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Assessing the contribution of grasslands to Australian national carbon sequestration under a changing climate

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Abstract: Australian grasslands cover over 70% of the continent. As one of the most dominant vegetation types in the country, grass constitutes a critical component of its terrestrial vegetation ecosystem and carbon sink. Grasslands and their ability to sequester carbon are closely regulated by climatic conditions, particularly temperature and precipitation, which can exert varying influences depending on regional climate regimes. The continent has experienced widespread warming over the past three decades. Rainfall patterns have been subjected to an interannual and periodic variability, primarily influenced by large-scale climate drivers such as El Niño–Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD). Using a high-resolution gridded national climate dataset from ANUSPLIN and a well-calibrated serial 1 km resolution monthly NDVI (Normalized Difference Vegetation Index), this study investigated the spatial distribution and temporal trends of major climates across Australia. It evaluated the impact of climate change on grassland carbon sequestration using Net Primary Productivity (NPP), a widely recognized proxy for carbon uptake. Grassland NPP was calculated using an improved Carnegie Ames–Stanford Approach (CASA) model featured by major climate variables and NDVI. NDVI data were obtained from AVHRR and MODIS, both widely used for remote sensing of vegetation. The AVHRR NDVI was calibrated to MODIS to ensure consistency between the two sources. Australian grassland areas were divided into three main zones: dry, temperate, and savanna. Each zone was further subdivided into eastern and western subregions to investigate spatial heterogeneity in response to climate change. The results indicated that: 1) The entire study area, which covers around 90% of the continent, has warmed at a rate of 0.25 °C decade^{-1} over the past 30 years. Western regions exhibited higher long-term mean temperatures compared to the east, along with a faster warming rate. This indicates an expanding gap in average annual mean temperature between the east and the west regions. The most rapid increases were observed in central Western Australia. 2) Rainfall has moderately increased over a broader area in the eastern part of the study area, with the most observable increases occurring along the Great Dividing Range. In contrast, much of Western Australia has experienced a decline in precipitation. Notably, the gap in mean annual rainfall between the eastern and western subregions of both the dry and savanna zones has narrowed over the past three decades. 3) Grassland NPP showed a widespread declining trend driven mainly by a warming temperature, except in most savanna areas and the northern temperate zone. The highest NPP (635.48 g C m^{-2} year^{-1}) was found in the eastern savanna zone, a controversial zone mixed by bushlands and forests. In the savanna zone, NPP (+2.89 g C m^{-2} year^{-1}) increased, even in western areas with declining rainfall (-51.3 mm year^{-1}). This suggested that rainfall in the western savanna remained sufficient to support grassland growth. In the temperate zone, where long-term mean rainfall was comparable between the east (447 mm) and west (446 mm), the long-term mean of grassland NPP (316.0 g C m^{-2} year^{-1}) was lower and exhibited a more pronounced decline (-14.98 g C m^{-2} year^{-1}) in the warmer west. In the dry zone, grassland NPP levels tend to converge because the hotter and more rapidly warming west experiences a faster and significant NPP reduction (- 24.91 g C m^{-2} year^{-1}). The eastern part of the dry zone, characterized by the lowest rainfall, yielded the lowest NPP (180.1 g C m^{-2} year^{-1}). Overall, grassland NPP demonstrates greater sensitivity to warming under conditions of limited rainfall. This study highlights the vulnerability of Australia's terrestrial carbon sink to climate change, pointing to the need for regionally-targeted adaptive management to support the nation's broader carbon neutrality efforts.

Keywords: *NDVI, grassland ecosystem, Net primary productivity (NPP), Climate change, carbon sequestration*

