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The Perpetual State of Emergency That Sacrifices Protected Areas in a Changing Climate

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Contributed Paper

The perpetual state of emergency that sacrifices protected areas in a changing climate

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Abstract: *A modern challenge for conservation biology is to assess the consequences of policies that adhere to assumptions of stationarity (e.g., historic norms) in an era of global environmental change. Such policies may result in unexpected and surprising levels of mitigation given future climate-change trajectories, especially as agriculture looks to protected areas to buffer against production losses during periods of environmental extremes. We assessed the potential impact of climate-change scenarios on the rates at which grasslands enrolled in the Conservation Reserve Program (CRP) are authorized for emergency harvesting (i.e., biomass removal) for agricultural use, which can occur when precipitation for the previous 4 months is below 40% of the normal or historical mean precipitation for that 4-month period. We developed and analyzed scenarios under the condition that policy will continue to operate under assumptions of stationarity, thereby authorizing emergency biomass harvesting solely as a function of precipitation departure from historic norms. Model projections showed the historical likelihood of authorizing emergency biomass harvesting in any given year in the northern Great Plains was 33.28% based on long-term weather records. Emergency biomass harvesting became the norm (>50% of years) in the scenario that reflected continued increases in emissions and a decrease in growing-season precipitation, and areas in the Great Plains with higher historical mean annual rainfall were disproportionately affected and were subject to a greater increase in emergency biomass removal. Emergency biomass harvesting decreased only in the scenario with rapid reductions in emissions. Our scenario-impact analysis indicated that biomass from lands enrolled in the CRP would be used primarily as a buffer for agriculture in an era of climatic change unless policy guidelines are adapted or climate-change projections significantly depart from the current consensus.*

Keywords: climate change, Conservation Reserve Program (CRP), emergency haying and grazing, Great Plains, nonstationarity, policy threshold, protected areas, scenario analysis

El Estado Perpetuo de Emergencia que Sacrifica a las Áreas Protegidas en un Clima Cambiante

Resumen: *Un reto moderno para la biología de la conservación es la evaluación de las consecuencias de las políticas que se adhieren a las suposiciones de inmovilidad (p. ej.: las normas históricas) en una era de cambio ambiental global. Dichas políticas pueden resultar en niveles inesperados y sorprendentes de mitigación dadas las futuras trayectorias del cambio climático, especialmente cuando la agricultura se fija en las áreas protegidas para amortiguar las pérdidas de producción durante los periodos de extremos ambientales. Evaluamos el impacto potencial de los escenarios de cambio climático sobre las tasas a las que los*

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pastizales enlistados en el Programa de Reservas para Conservación (CPR, en inglés) están autorizados para cosechas de uso agrícola por emergencia (es decir, extracción de biomasa), lo que puede ocurrir cuando la precipitación de los cuatro meses previos está por debajo del 40% de la precipitación media normal o histórica para ese periodo de cuatro meses. Desarrollamos y analizamos escenarios bajo la condición que las políticas continuarán operando bajo suposiciones de inmovilidad, autorizando así la cosecha de biomasa solamente como función de la separación entre la precipitación y las normas históricas. Las proyecciones de los modelos mostraron que la probabilidad histórica de la autorización de cosechas de biomasa por emergencia en cualquier año dado en la parte norte de las Grandes Planicies fue de 33.28% con base en registros climáticos de largo plazo. La cosecha de biomasa por emergencia se convirtió en la norma (>50% de los años) en el escenario que reflejó incrementos continuos en las emisiones y una disminución en la precipitación durante las temporadas de crecimiento, y las áreas en las Grandes Planicies con una precipitación media anual más alta históricamente estuvieron afectadas desproporcionalmente y estuvieron sujetas a un incremento mayor en la extracción de biomasa por emergencia. La cosecha de biomasa por emergencia disminuyó solamente en el escenario con las reducciones rápidas en las emisiones. Nuestro análisis de impacto de escenarios indicó que la biomasa de los terrenos enlistados en el CRP se usaría principalmente como amortiguador para la agricultura en una era de cambio climático a menos que las pautas políticas se adapten o las proyecciones del cambio climático se separen significativamente del consenso actual.

Palabras Clave: análisis de escenarios, áreas protegidas, cambio climático, Grandes Planicies, no inmovilidad, pastoreo y alimentación con heno por emergencia, Programa de Reservas para Reservas (CRP), umbral de políticas

