Vegetation history and climate records of Colombian lowland areas: rain forest, savanna and intermontane ecosystems
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Epilogue

This work aimed to improve understanding of the vegetation and climate dynamics of the Colombian tropical lowlands (0-2300 m elev.) and test the current hypothesis of environmental change from the Last Glacial Maximum (LGM) to today. Four sediment cores, from three different areas in Colombia (Chocó, Interandean valley and Llanos Orientales), have been analysed for pollen. This study adds new detail to the reconstructed scenario of vegetation and climate change during the late Quaternary and current key problems are discussed, in particular, reconstructions of palaeo-temperature, temperature lapse rate and history of precipitation patterns, concerning the tropical lowlands of northern South America. Due to the different levels of knowledge concerning vegetation and climate dynamics in the research areas, the specific research questions varied.

The Chocó area

A reconstruction of the local and regional vegetation history of this area was made on the basis of pollen, sediment and diatom analysis from core El Caimito. This multi-proxy study shows the importance of rivers for the formation of vegetation patterns in Chocó and demonstrates a development from:

(1) a high energy (coarse sediments) river-influenced basin, at a close distance to the coastal mangrove forest, from 3600 to 2600 $^{14}$C yr BP (BP), to

(2) an event of riverine erosion in the depression, causing a hiatus in the record from 2600 to 2070 BP.

(3) From 2070 to 600 BP the lake system was periodically affected by high energy events caused in the regional drainage system. Mangrove forest along the drainage system was very close.
(4) After 600 BP the lake became isolated from regional river system disturbances and was surrounded by a floristically diverse forest which possibly records the impact of human activities.

To provide a set of tools for future research, studies in Chocó were also focused on a summary of floristically identified actual forest types and their characteristic pollen taxa. Numerical analyses of pollen taxa in the sediment records were used to reconstruct internal forest dynamics at local and regional scales during the last 4400 years. It is shown that species diversity in Chocó always increased over this time period. The dynamic river system, permanently creating new habitats by river bed movements and changes of inundation patterns, would influence the speed of migration of different forest types and their competitive interactions, possibly causing a permanent influx of taxa to the study area during the last 4400 years.

Unfortunately it is also shown that the level of detail of these studies, especially in the tropical rain forest area, is limited, given that identification of pollen grains often stops at the family level (e.g. Arecaceae, Leguminosae, Rubiaceae, Euphorbiaceae).

The lower montane forest belt

In a similar manner to the Chocó area, the vegetation history and climate change in the lower montane (= subandean) forest belt was also poorly known. Palynological studies from the lower montane forest belt near Popayán, inventory studies of the last remnants of forest, combined with information of the potential natural vegetation from the ‘forest map’ and ‘ecological map’ of Colombia, were used to provide a calibration set of modern vegetation in this area for the interpretation of the Timbio and Piagua pollen records. An integration of the information from the available lower montane pollen records in Colombia is used to reconstruct and discuss climate and altitudinal lapse rate changes since the LGM.

After around 50,000 ¹⁴C yr B.P. (=50 kyr BP) temperature was relatively mild and at 1700 m about 3°C lower than today. Around 40 kyr BP temperature was only slightly warmer than at the LGM. Between 40 and 32 kyr BP temperatures increased again and were ca. 5°-6 °C cooler than today. After 32 kyr BP, temperature at 1700 m gradually decreased and at the LGM it reached values of ca. 6° to 7°C lower than today. After the LGM, temperatures continuously increased until ca. 14 kyr BP and were ca. 3°C lower than today. From 14 to 9 kyr BP the lower montane forest belt shows altitudinal shifts that mainly reflect the well known Late Glacial temperature oscillations: the ‘Susacá interstadial’, ‘Ciega stadial’. 

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'Guantiva interstadial'. The 'El Abrad stadial' shows temperatures of ca. 3°C cooler than today. The beginning of the Holocene, until ca. 7 kyr BP, is characterised by a transition to higher temperatures. From 7 to 5 kyr BP temperature was about 0.5°-1°C warmer than today. During the last 4.5 kyr BP pollen records at many places are affected by human activity and are not suitable for inferring palaeotemperature estimates.

These LGM temperature values at 1700 m (6°-7°C) are less than the estimated LGM temperature drop of 8°-9°C at 2500-3000 m, but higher than the estimated LGM temperature drop of 4°-6°C at sea-level and substantiate a steeper glacial lapse rate.

We also summarise the altitudinal distribution of the main vegetation belts through the Colombian Andes at the latitude of Popayán for the present and the LGM. The modern conditions show a lapse rate of ca. 0.6°C/100 m and the plot for LGM conditions shows a calculated lapse rate of 0.76°C/100 m and strongly suggest a steeper temperature gradient than today's.

The Llanos Orientales

The high resolution pollen record Las Margaritas and its detailed radiocarbon dating bring new insights to the dynamics of the forest/savanna transition zone in the Colombian Llanos Orientales during the Holocene. The record of vegetation dynamics corresponds with the nearest site Loma Linda, supporting the earlier reconstruction. The close correspondence between the pollen and the seasonality record suggests that the character of the vegetation in the Llanos Orientales depends upon the differences between the dry and wet seasons.

At the beginning of the Holocene strong seasonal changes and a generally drier climate probably favoured vegetation with a shorter life cycle and the Llanos Orientales was characterised by grassy savanna. Orbital parameters at the beginning of the Holocene indicate a relatively strong seasonality with warm summers and cool winters.

During the Holocene the Earth changed its position and came closer to the sun in December and farther away in June. As a consequence, the difference between dry and wet seasons became less, which is also shown by the continuously decreasing seasonality record. Therefore the Las Margaritas pollen record shows between ca. 5400 and 2300 cal BC the overall shift from savanna to forest dominated vegetation during a period with alternating abundance of both vegetation types. The forest domination lasted until about 2000 years ago. Forest could expand in the study area as seasonal changes in climate became weaker and water availability increased.

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The expansion of savanna after since ca. 2000 years ago is in contrast to the seasonality record, which is still low during this period. The possibility that expansion of savanna under conditions that favour forest vegetation might point to human influence in the area needs to be checked in future studies. Based on this study we conclude that since 550 cal BC water availability in the study area increased but savanna vegetation expanded.

The wiggle match dating strategy offered the possibility to investigate whether or not the alternation between forest and savanna dominance in the time interval from 4300 to 2100 cal BC could be connected to fluctuations in atmospheric \(^{14}\)C content, and thus to solar forcing of climate change. From ca. 4000 - 3320 cal BC some parallel developments between the forest/savanna alternations and the \(^{14}\)C record were visible, indicating an influence of solar forcing on climate change. During this period the vegetation changes followed the \(^{14}\)C changes after about 50 years, but fluctuations of \(^{14}\)C between 3350 and 2100 cal BC do not match the pollen record. Therefore, unambiguous evidence for the influence of changes in solar activity on climate fluctuations, and thus on vegetation, could not be proven in our record, but the idea and the present data deserve future attention and study.