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Relationship between pedodiversity and agro-phytodiversity on a zonal gradient in West Africa

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1. Introduction

Biodiversity is one factor that stabilizes ecosystems. Also in agro-ecosystems crop diversity helps to reduce various risks for the farmer including crop loss due to biotic (pests) and abiotic (weather) stresses.
Under West African conditions, the farming systems are often still characterized by a mixed use of (partly introduced) crops and wild plants. In order to cover both aspects, we introduce here the term agro-phyto-diversity, which means all plants which contribute to the well-being of a farm household.
In the frame of the BMZ financed CODE-WA project one major hypothesis (and consequently also strategy) was, that increased agro-phytodiversity would help farmers to stabilize or even increase income and reduce risk under a climate change scenario with increased inter-annual and intra-seasonal climate variability (varying crop cycle length, intra-seasonal droughts).
However, in order to sustainably influence agro-phytodiversity, it is first necessary to understand the factors governing existing diversity. Therefore four sites on a climate gradient in West Africa were researched in this regard. Exemplary results with emphasis on the northernmost Sahelian site are presented here.

Keywords: biodiversity, Niger, crops, woody vegetation, climate variability

2. The CODE-WA project and sites

CODEWA is a research for development (R4D) project financed by the German Federal Ministry for Economic Cooperation and Development (BMZ) and implemented by the International Crops Research Institute for the Semi-arid Tropics (ICRISAT) in collaboration with the University of Hohenheim. The goal of the project is to enhance the resilience of subsistence oriented farmers to climate related risks and hazards by enriching agro-phytodiversity across a climatic gradient. The collaborating partners are farmer organizations and national research institutions in the four countries Niger, Mali, Burkina Faso and Ghana. The project approaches include action and participatory research. Research areas tackled are: i. understanding climate variability in spatial and temporal dimensions, ii. enriching phytodiversity and enhance natural resource management to improve farmers' adaptive capacity to climate change, and iii. communication in the R4D continuum.

Within this framework a zonal approach is followed, comparing sites on an agro-ecological gradient starting from the Northern Sahel down to the Northern Guinea zone of West Africa. Four contrasting villages have been chosen as intervention zones based on properties like village territory size, number of inhabitants, terrain variability, accessibility etc…
These are:
- Serkin Haoussa in central-southern Niger, representing a North-Sahelian environment with 300-500 mm rainfall,
- Tominian in western Mali representing a South-Sahelian environment with 500-750 mm rainfall,
- Nobéré in central-southern Burkina Faso, representing a South-Soudanien environment with 750-1000 mm rainfall,
-Piisi in the Upper West Region of Ghana representing a North Guinean environment with 900-1200 mm rainfall.

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3. Methods

In order to understand the relationship between pedodiversity and agro-phyto-diversity, Warzou, a village situated in Serkin Haoussa district in the central southern Niger was used as central case study.

A QuickBird satellite image which offers a resolution of 1m at the ground so that all houses, wells, paths and even trees are distinguishable was used for delimitation of the village terrain and different terrain units in group discussion with about 20 male village members including the village chief. Also in group discussion farmers attributed crops and woody vegetation to each terrain unit identified.

In order to verify the results obtained in the group discussions two older village members, who had not participated but were known for their terrain knowledge, were invited to take part in transect investigation. In radial direction six paths were visited and every approximate 250 m the terrain type registered, including the GPS co-ordinates, amounting to 56 sampling points. The following field investigations used the same geographic locations. Based on farmers indication four soil profiles judged to be representative for the village terrain were described according to WRB 2006. In addition soil augering was executed on the transects and field size, crop species and crop varieties including surface coverage at peak rainy season determined in the directly adjacent fields, partly by expert estimation and farmer interviews. Also all trees and shrubs present at the transect points in an approximate radius of 50 m and with a crown radius >1 m (= visible on the QuickBird image) were determined.

4. Results

i. Soil mapping in Warzou, North-Sahel, Niger

Four different terrain units were identified and delineated with a field by field procedure by farmers (Figure 1):

- **Jigawa** literally means sand. It represents Haplic and Lamellic Arenosols and is found in lower landscape positions with easier access to groundwater, and showing poor soil development, as indicated by the whitish to greyish color and intact lamellae in the subsoil as well as low chemical fertility as indicated by the extremely low organic matter concentration.
- **Jampali,** literally meaning red soil, occurs in pronounced dune relief and is judged by farmers as the least fertile soil.
- **Gueza** is in the local Haoussa language the (bush) species *Combretum micranthum.* It represents Hypoluvic Arenosols, as they are widely distributed in southern Niger on older dune and cover sands. In more strongly eroded positions the subsoil contains sufficient clay so that soils key out as Haplic Acrisols.
- **Guezami-Guezami**, according to farmers, indicates an intermediate between Jigawa and Gueza but could hardly be distinguished by field mapping based on the WRB key.