摘要: *保护生物学目前面临的一个挑战是评估在全球环境变化的时代背景下, 遵循稳定性假设 (如历史常态) 的政策可能的结果。考虑到未来的气候变化轨迹, 这样的政策可能导致出人意料的减排水平, 特别是农业生产还依靠保护地来缓冲极端环境出现时的生产损失。我们评估了气候变化情景对纳入《土地休耕保护计划, CRP) 》的草地被授权用于农业用途的紧急采收 (即生物质移除) 比例的潜在影响, 当前 4 个月的降水量低于正常或历史上这四个月的平均降水量的 40% 时可以得到授权。我们发展并分析了当政策仍继续遵循稳定性假说时的情景, 这样对紧急生物质采收的授权仅依据降水量对历史常态的偏离。模型预测表明, 根据长期的天气记录, 在任意一年北美大平原北部被授权进行紧急生物质采收的历史可能性是 33.28% 。在排放量持续增长、生长期降水量下降的情景下, 紧急生物质采收将成为常态 (超过 50% 的年份), 北美大平原上历史平均年降雨量较高的地区会不成比例地受到影响, 紧急生物质采收大大增加。只有在快速减排的情景下, 紧急生物质采收会减少。我们的情景影响分析表明, 在气候变化的时代, 纳入 CRP 计划土地的生物质将主要被用于农业生产的缓冲, 除非政策准则能够作出相应的调整, 或气候变化预测显著偏离当前的共识。* ***翻译: 胡怡思; 审校: 魏辅文***

关键词: 气候变化, 《土地休耕保护计划, CRP) 》, 紧急割草和放牧, 北美大平原, 非稳定状态, 政策门槛, 保护地, 情景分析

Introduction

Global environmental change necessitates new approaches in environmental policy and management that embrace nonstationarity and move away from reliance on historical measures of central tendency (Craig 2010). Creating policies that account for future uncertainty and variability presents a challenge for the management of complex ecological systems. The historical foundations of ecology and natural resources disciplines are centered on concepts of equilibrium and retrogressive classification of ecological assembly and change (Twidwell et al. 2013). Policies aligned with these concepts have contributed to an overly naive sense of human dominion over nature that fosters overexploitation of many natural resources to support utilitarian production systems. The consequences of overexploitation of resources are well documented for nonstationary systems (Pauly 1995). The challenge for policy and management in an uncertain future is to assess the consequences of policies that adhere to assumptions of stationarity in nonstationary systems. Such information is critical for deciding whether current policies need to be adapted to conform to future scenarios of environmental change.

In both conservation and agriculture, strategies for resource harvest and acquisition have long relied on optimum or historic conditions to establish targets for production and sustainability. This approach has been criticized for ignoring complexity and variability inherent in natural systems and for being influenced heavily by historical norms rather than current, and potentially different, trajectories (Bossio & Gehab 2008). For example, determinations of maximum sustainable yield common in natural resource management rely on historical average conditions to provide sustainable-use targets (Swetnam et al. 1999; Chapin et al. 2010). Although maximum sustained yield and other optimization approaches function well under typical environmental conditions, they provide no safety net for the maintenance of ecosystem function in the face of environmental extremes (Anderies et al. 2007), which may become more frequent and severe in the future. As a consequence of this lack of consideration

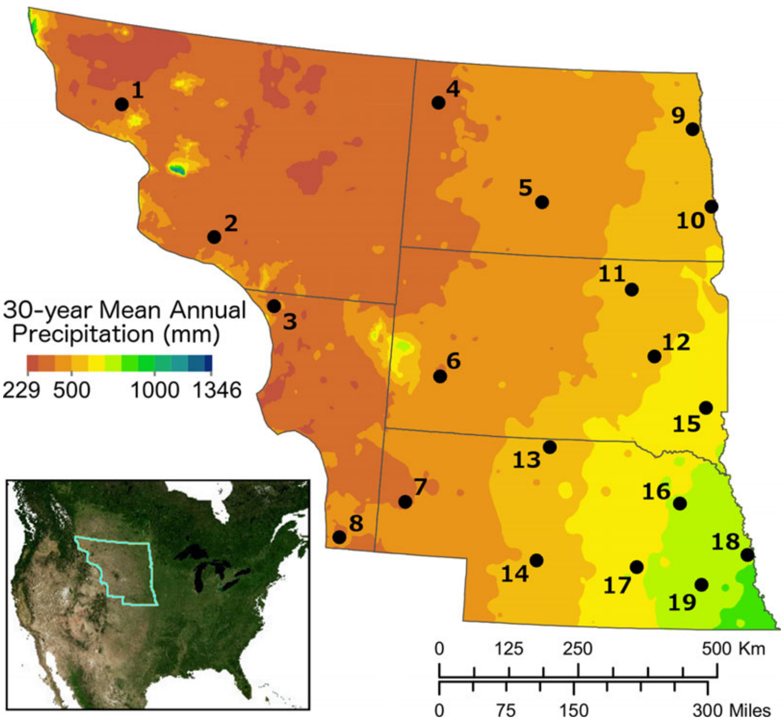

Figure 1. Map of areas with long-term and consistent precipitation data records in the northern Great Plains.

Table 1. Long-term precipitation data records for areas in the northern Great Plains.

