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Poaceae distribution in West Africa: evolution and conservation.

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Introduction

Biomes dominated by grasses (Poaceae) represent 40.5% of the total vegetation cover of the world (Suttie et al. 2005). Poaceae is an economically important family that includes most of our cereal crops, forage for cattle and provides material for construction and household items. In West Africa, grass biomes, and especially savannas, are the dominant ecosystem. Fire, herbivores, human activities and climate shape vegetation dynamics in savannas. The grass family has been shown to be a good predictor of total plant diversity for the Sahelo-Sudanian region (Schmidt et al. 2007). Good diversity indicators are necessary where information about vegetation and phytodiversity is still scarce as is the case in West Africa and many other regions in the tropics.

The majority of grasses in West African savanna biomes are characterized by the C4 photosynthetic pathway which evolved from the C3 pathway around 30 million years ago in response to decreasing CO₂ concentrations throughout the tertiary (Bond 2008). The C4 pathway is more efficient at low CO₂ levels and water stress, because of its effective mechanism of pre-fixation of CO₂. Additionally, the photorespiration is reduced drastically in C4 plants resulting in a higher net photosynthesis at high temperatures. Carbon isotope analysis of paleosols indicates an abrupt expansion of C4 grass dominated ecosystems about 7-8 million years ago (Bond 2008). Today C4 grass biomes form 25% of the world vegetation cover (Bond 2008) and account for 25% of the total CO₂ fixation (Still et al. 2003). Conservation of the highly productive ecosystems with dominating C4 plants is an important issue because of their role as direct and indirect food sources, their high biodiversity and their role as a carbon sink.

The aim of our study is to map the predicted total grass diversity and the distribution patterns of functional and systematic groups. Ecology and geographical distributions of grasses are supposed to be correlated with their photosynthetic pathways (Batanouny 1988) as well as systematic groups (Hartley 1958; Clayton 1981). Based on our data we aim at predicting distribution changes of Poaceae in the light of climate change.

Materials and Methods

The delimitation of West Africa in our study has been as follows: from the Equator to 25°N and from the longitude 20° W to 20° E. We compiled relevé data from large datasets (FloTrop from the CIRAD in Montpellier [Daget & Gaston 1999], VegDa from the Senckenberg Research Institute [Schmidt 2006]). The total database includes around 16,000 relevés including 471 grass species and represents a total of around 95,000 grass occurrences.

For our models, we used the maximum entropy method Maxent (Phillips et al. 2006) that allows us to predict species geographic distributions with presence-only data.

As predictors we chose six environmental Worldclim layers (www.worldclim.org) with a resolution of 2.5'. We selected the annual precipitation, the maximum precipitation of June and of September, the maximum temperature of June and of September, and the minimum temperature of February. Previous studies have shown strong correlations between the distribution of grasses and temperature and rainfall.

Results and Discussion

Our model of the present total diversity of grasses in West Africa is shown in Fig. 1. As expected, it displays the highest grass diversity in the Sudanian savanna zone with a sharp decrease towards the Sahelian zone in the North and the originally forested areas of the Congolian and Guinean forest. The Dahomey gap is identified as highly diverse in grasses. The predictions for the “mosaic forest” regions (White 1983) of Sierra Leone, Guinea and Liberia differ from those of the same vegetation type further in the south. This is probably due to a lack of data for those countries, as well as a distinctive climate.

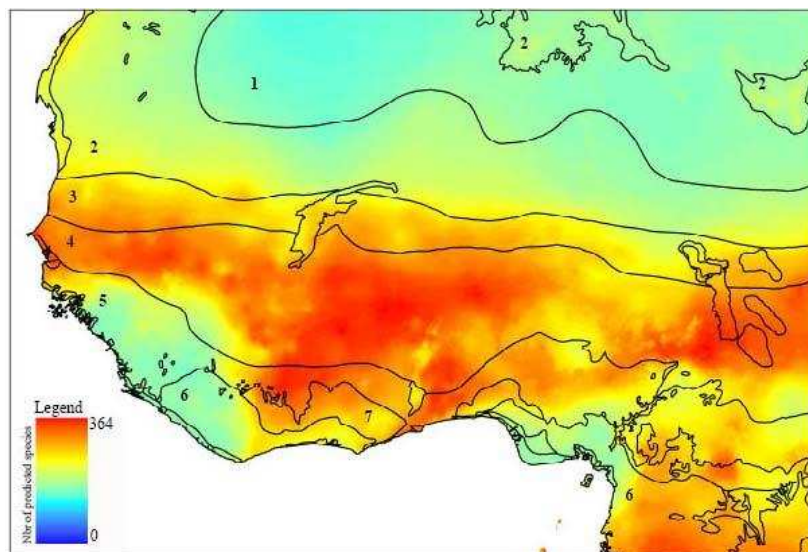


Figure 1: Total predicted grass diversity. For each grid cell (2.5'), we counted the number of species with a prediction higher than 20%. The lines delimit the vegetation zones as described by White (1983): 1) Desert. 2) Shrubland and grassy semi-desert. 3) Arid fertile savanna. 4) Moist infertile savanna. 5) Mosaic of forest. 6) Tropical lowland rainforest. 7) Dry forest and thicket.

