Community asynchrony increased its stability by mediating the relationship of diversity–stability relationships in Loess Plateau, China

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Abstract. Extreme weather such as heavy rainfall and drought are threatening the global grassland and its potential to mitigate climate change. Therefore, understanding the drivers that promote the stability of grassland ecosystems is considered to be critical to mitigate the adverse effects of climate change on grasslands. Here, we use precipitation addition (PA) + grazing experiment to explain how species richness, aboveground biomass, species asynchrony, functional group level stability, drought tolerance and grazing tolerance can maintain grassland productivity stability. The results showed that grazing counteracted the promoting effect of rainfall on vegetation to a certain extent, and weakened the sensitivity of species of grazing tolerant functional group to rainfall. Rainfall and grazing affect the asynchrony of the community through the influence of drought tolerance and grazing tolerance functional groups, and then affect the stability of the community through the mediation of the relationship between aboveground biomass and species richness. This effect was significantly correlated with the differences of vegetation characteristics and resource acquisition strategies, but not with the community species richness. This study provides more explanations for the maintenance mechanism of community stability.

Introduction

Climate change is increasing the frequency and severity of other extreme events such as heavy rainfall. More than 50% of the world's Grassland is affected by the increase in precipitation(Zhang *et al.* 2021), which seriously threatens the management and development of the global grassland ecosystem and impairs the world's Grassland's ability to serve as a carbon sink and a nature based solution to mitigate climate change (Piao *et al.* 2019). Therefore, stability, that is, the ability of grassland to maintain its function in the face of environmental pressure, is becoming the focus of grassland management and research.

About 42% of the grassland in the world is used for grazing (Sloat *et al.* 2018), which is the main driving force of grassland biodiversity and system stability. At present, a large number of convincing studies have shown that grazing can increase species richness, thus promoting the stability of community biomass production to cope with changing climatic conditions, such as drought or extremely rainy years. The research mainly focuses on the impact of grazing, drought and rainfall on the community structure and function, the impact of the interaction of grazing and rainfall on the relationship between species diversity and productivity, and whether this relationship can help mitigate the impact of extreme climate on grassland stability need to be studied, and the potential mechanism driving the biodiversity stability relationship in grassland ecosystem still lacks comprehensive understanding.

Methods and Study Site

From 2019 to 2021, we carried out the grazing + precipitation gradient test on the typical steppe of the Loess Plateau. The area of pasture is 100 × 50 m^2, while the area of the precipitation addition plot is 2 × 2 m2. The grazing rate is 2.67 sheep / hectare, and the grazing time is from early June to the end of September. The grazing mode is rotational grazing, which lasts only 10 days per month. Based on the precipitation in the growing season of that year, three gradients of 0% (natural rainfall), 30% and 60% were set up in the split area.

The study was conducted in Huanxian Grassland Agriculture Trial Station of Lanzhou University, Huanxian County, Gansu Province, China (37.12◦N, 106.84◦E, 1700 m a.s.l). It is a typical farming pastoral ecotone controlled by monsoon climate (Hu *et al*., 2019). Mean annual temperatures (MAT) are 7.1°C and mean annual precipitation (MAP) are 326.6 mm, of which over 70% of precipitation occurs in the growing season from late June to the end of September. The grassland was classified as cool temperate-semiarid temperate typical steppe,abbr (Ren *et al.* 2008). typical steppe. Dominant species are *Lespedeza davurica*, *Artemisia capillaris*, and *Stipa bungeana*.

Results and Discussion

Effects of rainfall and grazing on the stability of AGB and RS

The stability of AGB and AGB-SR were significantly positively correlated with the asynchrony of the community ($P < 0.05$) under the two different grassland management and utilization modes of grazing and no grazing, which gradually increased with the increase of asynchrony. However, there was no significant correlation between the stability and asynchrony of community SR, which indicated that the change of community SR would not affect its stability. No grazing increased the sensitivity of the stability of AGB and AGB-SR to asynchrony, while grazing decreased the sensitivity of the stability of AGB and AGB-SR to asynchrony, and increased the stability of the community, especially the stability of AGB-SR relationship. Its asynchrony can explain 51.3% of the variation of stability.