Area[a]	*Map number*[b]	*Lat., Long.*	*Years of weather data*	*Total missing data (no. of months)*	*Maximum string of missing data (no. of consecutive months)*	*Relative data missing (%)*
Great Falls, MT	1	47.5, −111.4	123	33	20	2.2
Billings, MT	2	45.8, −108.5	80	8	8	0.8
Sheridan, WY	3	44.8, −107	107	6	5	0.5
Fargo, ND	4	46.9, −96.8	133	0	0	0.0
Bismarck, ND	5	46.8, −100.8	140	9	9	0.5
Rapid, SD	6	44.1, −103.1	72	9	7	1.0
Grand Island, NE	7	41, −98.3	119	11	9	0.8
Cheyenne, WY	8	41.2, −104.8	143	3	2	0.2
Williston, ND	9	48.2, −103.6	120	24	23	1.7
Grand Forks, ND	10	48, −97.2	121	59	4	4.1
Aberdeen, SD	11	45.4, −98.4	121	34	2	2.3
Sioux Falls, SD	12	43.6, −96.8	121	5	1	0.3
Scottsbluff, NE	13	41.9, −103.6	121	21	2	1.4
Omaha, NE	14	41.3, −95.9	143	0	0	0.0
Huron, SD	15	44.4, −98.2	133	7	6	0.4
North Platte, NE	16	41.1, −100.7	140	9	9	0.5
Valentine, NE	17	42.9, −100.6	125	9	6	0.6
Norfolk, NE	18	42, −97.4	121	24	2	1.7
Lincoln, NE	19	40.8, −96.8	127	0	0	0.0

[a]*State abbreviations: MT, Montana; WY, Wyoming; ND, North Dakota; SD, South Dakota; NE, Nebraska.*
[b]*Numbers on map in Fig. 1.*

for environmental variability and uncertainty, emergency or disaster relief has increased in agricultural and natural resource sectors when environmental extremes do not conform to historical analogues (Dilley 2005). Such short-term mitigation may become increasingly inefficient as social-ecological baselines change rapidly.

Protected areas have served as reserves for agriculture when environmental extremes surpass thresholds of production concern. One of the best examples is the Conservation Reserve Program (CRP), the largest private lands conservation program in the United States and the largest grassland restoration program in the world. The CRP is a flagship policy for grassland biodiversity and conservation and serves as a safety net for livestock producers during severe drought. Grassland biomass on CRP lands is authorized for emergency agricultural harvest during drought when precipitation for the last 4 months is below 40% of the normal or historical mean precipitation for that 4-month period (USDA FSA EHG 2017). The concern in a changing climate is that this policy authorizes emergency biomass harvesting of CRP lands based on an assumption of stationarity in climate. If nonstationarity in climate trajectories is unaccounted for in policies serving multiuse outcomes, guidelines dependent on historical averages may result in unexpected and surprising levels of mitigation given future climate change trajectories. Considering the importance of CRP to grassland species throughout the Great Plains (Dunn et al. 1993), the periodic and more frequent removal of grassland biomass would functionally alter the interconnectedness and extent of the existing grassland patch network and would need to be considered as part of climate-change impact assessments on wildlife populations.

Scenario analysis provides a useful platform for conducting forward-thinking studies capable of assessing the implications of policies under alternate future conditions. Scenarios represent simplified but potentially realistic characterizations of alternate realities (e.g., Swart et al. 2004; Henrichs et al. 2010). Scenario analysis is most informative under moderate levels of complexity and uncertainty (Zurek & Henrichs 2007), which makes scenario analysis attractive to policy makers. We used a scenario-analysis approach broadly characterized as scenario-impact assessment (Moss et al. 2010). In scenario-impact assessments, scenarios represent a simplified range of future conditions that can be used to inform decision makers of the potential risks and opportunities of current policy in a changing world. We conducted a scenario-impact assessment to determine the potential impact of climate-change scenarios on the rates at which CRP lands are authorized for emergency biomass harvesting. We developed and analyzed scenarios under the condition that policy will continue to operate under assumptions of stationarity, thereby authorizing emergency biomass harvesting solely as a function of precipitation departure from historic norms. Results may provide the basis for informing decision makers on whether adaptation of policy is necessary given changes in the underlying probability of emergency biomass harvesting on CRP lands. We established the expected baseline rates for authorizing emergency biomass harvesting of CRP lands across the northern Great Plains (i.e., probability of precipitation falling below the threshold used to authorize emergency biomass harvesting), projected how rates of emergency biomass harvesting would change under various plausible future scenarios of precipitation change, and characterized how scenarios differentially affect CRP lands across the precipitation gradient of the northern Great Plains.