In hot climates, the light efficiency of C3 plants decreases as photorespiration increases whereas in C4 plants the light efficiency remains constant (Ehleringer & Monson 1993). Previous studies in Egypt and the USA (Batanouny 1988; Taub 2000) have shown a correlation between the distribution of C3/C4 grasses and temperature. In West Africa, the pattern is similar (Fig. 2). The C3 grasses are absent in the north, where the maximum temperatures and aridity are higher; they are most diverse in the southern part of West Africa.

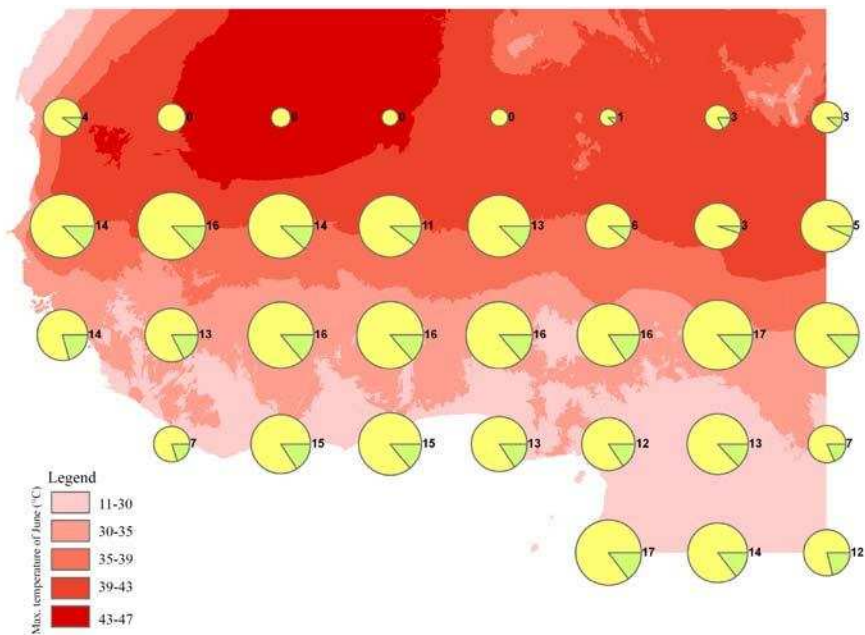


Figure 2: Distribution pattern of C3 and C4 grasses. For each grid cell (5°), we counted the number of Poaceae species with C3 and C4 photosynthetic pathway with predictions of occurrence higher than 50%. The results are shown as pie charts, in yellow the C4 and in green the C3. The black numbers indicate the number of C3 species. The size of the pie charts is determined by the number of species predicted in each grid cell. The map in the background represents the maximum temperature of June.

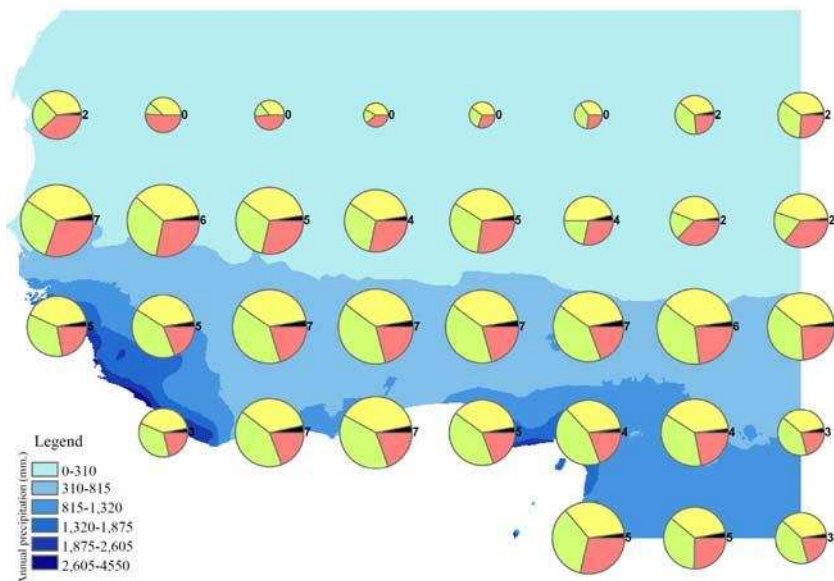


Figure 3: Distribution pattern of four major tribes of Poaceae. For each grid cell (5°), we counted the number of species of each tribe with predictions of occurrence higher than 50%. The results are shown as pie charts, the colour coding indicates: yellow - Paniceae; black - Oryzae; green - Andropogoneae; red - Chlorideae. The black numbers indicate the number of Oryzae species. The size of the pie charts is determined by the number of species predicted in each grid cell. The colour coding in the background indicates the amount of annual precipitation.

