1 Introduction

Land use is becoming a force of global importance. In Benin, enormous changes to forests, farmlands, waterways, and air are being driven by the need to provide food, fibre, water, and shelter to rapid growing population. Croplands, pastures, plantations, and urban areas have strongly expanded in recent 20 years (Paeth 2006), accompanied by large increases in energy, water, and fertilizer consumption. Such changes in land use have enabled local people to appropriate an increasing share of the natural resources, but they also potentially undermine the capacity of ecosystems to sustain food production, to maintain freshwater and forest resources, to regulate climate and air quality, and finally to preserve soil fertility. The ecosystem responses to land use vary according to the ecological setting and the type of land-use change, and have partially differentiated local, short-term as well as global, long-term effects. On the one hand, balancing the inherent trade-offs between immediate human needs and maintaining the capacity of other ecosystem functions requires comprehensive knowledge about these ecosystem functions on regional scale (Matson, Parton, Power, and Swift 1997; DeFries, Foley, Asner 2004; Foley, DeFries, Asner, et. 2005). On the other hand, reliable data about West-Africa are not always readily available. The need for practical and efficient indicators, which can describe and relate interdisciplinary phenomena on a suitable regional scale, is not only important for biological and ecological sciences, but also for economical and political implementation. The integrative indicators eco-volume and bio-volume as vegetation indicators opposed to the standard biomass indicators generally enable to better describe the reactions between vegetation dynamics and soil nutrients variation, precipitation, population dynamics and farming intensity on the regional scale.

Since vegetation cover has been rapidly declining in Benin, the agro-ecological constraints in the whole Oueme basin have been further investigated, allowing vegetation evolution to be reconstructed on a regional scale, which, in turn and combined with other research results, would enable a realistic policy analysis. The possible feedback between vegetation and precipitation dynamics is in the focus of this study on “Vegetation Dynamics in Oueme Basin, Benin, West-Africa”.

To make the test of the feedback between vegetation and precipitation empirically

possible, a suitable vegetation data compiling approach was developed together with the newly defined concepts of eco-volume and bio-volume. The portion of precipitation variability, originating specifically from vegetation variability, was defined as eco-precipitation. The *in situ* measured agro-ecological and farming system parameters of all three vegetation types were used to validate the agricultural statistics of each 62 administrative communes in the whole Oueme Basin from 1987 to 2004 and the land cover data of Global Landcover Classification (GLC2000). Thus for each of the 62 communes, the temporal and spatial dynamics of biomass, eco- and bio-volume were reconstructed. Other available datasets comprising annual precipitation, vegetative duration coefficient and population density were adapted to comparable time and spatial spans, and eventually analysed through linear multiple regressions and general linear model together with the reconstructed vegetation dynamics. The feedback between vegetation and precipitation was evaluated at different spatial scales including all 62 communes, all ten Departments (provinces), and eventually, the communal means regrouped into the south, middle and north Oueme Basin sub-regions. Moreover, the static regional scenarios of precipitation in relation to eco-volume in 2004, the temporal and spatial scenarios of bio-volume in relation to precipitation from1987 to 2025 have been simulated in order to detect possible future trends.

This study deals with interdependent processes between vegetation dynamics, precipitation variability and, on the human side, institutional arrangements, agricultural economics and population dynamics for the whole Oueme Basin. Farming systems are highlighted for their influence on the vegetation dynamics.

2 Agro-ecological Conditions in the Oueme Basin

2.1 Location and geography

Benin is located in West Africa. It is bound by Niger to the north, Burkina Faso to the northwest, Nigeria to the east, Togo to the west and the Gulf of Guinea to the south. The country has four natural topographical regions: (i) A coastal belt which has four lagoons, the Cotonou, Ouidah, Grand Popo and Porto Novo while further north the land rises slowly to a savannah plateau, (ii) The Lama which is a wide marshy depression, (iii) The Atakora Mountains in the northwest and, (iv) The eastern plains of Borgou and Kandi which slope to the Niger basin. The country is covered with different vegetation types and has many major rivers. The Oueme River is the longest river running southerly, starting from Atakora, down the middle of the country, ending till the coast. The Oueme River rises in the Atakora massif in north-western Benin. It is approximately 500 km in length and flows southward, where it is joined by its main affluent, the Okpara, on the left bank and by the Zou on the right bank. It then divides into two branches, one discharging into Lake Nokoué Abomey-Calavi, delta near Cotonou and the other one into Lagoon Porto-Novo. The Oueme Basin covers ten provinces (departments) encompassing 62 administrative Communes.