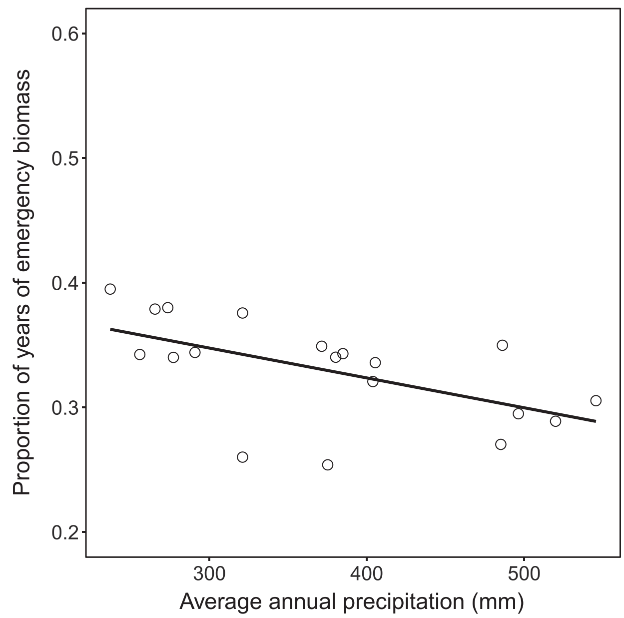

Figure 2. Relationship between average annual precipitation for a given weather station in the northern Great Plains and the proportion of years biomass removal would have been authorized over the entire precipitation record.

Methods

Study Region

We focused on CRP lands in the northern Great Plains of the United States. The 5-state region contains 21% of all CRP lands in the United States. Climate is semiarid in the west and becomes subhumid in the east (Fig. 1); 66–79% of precipitation falls in the growing-season months of April–September (based on long-term weather station records outlined in Data section below). Average monthly high temperatures range from 17 °C on the southern boundary to 2 °C in the north. Grassland vegetation consists predominantly of Agropyron, Stipa, and Bouteloua. The particular species present in a given area within this large region depend on the prevalent climate and disturbance regimes and current and historic land management and underlying soil properties (Van Dyne 1975).

Data

We used precipitation data from long-term weather stations located in the northern Great Plains. Potential weather stations with long-term weather records were identified using the National Oceanic and Atmospheric Administration (NOAA) National Center for Environmental Information and metadata (Historical Observing Metadata Repository [https://www.ncdc.noaa.gov/homr/reports]). Precipitation records for each weather station were explored using products from

Table 2. Scenarios used to assess future impacts of the U.S. Department of Agriculture policy provision authorizing emergency biomass removal from Conservation Reserve Program lands.

Scenario	*Description of scenario**	*Basis for scenario logic*
–GS +DS	redistribution of growing-season precipitation to the dormant season; no change in annual precipitation	RCP 8.5 (continued rise in emissions)
–GS = DS	reduction in growing-season precipitation and a corresponding decrease in annual precipitation; no change in dormant-season precipitation	localized trends in northern Great Plains shown in the National Climate Assessment (Walsh et al. 2014)
=GS +DS	increase in dormant-season precipitation and a corresponding increase in annual precipitation; no change in growing-season precipitation	RCP 2.6 (rapid emission reductions)

**A bounded range of variation (BRV) framework was used to establish upper and lower bounds of precipitation change. Upper and lower bounds corresponded to 40% and 10% changes in monthly precipitation, respectively, and intermediate levels of change were established at 10% intervals between the upper and lower bounds.*

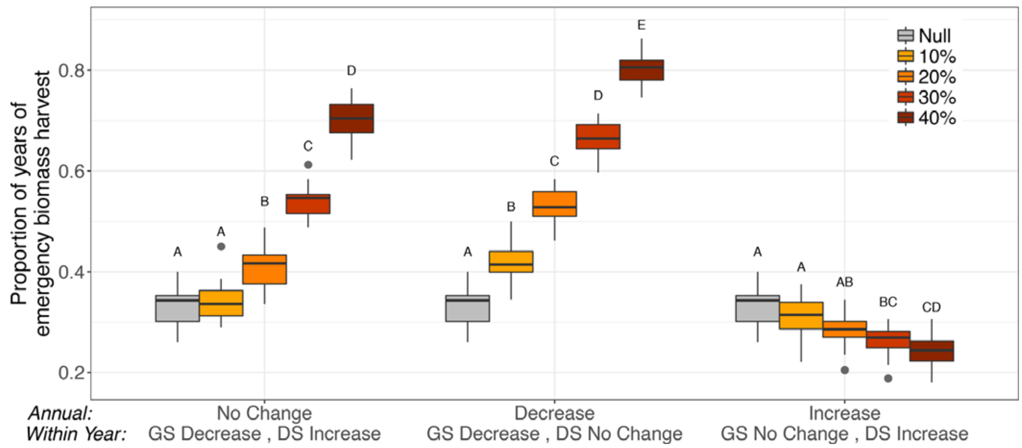

Figure 3. Changes in the proportion of years emergency biomass harvesting will be authorized on Conservation Reserve Program lands under future plausible scenarios of climate change given assumptions of stationarity in current policy (null, baseline precipitation from historical weather station records; GS, growing season; DS, dormant season).

the Applied Climate Information System through the High Plains Regional Climate Center. After cross-checking these data with NOAA's Online Weather Data portal for individual regions (e.g., http://w2.weather.gov/climate/xmacis.php?wfo=lbf), we identified areas with consistent long-term monthly precipitation records that had integrated data from individual weather stations in close proximity. We used locations that spanned the semiarid to subhumid climate gradient of the northern Great Plains (Fig. 1) and had <5% of monthly precipitation values missing from the long-term monthly summarized data archives dating back 72–143 years (Table 1).

