Classification of East-Andean Forest Amphibiomes in the Río Avisado Watershed, Alto Mayo Region, Northern Peru

Classificación de Bosques de Inundación en la Selva Alta, Quenca del Río Avisado, Region Alto Mayo, Norte del Perú

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Abstract
Amphibiome forests along North Peruvian Amazon Headwaters in the Alto Mayo region were studied for correlations between spatial distribution of vegetation types and edaphic factors. The study area included seasonally flooded forests along the lower Río Avisado at 800 m a.s.l., representing the highest reported sites for neotropical lowland "Aguajales", open palm stands of *Mauritia flexuosa* and "Renacales", dominated by heavily branched crowns of multiple trunked *Ficus* ssp. The areal extent of Aguajales and Renacales of the Alto Mayo was significantly reduced over the last two decades by destructive harvesting of edible Aguaje fruits and the partial suitability of the soils for rice cultivation. Efforts are now underway to formally protect the remaining Aguajales and Renacales.
Typical Aguajales form open palm stands with dense understory. Soils show impeded drainage over heavy clay layers and are almost permanently water saturated or flooded. They accumulate large amounts of barely decomposed organic material. Soil horizons are not well differentiated. Typical Renacales reach 25 m height with a dense crown layer of *Ficus trigona* and other Moraceae, Myristicaceae, Euphorbiaceae, Bombacaceae and Arecaceae. Lower branches are densely covered by epiphytes. Soils have differentiated horizons with a high groundwater table and seasonal flooding.
The distribution patterns of these amphibiomes are closely linked to the duration and intensity of flooding and waterlogging, which in turn depends mainly on topography and precipitation regime. The role of stand dynamics, especially tree growth rates and absolute tree age as well as successional series following site disturbances need further investigation.

Resumen
En este trabajo se estudió la correlación entre la distribución espacial de los tipos de vegetación y los factores edáficos en los anfibiomas forestales localizados a lo largo de las nacientes amazónicas nortes del río Avisado en la región Alto Mayo. El área de estudio incluyó los bosques inundados estacionalmente ubicados a lo largo del río Avisado, a una altitud de 800 m s.n.m.. Estos bosques representan los sitios de mayor altitud reportados para tierras bajas neotropicales como "Aguajales" que constituyen parcelas abiertas dominadas por la palmera *Mauritia flexuosa*, y "Renacales" que son áreas dominadas por una species de *Ficus* que se caracteriza por una alta densidad de ramas y por su tronco múltiple. Los Aguajales y Renacales de la región del Alto Mayo han sido significativamente reducidos en su extensión durante las dos últimas décadas debido a la cosecha destructiva del fruto comestible del Aguaje y la capacidad parcial de los suelos para ser usados en el cultivo de arroz. Actualmente existen planes para la protección formal de las áreas de Aguajales y Renacales.
Los Aguajales típicos forman parcelas abiertas con una cobertura densa en el sotobosque. Los suelos muestran problemas de drenaje debido a la presencia de capas de arcilla pesada que están

permanentemente inundadas o saturadas de agua produciendo la acumulación de materia orgánica parcialmente descompuesta. Los horizontes del suelo no están bien diferenciados.
Los Renacales típicos alcanzan hasta 25 m de altura y forman un dosel cerrado compuesto por *Ficus trigona* así como por otras Moraceae, Myristicaceae, Euphorbiaceae, Bombacaceae, y Arecaceae. Las ramas bajas de estos árboles están densamente cubiertas por epífitas. Los suelos presentan horizontes diferenciados con una napa freática alta y la ocurrencia estacional de inundaciones.
Los patrones de distribución de anfibiomas están estrechamente vinculados a la duración y a la intensidad de las inundaciones, que a su vez dependen principalmente de la topografía y del régimen de precipitación. En el futuro, se necesita desarrollar mayor investigación sobre la dinámica de las parcelas, especialmente sobre las tasas de crecimiento y la determinación de la edad absoluta de los árboles después de la ocurrencia de un disturbio.

Introduction

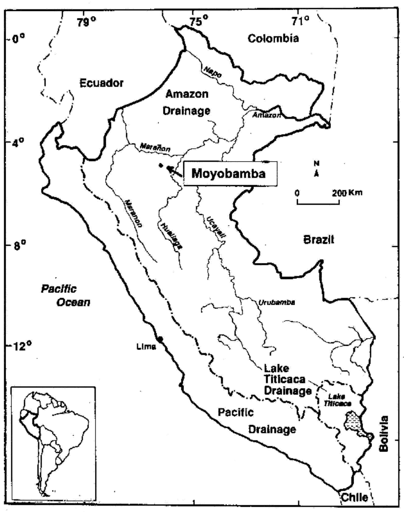

Fig. 1: Location o Moyobamba.

