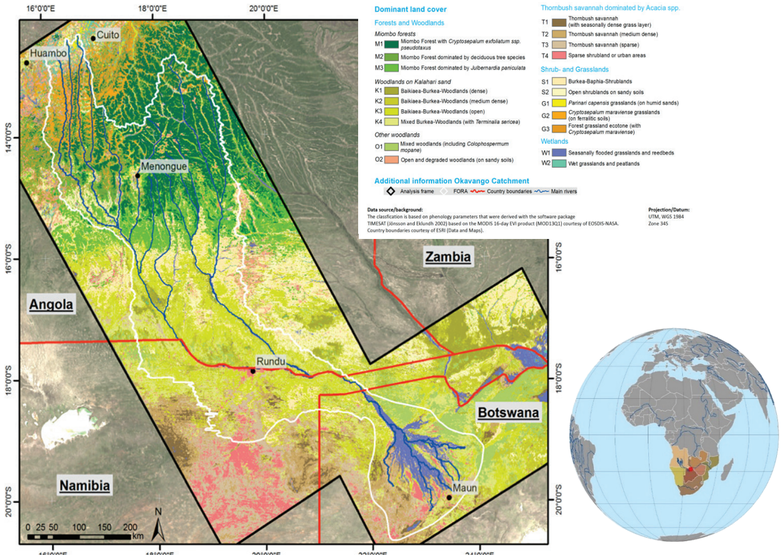
Case study: When food security compromises land resources and biodiversity

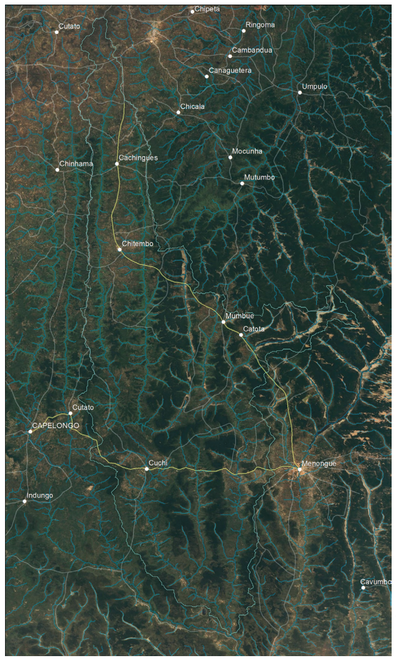
Quantifying choices for the upper Okavango catchment, Angola

The Okavango River system

The Okavango River system in southern Africa is accompanied by diverse and mainly traditional land uses. However, it is an area that is affected by population growth, climate change and the increasing and intensified use of natural resources, and is therefore expected to become a global hot-spot of land-use change. Three neighbouring countries share access to the Okavango system: Angola in the north and Botswana and Namibia in the south. Each of the countries relies on fresh-water provision by the riverine system to different extents and for different purposes. The headwaters of the Okavango River have their source in the central highlands of Angola and can be separated into an eastern (Cuito) and a western (Cubango) catchment. In the western part several tributaries form the Cubango River, which forms the border between Angola and Namibia and, after it is joined by the Cuito River, flows southwards to Botswana as the Okavango River to feed the Okavango Delta. The Okavango Delta is the world's largest intact inland delta; it is a biodiversity hub of global relevance and provides important services to mankind. The delta and the middle reaches rely on regular, seasonal pulses of fresh water to retain provision of ecosystem functions and services. In these areas, the predominant ecosystem services cover a wide variety, such as fresh-water provision, water purification, crops, fish, wildlife, fuel, timber, fibre and forage.



Dominant land use and land cover systems of the Okavango basin based on MODIS time series parameters[11].
Source: Stellmes, M. et al., 2013[11].



Cubango river basin (in cyan the Cubango Catchment).
Source: EOX IT Services GmbH[13], WWF[14], CIESIN - ITOS - University of Georgia. NASA[15].

The Angolan Cubango catchment

In the area of the Cubango catchment, intact forest systems occur along with steadily growing cities, and recently paved roads border and cross the natural woodlands.