2.2 Climate

The Oueme Basin, endures a tropical climate subdivided into three climatic zones according to different rainfall regimes by the Impetus project classification; (i) The north Oueme with an unimodal rainfall regime which has two seasons: the rainy season from May to October and the dry season which is hot with very low humidity, (ii) The south Oueme with a bimodal rainfall regime which has two wet seasons, a long one between March and July and a short one between September and mid November as well as a long dry season between November and March, (iii) The middle Oueme with a transitional rainfall regime which has a rainy season between March to October, with or without a small dry season during August. Rains mostly originate from the Guinean coast. The prevailing dry season wind is the Saharan Harmattan, a hot dry dust laden wind that blows from the northeast and occurs between December and March. Average annual precipitation varies between 960 mm in the north and 1340 mm in the south. Average annual temperature ranges in

Cotonou from 23 °C in August to 28 °C in May.

2.3 Soil

The Republic Benin locates in West-Africa and geographically between 06°00' to 12°00' northern latitude and 01°00' to 03°40' eastern longitude. It has a land area of 114870 km^2 (MDR/DAPS, 1998) or around 11.5 million ha. According to GLC2000 there are only 11.43 million ha for the whole of Benin. In this study the value of land area of GLC2000 was used. Table 2-1 shows the land use classification of the three climate regions of the whole Oueme Basin used in this study. The item "Real annual crops (ha)" has been extracted from the corresponding area sum from the agriculture statistic books by the MAEP/DPP, after correction for CIC (Cropping Intensity Coefficient), as detailed in Chapter 3.

Within Oueme Basin there are four major soil types. First in North and centre, the crystalline base soils Alfisol, so called "sols ferrigineux", are dominant. Such soils are expressed by concretion and lateritic crusts, most are sandy. Second in South, a depression with direction western to eastern separates the crystalline base soils. The soils in this depression are mainly comprised of hydromorph Vertisols, which are sandy loamy to loam soils. Third in South is a sand-stone plain ("Terre de Barre"), here the soils are dominantly deep, fertile and sandy to loamy Acrisol. Fourth after the sand-stone plain follows a coast zone, where the soils are dominated through quartz rich sand and characterized by expanded swamp zone and lagoon water (Fritz 1996, Herrmann 1996, Bohlinger 1998, van den Akker 2000).

Table 2-1 Classified land use area using remote sensing dataset (GLC2000) and corrected for CIC (Cropping Intensity Index) of the whole Oueme Basin

Depart-ment	Com-mune	IMPETUS Zone	AEZ	Total (ha)	Sum vegetation (ha)	Forest (ha)	Savannah (ha)	Real annual crops (ha)	Other (ha)
10	62	3	6	6780865	6745167	449871	5115482	1179814	35698
% to Total					99.47%	6.63%	75.44%	17.40%	0.53%
% to Sum of vegetation						6.67%	75.84%	17.49%	0.53%

- Source: Remote sensing dataset of land use in Benin in year 2000 from the GLC2000 Project, supplied by Michael Judex
- AEZ = Agricultural Ecological Zone
- Total (ha) = Total Land area in hectare of Benin according to GLC2000
- Sum vegetation (ha) = GLC2000 area of total vegetation in hectare
- Forest = mosaic forests and mangrove
- Savannah = Deciduous woodland + Deciduous shrubland with sparse trees + Sparse grassland+Swamp bushland and grassland (including perennial plantation crops)
- Real annual crops (ha) = annual crops area from Agriculture Statistics Book in year 2004 (MAEP/DPP 2004), then corrected for CIC
- Other (ha) = urban area and water bodies

2.4 Vegetation

Wezel and Bohlinger (1999) have classified Benin in four vegetation zones viz.; Coast Zone, Guinea-Congolian Zone, Guinea Zone with Southern and Northern Guinea Zone, and Sudanian Zone with Southern and Northern Sodanian Zone as shown in Figure 2-1. Northern part of Oueme Basin is mainly covered by the Southern Sudanian Zone and to a lesser extent by the Northern Guinea Zone. Northern parts of Donga and Borgou belong to the Southern Sudanian Zone, where the prevailing vegetation types are woodlands and savannahs and, *Isoberlinia* trees occur more frequently. Along rivers, gallery forests can be found. The Southern Parts of Donga and Borgou and part of Collines are dominated by the Northern Guinea Zone. The vegetation here is dominated by moist woodlands and savannahs and characterised by woodlands, tree and shrub savannahs with abundant *Isoberlinia* spp. and *Butyrospermum parkii* (Karité).