The highest elevation forest Amphibiomes of the neotropical lowland type are found along the East Andean slopes in the Alto Mayo Region of Northern Peru (c.f. Fig. 1). Forest types are transitions from open, palm dominated groves (Aguajales) to either dense multi-stemmed Fig tree swamps (Renacales) or tall mixed floodplain forests. These forests are subject to annual river flooding, persisting waterlogging and anoxic soil conditions. These biomes are extremly endangered due to recent anthropogenic destruction by clearing for rice fields, cutting of palm trees for harvesting of Aguaje fruits, and indirectly by disturbing the natural fluctuations of the hydrological regime.

The aim of the study was the classification of primary forests in the lower watershed of the Río Avisado, with the main focus on amphibiomes. Special emphasis was placed on correlations between vegetation and abiotic environmental factors. The studied area included the seasonal inundation forests at the lower Río Avisado (800 m a.s.l.), as well as adjacent forests on the upper terraces of the Río Mayo and of the lower and upper colline region (850-1050 m a.s.l.). The results of this study serve as a base for an ecological sensitivity assessment of the area and an assistance to administrative institutions for the development of an integrated management and protection plan for the region.

Material and Methods

Representative primary forests were identified along a topographical and hydrological gradient. Analysis of thematic maps, aerial photography and radar images was included for the selection of plots. A total of 71 topographically stratified plots were obtained covering inundation forests and adjacent upland forest types.

On each site recordings of the vegetation structure were made, considering three relative layers in all stands which totaled stand height. Thirty-seven structural features were recorded based on areal vegetation classification systems from Richards et al. (1940), Webb et al. (1970) and individual plant classification systems by Werger et al. (1982), including descriptive parameters on tree crowns, aboveground roots, leaves and special life forms in the respective layers. Above ground biomass was estimated on the basis of tree dimension measurements, using allometric equations between stem diameter and tree height described for the calculation of above and below ground biomass for different tropical forest types by Ogawa et al. (1965). At each plot, a soil profile was described and samples for physical and chemical analysis taken. Parameters were obtained for top- and sub-soil properties, including soil texture, total carbon and nitrogen content, exchangable phosphorous, potential cation exchange capacity and Al^{3+} saturation.

For interpretation of aerial photos and satellite images, aerial photography from 1992 and two JERS-1-Radar-images from the wet and dry season (from 1995 and 1996, respectively) were available. The strong backscatter signal in the radar image from the flooded forests during the rainy season and from the depressions with remaining stagnant water during the dry season allowed their distinction from adjacent drier forest areas and cultivated land.

Results and Discussion

Hierarchical cluster analysis was performed separately for the structural, biomass and soil data sets. Analysis of the vegetation structure resulted in four forest types for the study area. Two very distinct structural types are found exclusively in the seasonal flooded inundation forests and can be identified by their dominant tree species. The forest type “Aguajales” represents stands with open canopy, but dense understorey, dominated by the palm tree *Mauritia flexuosa*. Frequent flooding of these sites is indicated by the presence of aerial roots. The heavily branched, round crowns of multiple trunked species of *Ficus* spec. characterise the forest type “Renacales”. These crowns are dense, allowing little light penetration to the ground, and almost no development of understorey vegetation. Epiphytes, especially different fern species, densely cover the branches of the fig trees. Two other forest types occur in the hill region.

In the permanently flooded Aguajales at the lower Río Avisado the lowest stand densities in the study area were recorded with 412 stems/ha (c.f. Fig. 2), forming very homogeneous stands due to the common dominance of slender, high stems of *Mauritia flexuosa*. At the slightly better drained sites of the Renacales and mixed forest types the stands have about 1000 stems/ha. For swamp forests in northern Costa Rica Liebermann et al. (1985) found longer duration of flooding to be one reason for a decrease in stem density. These reduced stem densities were linked with a decrease in the number of species which was refered to the exclusion of species intolerant to flooding. In the hill region almost all recorded stands contain more than 1000 stems/ha, the average was 2239 stems/ha.

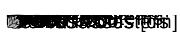

Fig. 2: Distribution of stems in different classes of circumference at breast height (CBH). The groups of plots result from hierarchical cluster analysis based on tree dimension measurements.

Fig. 3: Average aboveground biomass calculated after Ogawa et al. (1965) for the groups resulting from hierarchical cluster analysis.

Aboveground biomasses estimated after Ogawa et al. (1965) were in the lower range compared to values from literature given for tropical lowland and montane forests (Gonzáles 1974; Cannell 1982; Kahn & Mejía 1990; Richter 2000). Biomass in the inundation forests was on average 206.5 (± 60.1) t/ha, in forest stands of the hill region 190.4 (± 56.2) t/ha (c.f. Fig. 3). The stand biomass in the inundation forests and adjacent river terrace forests was mainly concentrated on a few big individual trees (tree height > 35 m, circumference at breast height (CBH) > 2m), whereas it was evenly distributed on numerous, but small trees in the upper hill forests.