Baseline Expectations for Emergency Biomass Removal

Emergency biomass harvesting of CRP lands for livestock is authorized when precipitation during the preceding 4 consecutive months is ≤40% of the historical mean for this period (USDA FSA EHG 2017). We calculated the probability of precipitation falling below this threshold for long-term weather-station data available in the northern Great Plains.

The historical mean precipitation was calculated for each month of the calendar year from data in precipitation archives dating back to the first year on record for each weather station (range 72–143 years). For each year on record for a given station, we determined the total number of times a 4-month window that included growing-season months (April–September) received, in total, <40% of the historical mean for the same 4-month window. Thus, for each year on record, there were 6, 4-month windows ranging from January–April through June–September. If precipitation data were unavailable for 1 of the 4 months in a 4-month window, that 4-month window was excluded from the analysis. For each weather station, we then determined the total number of years on record for which precipitation fell below this threshold one or more times during a calendar year. The probability of authorizing emergency harvest for each weather station was thus calculated by dividing the total number of years a 4-month window fell below this threshold one or more times on a given year by the total number of years of available precipitation data. We used the total precipitation record to represent the historical mean because explicit information on what constitutes the historical mean was not evident in the policy description. Probabilities of authorizing emergency biomass removal therefore provided a baseline expectation for how often emergency conditions could be expected during the growing season over the last several decades in the northern Great Plains.

Scenario Development and Analysis

Patterns of future precipitation change from the CMIP5 simulations were used as the basis for scenario logics. The CMIP5 projects that the northern Great Plains will have similar or slightly higher annual precipitation by the end of the 21st century, but major changes in the seasonal distribution of precipitation, depending on future emissions, will also occur (Walsh et al. 2014). Simulations based on continued increasing emissions (RCP 8.5) project that annual precipitation throughout the majority of the northern Great Plains will increase and manifest seasonally as increases of 20–40% in spring and winter months and 10–20% decreases in the summer. More southerly portions of the northern Great Plains are projected to experience the same annual precipitation but with a 10–20% seasonal redistribution of precipitation from the summer to the spring. Simulations based on rapid reductions in emissions (RCP 2.6) project no change in summer precipitation and an increase in spring and winter precipitation driving a 10–20% annual increase. Given that climate models exhibit high variability in predicted precipitation patterns, especially at local scales, and some portions of the northern Great Plains have received less annual rainfall in recent decades (Walsh et al. 2014), we also developed a scenario corresponding to reductions in annual precipitation in which summer precipitation is reduced and spring precipitation remains constant.

We used a bounded range of variation (BRV) framework (Moritz et al. 2013) to design and conduct a future-scenario impact assessment of continuing to follow policy that uses historical measures of central tendency in precipitation as the basis for mitigation and authorization of biomass removal on CRP lands. The BRV framework specifies boundaries corresponding to plausible upper and lower scenarios for a given process and identifies thresholds of potential concern. Three scenarios, corresponding to changes in annual precipitation and its seasonal distribution featured in CMIP5, were created for this impact assessment. Table 2 provides more information and the rationale for the scenarios we used. Within each scenario, upper and lower bounds of precipitation change for each scenario were set as a 40% and 10% departure in monthly precipitation, respectively, to correspond to realistic upper and lower limits of potential future precipitation change. Intermediate levels of change were established at 10% intervals between the upper and lower bounds. Because scenario-impact assessments should rely on simplistic assumptions of future conditions and there is considerable debate regarding how variance in precipitation will manifest in the northern Great Plains in the near future, we evenly distributed precipitation change across all months in a 4-month window–depending on individual scenario logics. For example, a scenario with a 10% future increase in precipitation during the growing season resulted in a 10% increase to the recorded precipitation for each month in the historical data records.

For each scenario, we assessed whether probability authorization of biomass removal differed among 0%, 10%, 20%, 30%, and 40% changes in precipitation with linear mixed-effects models. Realistically, biomass removal can only be authorized once per year, so changes in the underlying probabilities were determined on an annual basis. Probability of authorization was the dependent factor and percent change in precipitation was a categorical fixed effect. This model in which probability of authorization is predicted by percent change in precipitation was compared with a likelihood ratio test to baseline expectations (the null model) in which probability of authorization is predicted by its overall mean to assess the significance of the model. Location of weather stations was included as a random effect to account for differences in within- and between-subject error structure. Within each scenario, a Tukey's honest significant difference test with pooled SD was used to compute individual pairwise comparisons among levels of precipitation change (0%, 10%, 20%, 30%, and 40%). A Benjamini–Hochberg procedure was applied to control the false discovery rate for multiple comparisons.

