought by season interaction, and selected covariates on psychological job strain ratio, decision latitude, and job demand. Effect estimates represent the change in psychological job strain ratio, decision latitude, or demand for each categorical variable compared to the referent group with a 95% confidence interval.

Parameter	Category	Job strain ratio[A]		Job decision latitude (Control)		Psychological job demand	
Empty Cell	**Empty Cell**	**Effect est.**	**95% CI**	**Effect est.**	**95% CI**	**Effect est.**	**95% CI**
Drought	Normal conditions	Referent	–	Referent		Referent	
	Drought conditions	−0.026	−0.036, −0.01	1.06	−0.82, 2.94	−1.49	−2.27, −0.70
	Wet conditions	0.008	−0.008, 0.024	−1.57	−3.97, 0.83	0.11	−0.89, 1.11
Season	Non-growing season	Referent	–	Referent		Referent	
	Growing season	0.001	−0.002, 0.005	−0.01	−0.54, 0.53	0.11	−0.11, 0.34
Drought and season interaction	Drought during growing season	0.031	0.012, 0.05	−1.14	−3.89, 1.61	2.09	0.94, 3.24
	Wet during growing season	0.012	−0.01, 0.033	−0.19	−3.30, 2.93	0.67	−0.63, 1.97
Primary occupation	Non-farming	Referent	–	Referent		Referent	
	Farming	−0.013	−0.021, −0.007	3.17	2.15, 4.20	0.19	−0.25, 0.62
Pain	No seasonal pain	Referent	–	Referent		Referent	
	Seasonal muscular pain	0.003	−0.002, 0.007	0.72	0.04, 1.39	0.37	0.09, 0.65
Negative affect[B]	Low	Referent	–	Referent		Referent	
	High	0.016	0.011, 0.021	−1.37	−2.10, −0.64	0.71	0.40, 1.01
Age[C]	–	−0.001	−0.002, −0.001	−0.08	−0.13, −0.03	−0.13	−0.15, −0.11

[A] Estimated as the ratio of psychological job demand over job decision latitude.

[B] Based on the positive and negative affect schedule. Individuals above or below the median are high and low negative affect, respectively.

[C] Age is a continuous variable and results are interpreted as change in outcome for each 1-year increase in farmers age.