Fig. 4: Total nitrogen contents in top- and sub-soils (top-soil = rooting zone) of inundation forests exceeds that of adjacent upland forest by ten times.

Fig. 5: Correlation between the content of exchangeable Phosphorous in the top-soil (rooting zone) and the parameter stems per hectare.

Analysis of physical and chemical soil parameters showed a clear distinction between the soils of the inundation forests and the soils on well-drained sites. The soils of the inundation forests are characterised by a clay texture, high proportions of undecomposed organic matter and thus high carbon (22.1 %) and nitrogen (2.1 %) contents (c.f. Fig. 4), moderately acid pH (4.7 in upper and 5.0 in the lower horizons) and low Al^{3+} saturation (2.6 %). In small depressions prolonged water logging occurs due to impeded drainage on the clayey substrate and mineralization seems to be reduced due to the anoxic conditions. Therefore, the very high P- and N-content of the soils can not be used efficiently by plant roots for tree growth.

In contrast to the findings for the amphibiome soils, soils in the upland forests have a loamy to sandy texture, the soil reaction is acid to strongly acid and the Al^{3+} saturation is often very high. For the entire study area significant correlations were found between the number of stems per area and soil parameters like low pH (Spearman’s correlation coefficient r=-0.74 for sub-soil pH, $P<0.01$) and low content of exchangeable phosphorous (r=-0.73; c.f. Fig. 5). The occurrence of stems with large CBH was positively correlated with high contents of clay (r=0.50) and negatively with high Al^{3+} saturations in the soil (r=-0.52). However, there was only a weak correlation between Al^{3+} saturation and total above ground stand biomass (r=-0.30). Variation in biomass can not be entirely explained by the investigated soil parameters. The measurement of nutrient contents of the soil should be completed by an estimation of the mobilisation of nutrients from mineralization and weathering of the parent material and measurements of nutrient concentrations in the plants.

Analysis of aerial photography and radar imagery (wet season/dry season temporal change analysis, c.f. Fig. 6) showed a good correlation between the distribution of Aguajales and Renacales and the extent of flooding. The radar signal penetrates open canopies more easily and the reflected signal is stronger for wet soil surfaces and water relative to dense forest canopies with underlying dry soils (Lillesand & Kiefer 1994). The aera with heavy flooding remains waterlogged throughout the year and typically carries open Aguajales. The depression between the upland hill areas north of the Río Avisado and the large Río Mayo floodplain in the south is caused by heavy sedimentation along the banks of the Río Mayo. The flood waters of the Río Mayo further impede the drainage of the lower Río Avisado.

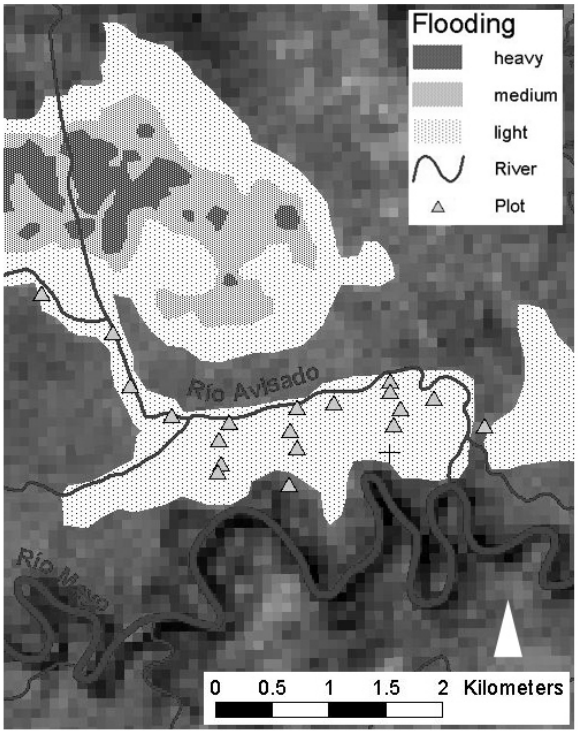

Fig. 6: Example for the extend of flooding in the lower Río Avisado watershed during the peak of the wet season in November 1995. The mapping was based on a JERS-1 radar image, with a resolution of 100m, provided by the Jet Propulsion Laboratory, Pasadena. Higher backscatter values indicate open canopy and underlying water saturated or flooded soils.

Conclusions

Classification of forests in the study area was successfully achieved by combining data of structural vegetational features, the distribution of above ground biomass within the stands and site soil parameters. The distribution patterns of amphibiome types correlated with the duration and intensity of flooding and soil chemical conditions.

Acknowledgements

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