We used linear regression analysis to assess how scenarios differentially affected emergency authorization across a west to east spatial gradient in the northern Great Plains. For each scenario, we used linear regression analysis to model the relationship between mean growing-season precipitation (calculated by summing precipitation from April to September for each year at each station and then averaging across all years on record) and the percent change in the probability of authorizing emergency biomass removal under current policy guidelines. We used the slopes of the regressions for each percentage of change in precipitation to identify relative differences in percent change in emergency biomass harvesting across this spatial gradient. All statistical analyses were performed with R statistical software (R Core Team 2017) and packages nlme (Pinheiro et al. 2017) and multcomp (Torsten et al. 2008).

Model Assumptions

Our scenario impact assessment integrated descriptive and normative scenarios to strike a balance between the strengths and trade-offs of quantitative and qualitative scenario development and assessment (trade-offs reviewed in Swart et al. [2004]). Our scenarios served as alternative hypothetical future conditions, based on prevailing logics from climate-forcing models, with the purpose of drawing attention to the relationship between decision points in current policy and simple but meaningful changes in the climate system. We assumed policy guidelines are being followed in practice (an important assumption that was the focus of our model validation process below). We used a method of seasonal averaging that does not account for potential drift, discontinuities, or the emergence of novel precipitation trends over time.

A number of limitations in the policy itself carried over as assumptions in our model. The policy does not account for differences in vegetation across the northern Great Plains, the potential for vegetation to change over time and adapt to climate change, or the potential for vegetation to change as rates of biomass removal from this program surpass past rates of disturbance-driven removal of biomass.

Model Validation

An important model validation step in scenario-impact assessments is to identify whether policy thresholds actually serve as the basis for decision making in practice. We requested access to data from the Farm Service Agency (FSA) to perform 2 validation steps: determine whether precipitation deficits over a 4-month window predict a marked increase in the probability of enacting emergency biomass removal as the deficits between current levels and historic norms increase and assess changes in the probability of enacting emergency biomass removal relative to the −40% threshold outlined in FSA policy. Data provided from the FSA included a list of counties that had been authorized for emergency biomass harvesting each year from 2009 to 2014. Records did not include the following information that would have allowed us to perform a more robust validation procedure, particularly for the second step: precipitation at the time of policy authorization; a list of counties not authorized for emergency biomass removal even though precipitation deficit surpassed the −40% policy threshold; or a list of counties authorized for biomass removal even though precipitation deficit had not yet crossed the −40% policy threshold. Because we lacked this information, we used PRISM's monthly precipitation records at the county level (4-km^2 resolution). PRISM Climate Group raster data were used for all calculations (PRISM Climate Group 2015). We used these data to design a generalized linear model with a binomial distribution in which the binary response variable was whether emergency biomass removal was enacted or not each year by county and the predictor variable was set as the 4-month percent difference in precipitation from historical averages (which corresponded to the 30-year 4-month mean in PRISM).

Results

Baseline Rates of Emergency Biomass Removal

Based on the archives available from weather stations with a long and consistent history of data, the probability of emergency biomass harvesting being authorized was 33.28% of the time in the northern Great Plains. The highest and lowest rates of authorization were 40% (Billings, Montana) and 26% (Grand Forks, North Dakota), respectively (Supporting Information). The probability of authorizing biomass removal was highest in areas with relatively low mean annual rainfall and decreased as mean annual precipitation increased ($R^2 = 0.28$, $p < 0.05$) (Fig. 2).

Scenario-Impact Assessment

The scenario with continued rising emissions (corresponding to a decrease in growing-season precipitation, increase in dormant-season precipitation, and no net annual precipitation change; −GS + DS scenario in Table 2) led to significantly increased rates of emergency biomass removal at a 20% decrease in growing-season precipitation (estimate for null vs. 20% decrease in precipitation 0.076 [SE 0.009], $z = 8.37$, $p < 0.001$). Emergency biomass harvesting became the norm as growing-season precipitation continued to decrease (Fig. 3). At 30% and 40% reductions in growing-season precipitation, emergency biomass removal was authorized 55% and 72% of years (Fig. 3).

As future conditions became increasingly different from historical trends, changes in emergency biomass removal from CRP lands were disproportionately higher in portions of the northern Great Plains where historical mean annual rainfall was higher relative to drier locations (Fig. 4; model output for individual weather stations provided in Supporting Information). Percent change in the probability of authorizing biomass removal increased once growing-season precipitation decreased 30%, despite an increase in mean annual precipitation (Fig. 4). At 30% less precipitation, the mean annual precipitation gradient in the northern Great Plains was no longer significantly related to the probability of meeting the threshold necessary for authorizing biomass removal from CRP lands. This was a major departure from past relationships depicted in the null model, which showed biomass removal was highest in areas with relatively low