The main vegetation unit of the study area is Miombo forest, which is dominated by *Brachystegia, Julbernadia* and *Cryptosepalum* species. Miombo forests cover large areas in southern Africa and provide essential products like timber, firewood and charcoal. On the southern African subcontinent the Miombo forests are regarded as one of the tipping points in the Earth system[1], as summer rainfall and humidity are transported from the Congo rainforest zone via the Miombo belt towards the southern arid savannas. Floral diversity is high, while faunal diversity is relatively low, which may be due to the extensive dry season[2]. The wet and dry seasons are highly distinct, and the majority of the rainfalls occur during the wet season (November to April). The landscape of the study area is characterised by large floodplains, mainly stretching from north to south, and lateral valleys fragmenting the woodlands that are situated on higher slopes and hilltops. On the floodplains, thick peat layers occur due to the constant interflow from the slopes. Two main paved roads and several minor roads and earth tracks cross the area, connecting the major cities (Menongue, Chitembo and Cuchi) and several smaller villages, as well as agricultural areas.

The landscape of the study area is comprised of large areas covered by medium-dense to dense Miombo forests, mainly on the hilltops and slopes, grasslands in the valleys and wetlands in the valley bottoms with thick peat layers.
Source: Röder, A., Stellmes, M., Schneibel, A.

The Angolan civil war

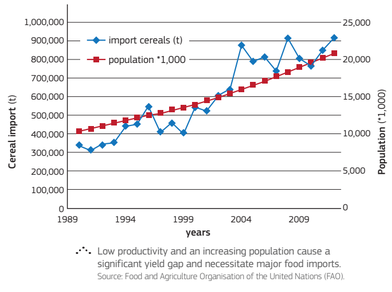
Rural Angola was severely affected by the civil war, which intermittently lasted for 27 years (1979-2002) and led to the displacement of the rural population and the breakdown of the agricultural sector[3] (Kibble, 2006). Ground data are almost absent in the study area, as are reliable statistics, due to the conflicts and the resulting massive population movements[4]. Basic provision of food, medicine and education is still insufficient, especially in rural areas[5]. After the end of the civil war people returned to their former homesteads, but were confronted with heavily mined landscapes, the lack of basic supplies and destroyed infrastructure. Repopulation of abandoned areas after the ceasefire resulted in a fast and extensive expansion of agricultural fields to meet rising food demand. But to this day people rely on ineffective cultivation practices due to a lack of fertilisation and poor agricultural practices. Yet the increase in crop production at the expense of natural resources carries an inherent potential for conflict, since the demand for timber and wood extraction is also expected to rise.

The Angolan government spends large amounts on reconstruction and the improvement of infrastructure, along with agricultural development[4]. Nevertheless, this support is slow and insufficient, especially regarding future changes (e.g. climate change, population growth, foreign investments in large-scale agricultural projects). Politicies will be challenged to find adaptive pathways to protect natural areas while supporting the provision of sufficient food for a growing population.

Agricultural production was severely affected during the civil war by open hostilities and by the extensively spread landmines. Demining is still in progress.
Source: Röder, A., Stellmes, M., Schneibel, A.

Upstream–downstream perspectives

Besides the national perspective, the very nature of this system poses potential conflicts, because any development in upstream Angola may negatively affect downstream neighbours and economic sectors. This includes deforestation for smallholder agriculture or the creation of dams for energy provision, which are expected to disrupt the flood pulse cycle. The increased usage of fertilisers and pesticides is also expected to negatively affect water quality.



Low productivity and an increasing population cause a significant yield gap and necessitate major food imports.
Source: Food and Agriculture Organisation of the United Nations (FAO).

Land use in rural Angola

Traditional smallholder agriculture in the region is largely based on a shifting cultivation system with slash-and-burn techniques for field clearing and, after a period of cultivation, long-term fallows of several decades for the regeneration of soil fertility[6]. The main crop in the study area is maize, in addition to secondary crops like beans and manioc and a variety of tertiary crops, mainly vegetables and tubers[6].

Every 5 to 10 years (depending on soil fertility), these areas are abandoned and the household moves deeper into the forest to clear a new patch of forest for the establishment of its next cultivation area. In contrast, in areas where land pressure is increasing, it appears that semi-permanent and permanent forms of smallholder agriculture are becoming or will become increasingly important.