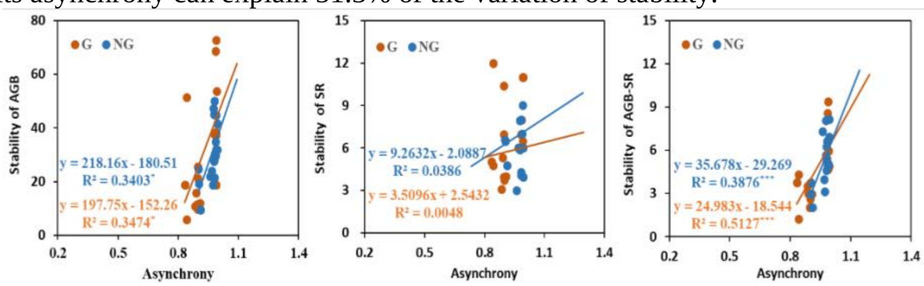


Fig.1. The relationship between asynchrony and stability of AGB, SR and AGB-SR in communities

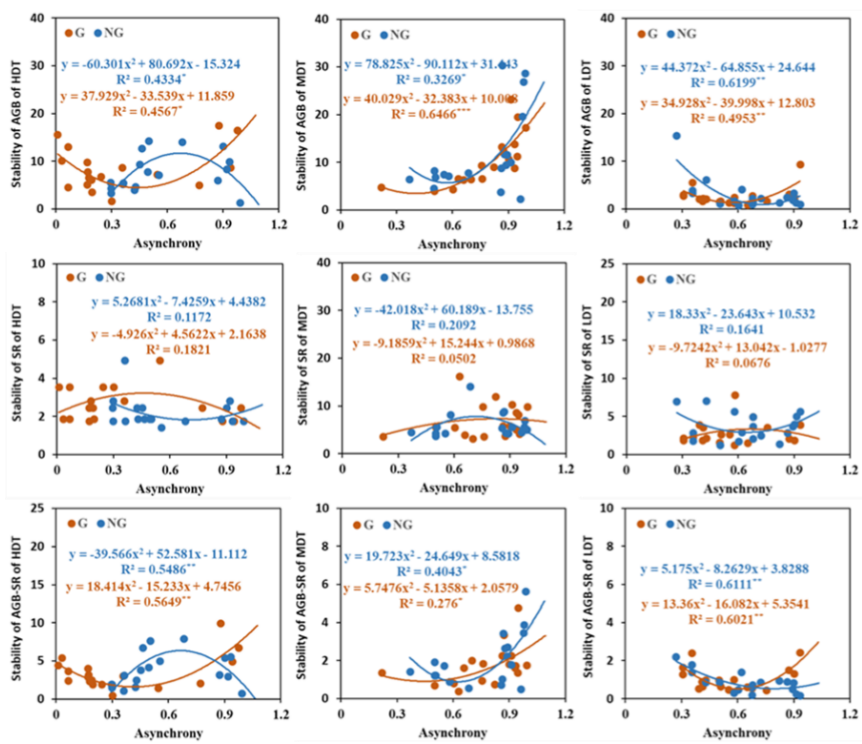


Fig.2. The relationship between asynchrony and stability of AGB, SR and AGB-SR in drought resistant functional group

Under different grassland management and utilization modes, the stability of AGB and AGB-SR relationships of the three DTFs were significantly correlated with asynchrony respectively ($P < 0.05$), while the asynchrony of SR was not significantly correlated with stability. The stability of AGB and AGB-SR relationships of the three DTFs in grazing land showed a parabola that decreased first and then increased with the increase of asynchrony. The stability of AGB and AGB-SR relationships of HDT functional groups in no grazing land showed a parabola of first increasing and then decreasing with the increase of asynchrony, which was opposite to the change trend of grazing land. The stability of AGB and AGB-SR relationship of MDT and LDT functional groups in no grazing land with asynchrony showed the same trend as that in grazing land, which showed a trend of decreasing first and then increasing. The asynchrony of MDT functional groups in grazing land and that of LDT functional groups in no grazing land can explain more than 62% of the variation of AGB stability. The asynchrony of LDT functional groups under grazing and no grazing conditions can explain more than 60% of the variation of AGB stability.

