Introduction to the reconstruction and modeling of grass-dominated ecosystems - Preface

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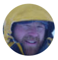

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Preface

Introduction to the reconstruction and modeling of grass-dominated ecosystems

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1. Introduction

The Poaceae contains an ecologically and taxonomically diverse array of species (> 10 000 species and 655 genera) whose distributions range from the warm tropics to within the Arctic circle. Grass-dominated biomes support a rich biological community of grasses in association with seasonal herbaceous flowering plants and limited drought and fire-resistant arboreal components. Grasses and their associated species within grassland ecosystems possess a broad array of physiologies and ecologies including variable quantum yield efficiencies and adaptations to frequent disturbance (herbivory and fire). These ecosystems currently cover a substantial part of the Earth's surface and, because they are highly productive, play a vital role in modern biogeochemical cycles.

Expansion of grass-dominated biomes is generally concomitant with periods of aridity in the Earth's climatic history. Thus, paleo-botanical evidence for grassland expansions often provides paleo-climatic interpretation. Grasses can serve as particularly good indicators of past climates as they generally have short life cycles (relative to woody perennial trees and shrubs) and are likely to be able to adapt quickly to environmental changes including variation in $p\mathrm{CO_2}$, temperature and moisture availability. Environmental variability is recorded by the vegetation composition of grass-dominated ecosystems. For example, C_3 grasses are typically indicative of cool or moist conditions whereas C_4 species thrive in hot, moisture-limited environments. In addition, specific C_4 grass species utilize different photosynthetic substrates, allowing distinction between mesic (NADP-ME) and xeric (NAD-ME) habitats. Thus, any investigation of paleo-grassland evidence should seek to obtain C_3 and C_4 grass distribution and abundance data so that both climatic variability and paleo-ecophysiology can be reconstructed.

Since any single proxy of past vegetation often lacks taxonomic resolution and subsequent ecophysiological information, paleo-ecological reconstruction and modeling of grass-dominated ecosystems is reliant on the information supplied by multiple disciplines and the analysis of multiple proxies. Proficiency in a single proxy demands years of training and the success of the multi-proxy approach therefore requires collaboration between scientists. The first Paleo-Grassland Research workshop (PGR 2000), held in Westbrook, CT, USA, fostered such collaboration by bringing together over 40 participants, representing 12

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countries within North and South America, Europe, Asia and Africa. The primary goals of the meeting were (1) to promote interdisciplinary collaborative research, (2) to synthesize an informed multi-proxy approach to the reconstruction of past grasslands and (3) to establish a network of scientists concerned with grassland paleo-ecology.

The 13 papers in this special issue stem from presentations made at the PGR 2000 meeting and are divided here into three main sections: (1) pollen and modeling, (2) phytoliths and other plant fossils and (3) isotopes and other techniques. The first section comprises four papers involving pollen analyses and modeling techniques; the second section of four papers presents papers involving the analyses of phytoliths, grass cuticles and plant macrofossils; and the third section contains five papers involving stable isotope techniques or ungulate tooth morphology. The division of these 13 papers into three categories was somewhat arbitrary since many of the contributors have utilized multiple techniques for investigation of past grass-dominated ecosystems.

2. Pollen and modeling

The first section is devoted to palynological research. Mark Bush reviews alternative interpretations for fossil Poaceae pollen from the lowland humid neotropics. Hermann Behling synthesizes data from available pollen records of the late Quaternary in south and southeastern Brazil. Climatic implications of the spatial and temporal shifts in the distribution of grass-dominated ecosystems within this region are presented. Robert Marchant et al. compare pollen-based biome reconstructions from the Funza-2 core in Colombia with model-based (BIOME 3) vegetation reconstructions. Their results suggest that changes in atmospheric pCO$_2$, temperature and precipitation all contributed to vegetation change in this region during the Pleistocene. Louis Scott presents pollen, phytolith and stable carbon isotope evidence related to grassland development in South Africa during the Late Quaternary. Since pollen from different grass species is morphologically identical the presentations by palynologists emphasized the need for additional proxies of past grasslands with which to compare the pollen data.

3. Phytoliths and other plant fossils

The particles of biogenic silica produced in the leaves of grasses, known as phytoliths, have greater morphological variation as compared to grass pollen and are an effective resource for grassland reconstruction. Caroline Strömberg presents phytolith evidence for grass-dominated biomes in the late Tertiary of North America and subsequently relates her findings to faunal evolution. Mikhail Blinnikov et al. also present phytolith data to reconstruct the late-Pleistocene grasslands of the Columbia river basin, USA, and interpret vegetation changes as responses to large-scale climatic controls. In addition to phytoliths, leaf fragments and plant seeds preserve additional morphological features that often provide even greater taxonomic resolution, compared with phytoliths. Richard Baker et al. investigate the movement of the prairie-forest ecotone in southeastern Minnesota during the Holocene using analyses of plant macrofossil assemblages and stable carbon isotopes. In addition to increased taxonomic resolution the features on fossil leaves, such as stomata, can provide indicators of past environmental change. The final paper in this section, by Matthew Wooller and Andrew Agnew, presents some of the first measurements of stomatal size and density from fossil grass cuticles from the tropics, which are subsequently related to environmental change over the last glacial–interglacial transition.

4. Isotopes and other techniques

The final section contains work by Katherine Ficken et al. who present a multi-proxy approach, including pollen, compound specific stable carbon isotope and grass cuticle analyses, to reconstruct the grass-dominated habitat surrounding Lake Rutundu on Mount Kenya. Arnoud Boom et al. also present stable carbon isotope data, which they use in conjunction with pollen and vegetation modeling data to reconstruct past atmospheric

CO_2 concentrations. Kristina Beuning and Jessica Scott investigate the effect of charring on the stable carbon isotope composition of grass cuticles. Their findings highlight the potential for using data derived from stable carbon isotope analysis of fossil grass cuticles as a method of tracking the past proportions of C_3 and C_4 grasses surrounding lake catchments. The last two papers utilize additional proxies of past vegetation change. Christine Janis presents data derived from the morphological analyses of fossil animal teeth from the Miocene, relating these data to changes in taxonomic diversity, climate and vegetation. The final paper, by Konstantin Pustovoytov, presents a review of the methods for characterizing pedogenic carbonate cutans on the surface of clasts and demonstrates how information from this source can be applied to the research of past grass-dominated environments.

5. Further research

Modeling exercises and the multi-proxy approach are the most appropriate methods for the reconstruction of past grasslands. The analyses of pollen, carbon isotopes (including compound-specific analyses), grass cuticles and phytoliths provide a diverse array of methods to investigate paleo-grasslands. Development of new techniques to provide specific grass species data is ongoing and should be done in conjunction with the modeling community. This collaboration establishes a co-ordinated strategy for hypothesis testing and paleo-grassland reconstruction. The primary outcome of this workshop has been the formulation of a working group of the scientific community aiming to reconstruct global grassland evolution and response to climate, herbivory, fire and human activities.

We thank our referees for their interest and timely responses. We also thank PAGES and NSF for their support of this meeting. A PGR 2002 meeting is being planned. We look forward to sharing ideas with participants from a wide geographical distribution and range of disciplines at this event.