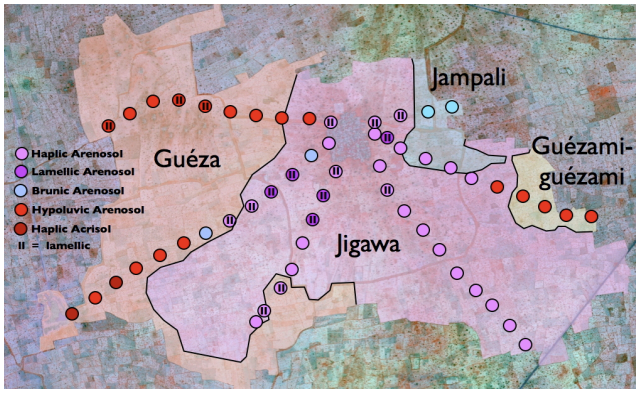

Figure 1: Village boundaries, terrain units and WRB soil mapping results at Warzou village, Maradi region, North-Sahel, central southern Niger (Map basis: QuickBird image, September 2008)

ii. Crop species

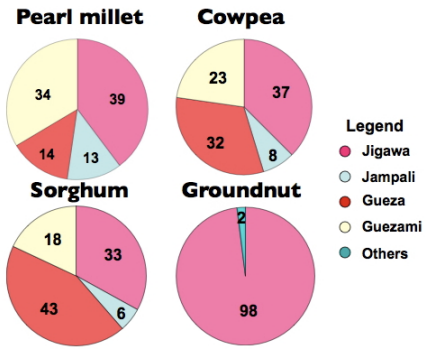

Figure 2: Crop surface shares as determined by transect investigations on the village territory of Warzou, Maradi regiion, central southern Niger

Crop attribution by local farmers to terrain types and results of transect investigation

(Figure 2) for the main crops match in general. Pearl millet is the most frequent crop on Jigawa, whereas sorghum covers a greater share on Gueza. Groundnut nearly exclusively occurs on Jigawa close to the village and cowpea is over proportion present on the transitional soil types far away from the village.

iii. Woody species

Also in this respect trends as revealed by farmer group interviews and transect investigation match (results not shown).
The first obvious feature is the presence of the highest species diversity on Jigawa and of least diversity on Jampali (as for the crop species). The second obvious feature is the high frequency of *Faidherbia albida* close to the settlements. According to farmers, species found near the village are protected ones and those which require fertile soils.
Further away from the settlements mixed stands are frequent. Especially on the Gueza terrain unit *Combretaceae* dominate: *Combretum glutinosum, Guiera senegalensis and Combretum micranthum.*
In contrast Guezami-guezami shows dominance either of *Combretum glutinosum* or *Piliostigma reticulata*.

iv. Inter-site comparison

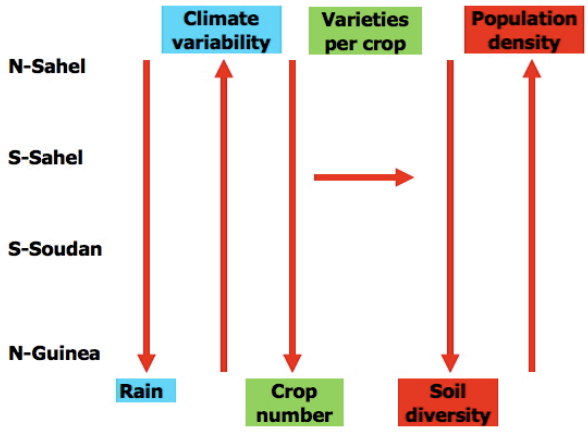

Figure 3: Zonal gradients as revealed by the study in West Africa. Flesh direction = increase