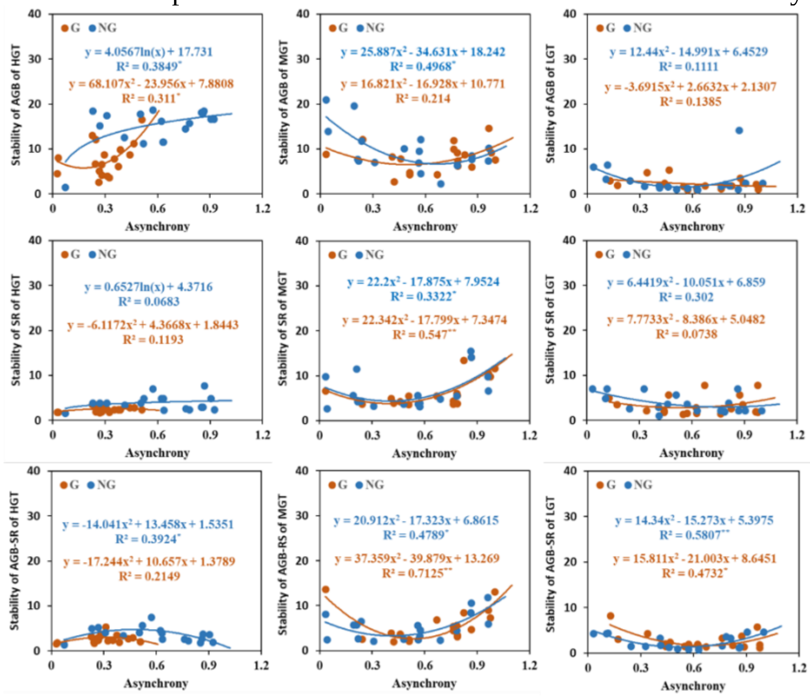
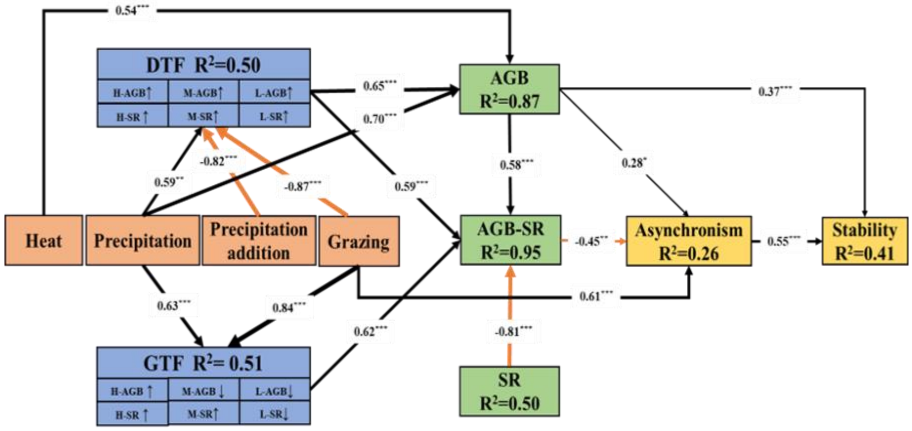


Fig.3. The relationship between asynchrony and stability of AGB, SR and AGB-SR in GTF

Under different grassland management and utilization modes, the stability of AGB-SR relationship of the three grazing tolerance functional groups was significantly correlated with asynchrony at the levels of 0.05 and 0.01. There was no significant correlation between the asynchrony and stability of HGT, LGT species richness and LGT aboveground biomass. Except that AGB stability of grazing land increases with asynchrony, asynchrony can explain 38.4% of the variation of stability. The other stability of HGT increases first and then decreases with the increase of asynchrony, and asynchrony has a low degree of explanation for stability. Under different management and utilization modes, the stability of AGB, SR and AGB-SR of MGT and LGT presents an open parabola with the increase of asynchrony. There is an obvious inflection point at the asynchrony of about 0.6, showing a trend of decreasing first and then increasing.