Hartley (1958), Taub (2000) and Cabido et al. (2008) have shown a correlation between the distribution of systematic groups and the amount of rainfall. The grass tribe Chlorideae is principally found in dry habitats, the members of tribe Andropogoneae predominantly occur in wetter climates, and the tribe Paniceae displays no clear preferences. Fig. 3 illustrates that the distribution of tribes follows a similar pattern as described before. The tribe Oryzae, including

C3 species only, has its maximum of predicted species in the southern part of West Africa. The Chlorideae are predicted to be more diverse in the North where the annual rainfall has a mean of 150mm. Andropogoneae are more diverse in the Sudanian savanna region where rainfall amounts are between 300 and 800 mm per annum. The Paniceae do not display any clear pattern.

Conclusion

As expected, Poaceae diversity patterns as well as the distribution of physiological types and systematic groups is correlated to climate. The data now at hand provide an excellent base for the analysis of the actual and potential distribution of Poaceae species, contribute to a better knowledge of the savanna ecosystem and thus to the understanding of future developments under increasing human impact and climate change.

Perspectives

To improve our models, we intend to add to our database specimen data from relevant herbaria (FR, OUA, G, K, P, B). Indeed, relevé data tend to overrepresent common species, while data from herbarium collections tend to stress rare species (Schmidt et al. in press, Guralnick & van Cleve 2005). Therefore a combination of both data will provide the most reliable information on the distribution of grasses.

The impact of climate change on protected areas and areas under high anthropogenic impact will be assessed in order to provide recommendations for future priority areas for conservation.

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Bibliography

Batanouny KH, Stichler W & Ziegler H (1988) Photosynthetic pathways, distribution, and ecological characteristics of grass species in Egypt. *Oecologia* 75: 539-548.

Bond WJ (2008) What limits trees in C4 grasslands and savannas? *Annual Rev. Ecol. Evol. Syst.* 39:641-59.

Cabido M, Pons E, Cantero JJ, Lewis JP & Anton A (2008) Photosynthetic pathway variation among C4 grasses along a precipitation gradient in Argentina. *J. Biogeogr.* 35: 131-140.

Clayton WD (1981) Evolution and distribution of grasses. *Ann. Missouri Bot. Gard.* 68:5-14.

Daget P & Gaston A (1999) Flotop : constitution d'une base de données sur les pâturages d'Afrique tropicale septentrionale. *Sécheresse* 10: 183-189.

Ehleringer JR & Monson RK (1993) Evolutionary and ecological aspects of photosynthetic pathway variation. *Annual Rev. Ecol. Syst.* 24: 411-439.

Guralnick R & Van Cleve J (2005) Strengths and weaknesses of museum and national survey data sets for predicting regional species richness: comparative and combined approaches. *Diversity and Distributions* 11: 349-359.

Hartley W (1958) Studies on the origin, evolution and distribution of the Gramineae. I. The tribe Andropogoneae. *Austral. J. Bot.* 6: 115-128.

Philips SJ, Anderson RP, & Schapire RE (2006) Maximum entropy modelling of species geographic distributions. *Ecol. Modelling.* 190: 231-259.

Schmidt M (2006) Pflanzenvielfalt in Burkina Faso - Analyse, Modellierung und Dokumentation. Dissertation J.W.Goethe-Universität, Frankfurt am Main.

Schmidt M, Dressler S & Zizka G (2006) Herbarium online!. *Natur und Museum* 136: 75-76.

Schmidt M, Kreft H, Thiombiano A & Zizka G (2007) Indicator value of different vascular plant families for overall plant diversity in the savanna belt of Western Africa. *Ecotropica* 13: 135-142.

Schmidt M, Thiombiano A, Dressler S, Hahn-Hadjali K, Guinko S & Zizka G (in press) Phytodiversity Data - strengths and weaknesses. A comparison of collection and relevé data from Burkina Faso. *Proceedings of the 18th AETFAT Congress, 26 February - 2 March 2007*

Still CJ, Berry JA, Collatz GJ & DeFries RS (2003) Global distribution of C-3 and C-4 vegetation: carbon cycle implications. *Global Biogeochem. Cycles.* 17: 1006.

Suttie JM, Reynolds SG & Batello C (2005) Grasslands of the world. FAO, Rome, Italy.

Taub DR (2000) Climate and the U.S. distribution of C4 grass subfamilies and decarboxylation variants of C4 photosynthesis. *Amer. J. Bot.* 87(8): 1211-1215.

White F (1983) The vegetation of Africa. Unesco, Paris, France.