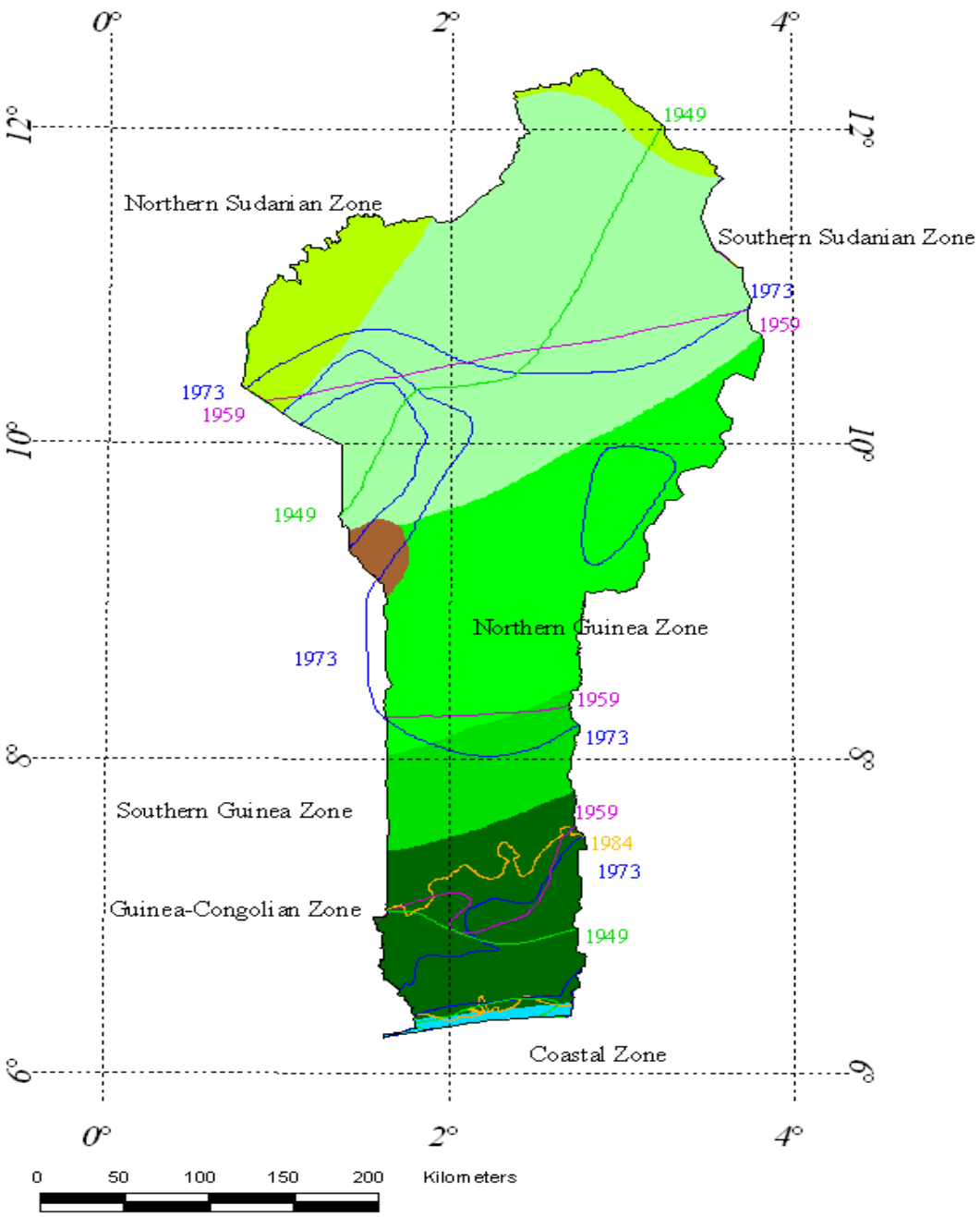

Figure 2-1 Vegetation zones of Benin

Central Oueme Basin is dominated by the Northern Guinea Zone. The separation between a Northern and a Southern Guinea Zone coincide with the northern boundary of bimodal rainfall in southern Benin.