Path analysis of community stability



Note: DTF represent drought tolerant functional group, GTF represent grazing tolerance functional group.Black and orange arrows represent significant positive and negative pathways, respectively. Bold numbers indicate the standard path coefficients. The arrow width is proportional to the strength of the relationship. R^2 represents the proportion of variance explained for each dependent variable in the model. The double-layer rectangle represents the first principal component in the principal component analysis, wherein DTF and GTF include H-AGB, M-AGB, L-AGB, H-SR, M-SR and L-SR, respectively. The symbols' ↑ 'and' ↓ 'respectively indicate the positive or negative relationship between the variables in the principal component analysis and the first principal component. $^{***}P$ <0.001, $^{**}P$< 0.01, $^{*}P$< 0.05. Site(a) CHI/DF = 1.334, P = 0.115; root mean square error of approximation (RMSEA) = 0.056.

Fig.4. The structural equation model (SEM)

Precipitation,PA and grazing indirectly affect the AGB of DTF and then affect the stability of the community. Precipitation has a significant positive effect on DTF, while increasing precipitation and grazing have a significant negative effect. Precipitation, increasing precipitation and grazing explain 59%, 82% and 87% of the changes of DTF respectively (P<0.05) (Fig. 5). Precipitation and grazing explained 63% and 84% of the changes in GTF, respectively. DTF contributed significantly to AGB, and heat and rainfall also promoted AGB. Both DTF and GTF significantly promoted the AGB-SR relationship and explained 59% and 62% of its changes respectively (P<0.05). AGB and SR of the community had positive and negative effects on AGB-SR respectively. AGB and AGB-SR explained 28% and 45% of the asynchrony of the community (P<0.05). Both DTF and GTF affect the asynchrony of the community by acting on AGB-SR, and then indirectly affect the stability of the community. Grazing significantly affected the asynchrony of the community and directly explained 61% of the asynchrony (P < 0.05). Except for the direct effect of grazing on DTF and GTF, the others are indirect effects; The increase of precipitation directly affects DTF and explains 82% of its change. The increase of precipitation has a significant indirect effect on other indicators (P＜0.05).

Conclusions

Our results provide experimental evidence that the insurance effect of diversity stabilizes community productivity in grassland ecosystems. We show that the stability of grassland community productivity increases with the increase of SR, and the asynchronous productivity of coexisting species is the main mediator of this diversity effect. The two different types of functional groups affect the asynchrony of the community through the relationship between the AGB and the SR, thus improving the stability of the community, but this effect is not related to the SR. As hypothesized, community asynchrony affects its stability by mediating the relationship between AGB and SR.

References

Zhang, W., Furtado, K., Wu, P., Zhou, T., Chadwick, R., Marzin, C., Rostron, J.W. & Sexton, D.M.H. (2021) Increasing precipitation variability on daily-to-multiyear time scales in a warmer world. *Science Advances*, 7, eabf8021.

Sloat, L.L., Gerber, J.S., Samberg, L.H., Smith, W.K., Herrero, M., Ferreira, L.G., Godde, C.M. & West, P.C. (2018) Increasing importance of precipitation variability on global livestock grazing lands. *Nature Climate Change*, 8, 214-218.

Piao, S., Zhang, X., Chen, A., Liu, Q. & Wu, X. (2019) The impacts of climate extremes on the terrestrial carbon cycle: A review. *Science China Earth Sciences*. 62, 1551-1563.

Hu, A., Zhang, J., Chen, X.J., Millner, J.P., Chang, S.H., Bowatte, S. & Hou, F.J. (2019) The composition, richness, and evenness of seedlings from the soil seed bank of a semi-arid steppe in northern China are affected by long-term stocking rates of sheep and rainfall variation. *The Rangeland Journal*, 41, 23-32.

Ren, J., Hu, Z., Zhao, J., Zhang, D., Hou, F., Lin, H. & Mu, X. (2008) A grassland classification system and its application in China. *The Rangeland Journal*, 30, 199-209.