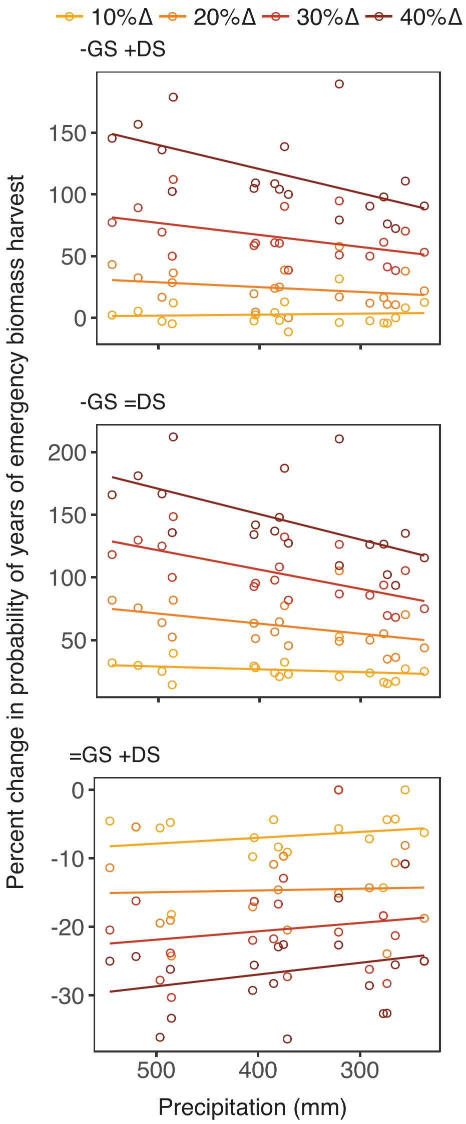

Figure 4. Changes in the relationship between probability of emergency biomass removal and mean annual precipitation as future precipitation increasingly departs from baseline precipitation levels. Precipitation scenarios represent different emission scenarios (described in Table 2): −GS +DS, decrease in growing season, increase in dormant season, no annual precipitation change; −GS = DS, decrease in growing season, no change in dormant season, decrease in annual precipitation change; −GS +DS, no change in growing season, increase in dormant season, increase in annual precipitation change (%Δ, percent change from baseline precipitation, range 10–40%; o, individual weather stations).

mean annual rainfall and decreased as mean annual precipitation increased (Fig. 2).

Significant increases in emergency biomass harvesting occurred at a 10% decrease in growing-season precipitation in the scenario representing localized climate trends (Fig. 3; reduction in growing-season precipitation, a corresponding decrease in annual precipitation, and no change in dormant-season precipitation; −GS = DS scenario in Table 2) (estimate for null vs. –10% was 0.081 [SE 0.008], $z = 10.46$, $p < 0.001$). Emergency biomass harvesting became the norm at 20% decrease in growing-season precipitation (Fig. 3). At a 40% decrease, emergency biomass removal occurred 84% of the time.

Similar to the −GS + DS scenario, subhumid portions of the northern Great Plains were disproportionately affected relative to semiarid locations as future conditions became increasingly different from historic norms (Fig. 4). Emergency biomass harvesting could no longer be predicted significantly along a precipitation gradient at a 30% reduction in growing-season precipitation (Fig. 4).

A scenario of rapid emission reductions (no change in growing season, increased dormant season, and a corresponding increased change in annual precipitation; GS + DS scenario in Table 2) resulted in reduced rates of emergency biomass removal (Fig. 3), which countered trends and thresholds observed in the other 2 scenarios. Emergency authorization of biomass removal decreased significantly at a 30% increase in dormant-season precipitation (estimate for null vs. +30% was 0.069 [SE 0.069], $z = -15.18$, $p < 0.001$). Increases in precipitation in months at the end of the dormant season were sufficiently high to offset relatively dry periods that occurred in months at the beginning of the growing season.

Changes in the probability of emergency biomass removal along a precipitation gradient did not occur and instead reinforced past trends (Fig. 4 & Supporting Information). Probability of emergency harvesting generally decreased along a semiarid to subhumid gradient for each stepwise change in within-year precipitation (Fig. 4).

Model Validation

Our model-validation process provided general support that practice followed policy guidelines, thereby validating our scenario results and model logic. The probability of policy authorization markedly increased as precipitation deficits over a 4-month window became increasingly different from historic norms, and the local minimum and turning point in the relationship occurred in a reasonable proximity to the −40% threshold in precipitation deficit that is the basis for policy (Supporting Information). Given that additional information would need to be collected from policy authorities to reduce model error and more precisely test for a turning point in the relationship, we caution against using our model-validation process to overly scrutinize the degree to which practitioners are authorizing biomass removal prior to reaching the current policy guideline (as evident by the relatively low probability of occurrences of policy authorization preceding the −40% threshold in precipitation deficit [Supporting Information]).