The Southern Oueme Basin comprises three vegetation zones: (i) The Southern Guinea Zone where moister types of woodland and savannahs with abundant *Daniella oliveri* are found, (ii) The Guinea-Congolian Zone and, (iii) A Coastal Zone

with a small band of coastal vegetation existing along the Atlantic Ocean. In the Guinea-Congolian and Coastal Zones mosaic forests and savannahs exist. In these two zones most of the original vegetation is replaced by secondary grasslands or savannahs due to human impact.

2.5 Population dynamics

Since the beginning of 80's Benin experiences a rapid population growth with an average annual rate of ca. 2.8%. According to the last census there were 6750000 inhabitants in Benin in the year 2002 (INSAE 2003). The figures 2-2 and 2-3 show the total national population growth and projection from 1961 to 2025.

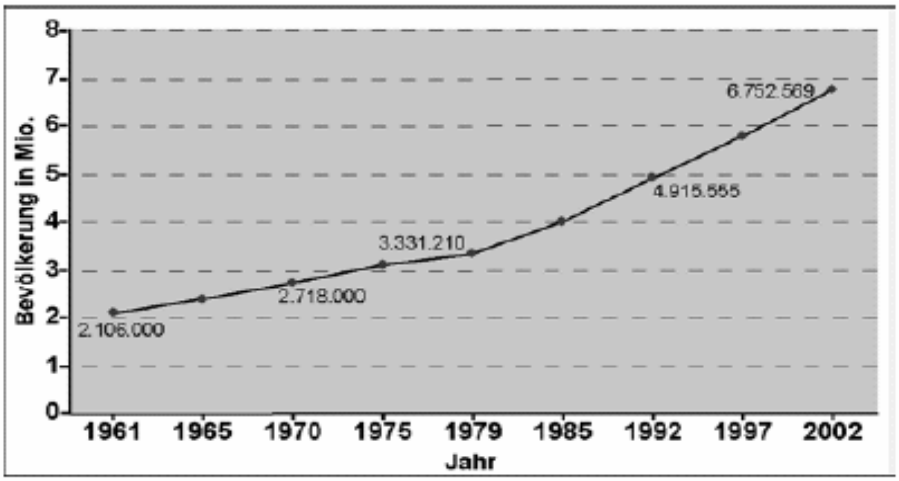

Figure 2-2 Total population growth in Benin 1961-2002 (source: Doevenspeck 2004, Bevölkerung=population and Jahr=year)

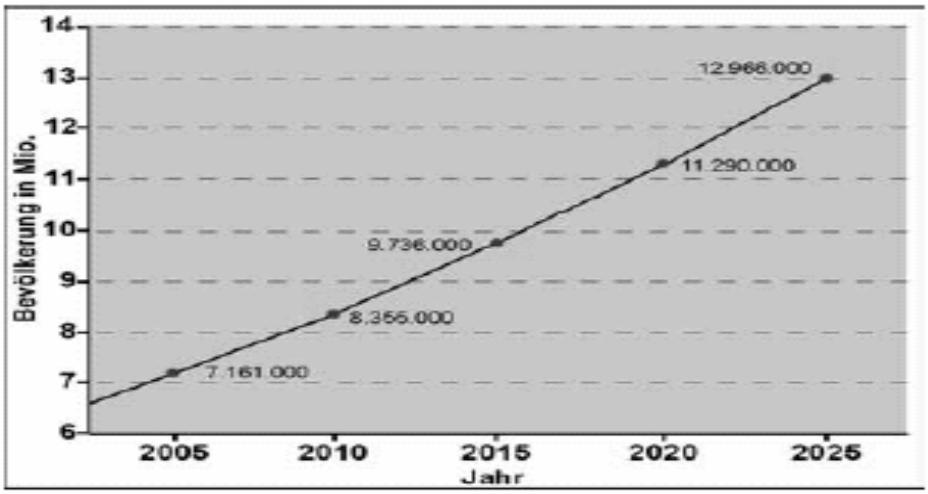

Figure 2-3 Population projection for Benin 2005-2025 (source: Doevenspeck 2004, Bevölkerung=population and Jahr=year)