The annual rainfall is increasing on the zonal gradient from the Sahel in the north to the Guinea zone in the south. This has an important influence on the drainage system present in these environments. At Warzou (North Sahel) with the lowest rainfall no drainage system at all is developed on the village territory. The geomorphology is dominated by eolian influence leading to relative homogeneity of parent material and texture in turn leading to low soil type diversity, dominantly Arenosols occurring. In contrast, the southernmost terrains are clearly marked by fluvial systems dissecting the terrain and thus leading via material redistribution to higher textural and soil type diversity. In example, at the southernmost site Piisi in Ghana, Plinthosols are dominant but associated with Cambisols on younger surfaces, Arenosols where material has been redistributed by slope processes and Gleysols in the low terrain positions.
In contrast to rainfall, climate variability as indicated by the interannual variation of rainfall increases northwards. Since in the same direction also the length of the vegetation period decreases, crop diversity decreases likewise, since only few crops are adapted to the harsh Sahelian conditions with high temperatures, high wind speeds, extremely sandy and chemically poor soils and a short vegetation period at the same time. With respect to the number of crop varieties grown, no zonal gradient could be detected. This aspect seems to be more influenced by farm size and gender.
In opposition to our assumption, the population density increases northwards. We attribute this to higher disease risk especially caused by the occurrence of the tse-tse fly southward.

5. Discussion

Though farmers differentiate four local terrain units in Warzou, these represent only two WRB soil reference groups: Arenosol and Acrisols, the latter occurring only were cover sands are not thick enough and representing less than 5% of the sample population. Even on the next WRB level, introducing qualifiers, only five units could be differentiated. Field mapping of those was quite demanding due to the only very small subsoil clay concentration differences.
Despite its poor soil development and its low chemical fertility Jigawa is the terrain unit preferred by farmers for cropping. Actually it is the terrain where the village was intentionally founded. We attribute this to the lighter texture, which eases tillage operation and leads to less surface crusting and

consequently higher infiltration, and to the terrain position closer to the groundwater and receiving additional water by lateral surface and interflow.

Astonishing to note is the highest diversity of crops and woody species on this soil type. An important factor contributing to this is human influence by i. fertilization (the more the closer to the village) and ii. more intense care for certain crops (i.e. groundnut as cash crop) and trees (i.e. *Faidherbia albida* with slow initial development needing protection as well as beomg a high value fodder producer). Sorghum, which has a higher water demand and is less resistant to high soil temperatures in early phases, occurs - as already indicated by the farmer group discussion - more frequently on Gueza with its higher clay concentration in the subsoil. It is interesting to note, that generally speaking the rapid appraisals via farmer group discussions were proven by scientific data collection. Consequently for rapid agro-ecological appraisals, including local knowledge can be advantageous.

Faidherbia albida is the dominant woody species close to settlements. For the case of Warzou this is true for the central village as well as for the small Peulh hamlet in the west. There are three supposed reasons for this fact: i. Anthropic disturbance allows *Faidherbia* to germinate and develop. *Faidherbia* is known to have a slow initial development, and is suppressed by faster growing species if the soil is not kept open (Barnes & Fagg 2003). ii. Active protection by man since it is a valuable fodder source in the dry season (Maydell 1990). In fact Faidherbia is an anticyclic tree in the sense that it develops the canopy mainly in the dry season („reverse leaf phenology“). So it does not create concurrence for the annual crops during the rainy season but provides valuable fodder by its leaves as well as fruits in the dry season (Roupsard 1997) and shade for the domestic animals which in turn leave their droppings under the tree increasing fertility. iii. The sandy soils closer to the groundwater. According to Maydell (1990) *Faidherbia* needs relative shallow groundwater in order to survive for longer time spans.

With respect to the inter-site comparison on the zonal gradient, the Sahelian site Warzou is the most disfavored. There are no, not even seasonal open water surfaces on the village territory, indicating the limitation in this respect. In addition, neither forest nor fallows exist on the village territory, caused by the high population density and low productivity of soil resources under the given climatic circumstances. This high pressure on land surely influences agro-phyto-diversity. This is proven by interviews during which farmers stated the loss of certain wild tree species like *Cadaba farinosa* and *Lannea microcarpa.* In contrast, nearly no diversity loss was reported at the southernmost site.

In accordance with the latest IPCC report (2007) especially the Sahelian sites with low rainfall, as well as low pedo -and agro-phytodiversity, will be hit by climate change. Consequently, it is these sites which need concerted action in order to stabilise or better improve agro-phytodiversity for better adaptation to climate variability and cropping risk reduction.

6. Conclusion

The presented study shows that different factors govern agro-phytodiversity depending on the spatial scale considered. While at the zonal scale climate via rainfall amount and length of the vegetation period is considered dominant, at the local scale soil diversity and human influence appear more important. At the northern sites the relation between pedodiversity and agro-phytodiversity appears to be more affected by soil fertility, at southern sites more by soil hydrology.

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