Discussion

The inability to deal with variation in nature has been one of the grand challenges for planetary stewardship (Chapin et al. 2010), and the surprising and unexpected levels of biomass removal on CRP lands for agricultural use, both in past decades and under future scenarios of precipitation change, add further evidence of the challenge confronting the future of the conservation discipline. Livestock production systems are already reliant on biomass from protected areas to buffer against environmental variability. Over the last century, so-called emergency conditions necessitating the removal of biomass on CRP lands occurred one-third of the time in the northern Great Plains. Policy-driven authorization of emergency biomass removal on CRP lands is projected to increase, based on current expectations for future shifts in precipitation. Consensus among climate-change models suggests the northern Great Plains will be subject to more droughts in the growing season and no change or slight increases in total annual precipitation. Our scenario impact analysis indicated that unless policy changes or climate-change projections significantly depart from the current consensus, biomass from CRP lands will be used primarily for agriculture in an era of climatic change.

An improvement to current policy would be to move away from historical measures of central tendency as the basis for drought mitigation. Many national and international policies focus on meteorological drought, which is defined as a prolonged period of precipitation deficit (Trenberth et al. 2014), as the basis for drought mitigation. Measures of precipitation deficit rely on assumptions of low variance in weather conditions and stationarity in climate to be effective, which is why drought affects more people throughout the world than any other natural disaster (Hewitt 1997). The fact that variability in precipitation is often characterized as a natural disaster demonstrates the need for policy-based mitigation to move away from meteorological drought as the basis for mitigation. Measures of central tendency in dynamic systems beget oversimplified strategies of resource harvest that fail without external subsidies and support. Such an approach has been heavily criticized—even under a context of high short-term variance imposed on a long-term equilibrial trend—but mitigation based on past central tendency becomes increasingly problematic and erodes resilience in a nonstationary system that is also characterized by high short-term variance (Rist et al. 2014).

Efforts have been made in recent years to develop drought early-warning systems that are capable of capturing more rapid changes in plant-water availability, provide more direct measures of the impact of drought, and increase the time available to prepare for drought impacts (Ford et al. 2015). Several remote-sensing indicators provide more direct measures of drought impacts (e.g., Evaporative Stress Index and U.S. Drought Monitor), and preferred soil-moisture indices can be used as proxies for plant stress (e.g., fraction of available water capacity derived from soil-moisture networks). Remote sensing of plant reflectance is also increasingly being used to quantify plant-water stress and primary productivity (Ač et al. 2015) and could be readily incorporated into drought-mitigation policies.

Conservation Implications

The probability of harvesting CRP lands demonstrates the extent to which agriculture relies on biomass from protected areas because of inabilities to meet high human demands for resources in systems that exhibit high variance. In the Great Plains, it has been known for a long time that precipitation is highly variable and that policy makers and managers need to consider such variability to meet natural resource sustainability targets (Webb 1959; Wilhite 1983). Yet, policy governing CRP biomass removal is entirely focused on departures from historical mean conditions. Given that emergency conditions occurred one-third of the time, on average, in the northern Great Plains, it is clear that current approaches to livestock production systems are having a greater impact on the potential for CRP lands to meet conservation goals than previously thought. The CRP lands serve as an important repository for regional biodiversity in the Great Plains (Reynolds et al. 1994; Askins et al. 2007), but unless changes in policy occur, projected changes in precipitation will cause biomass from CRP lands to be used primarily as a buffer for agriculture in the coming decades, potentially compromising biodiversity conservation.

The clear implication for the discipline of conservation biology is that more attention needs to be paid to the specific details of agricultural policy and the clauses within conservation-based programs affecting protected areas. It is too easy to ignore the specifics of policies from disciplines known to detrimentally impact biodiversity. Conservationists should be surprised and alarmed that emergency condition for biomass removal from protected areas means once every 3 years. Numerous conservation-based initiatives are linked to the CRP (USDA FSA EHG 2017). The CRP lands increase grassland connectivity throughout an agriculturally dominated matrix (Tanner & Fuhlendorf 2018) and are increasingly being looked upon to provide multiple ecosystem services (Ribaudo et al. 2001), including pollinator habitat (Kremen et al. 2002), mitigation for soil erosion (Young & Osborn 1990), and habitat for multiple diverse native taxa (King & Savidge 1995; McCoy et al. 1999). Given that losses in endemic species richness and abundance in the Great Plains rival other biomes (in terms of proportional declines [Newbold et al. 2016]), conservation scientists should question whether listing a diverse array of conservation-based initiatives on CRP lands is misleading the public at large. Without costly and intensive responses, conservation-based initiatives will be undermined when CRP lands are used most years to support short-term economic priorities for the northern Great Plains. The use of CRP lands during periods of environmental extremes (e.g., drought) has been prioritized for agriculture in the past, and the rate at which this occurs is projected to increase, given likely trajectories of future climate change.

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Supporting Information

Results of the scenario-impact assessment (Appendix S1) and model validation (Appendix S2) are available online. The authors are solely responsible for the content and functionality of these materials. Queries (other than absence of the material) should be directed to the corresponding author.
Appendix S2. Model validation results used to assess the authorization of emergency biomass removal from CRP in practice.

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