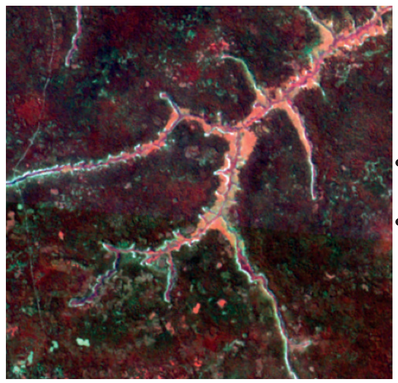
With limited access to markets, and thus mainly relying on subsistence agriculture, the rural population in Angola is heavily dependent on natural resources, which can also provide additional household income (e.g. honey, charcoal or bushmeat)[6,7]. Currently, the rural population adopts a 'modern', consumption-driven lifestyle that leads to rising aspirations for cash income. This in turn results in rising levels of charcoal production, which is the best available cash income source for many rural households[6]. However, this leads to deforestation and thus the erosion of the traditional livelihood base[8]. The predominant slash-and-burn agriculture, honey and charcoal production already put a high pressure on natural resources in the study area and challenge land-use sustainability[9].

Forests are traditionally used for the extraction of timber and firewood, charcoal production, slash-and-burn agriculture and honey production.
Source: Röder, A., Stellmes, M., Schneibel, A.

Roads are spatial drivers of deforestation

Deforestation patterns are clearly connected to the proximity of settlements and the abundance and quality of roads. Almost half of the new fields were established closer than 1 km to existing roads (46 %). More than 70 % lie within a 2 km radius and more than 90 % are within a distance of 5 km. This indicates that new fields are mainly established within a short walking distance of roads and tracks. Fields are more likely to be established along tar roads than earth roads. These patterns can be explained by better connectivity of agricultural areas and markets and the connection of fields to larger settlements, which are mainly located along tar roads.

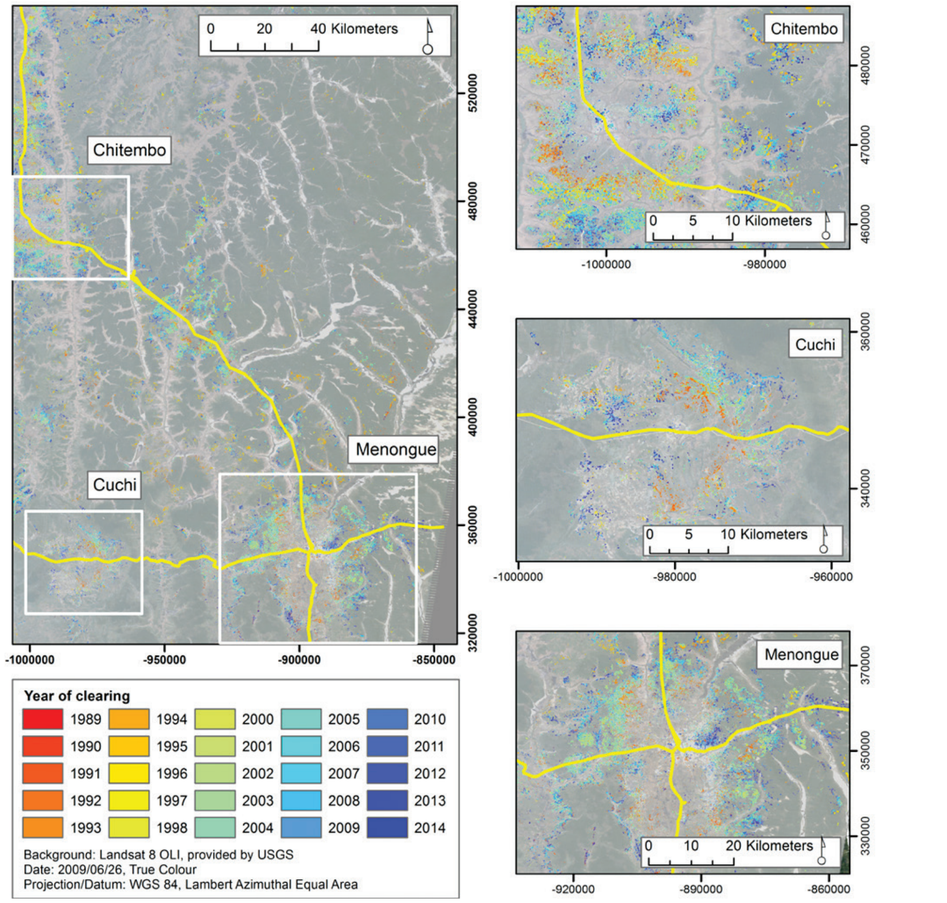
1989



2014

Population growth and resettlement after the end of the civil war has led to massive deforestation of intact Miombo forests. Landsat false colour image RGB=4-2-1.
Source: United States Geological Survey (USGS).

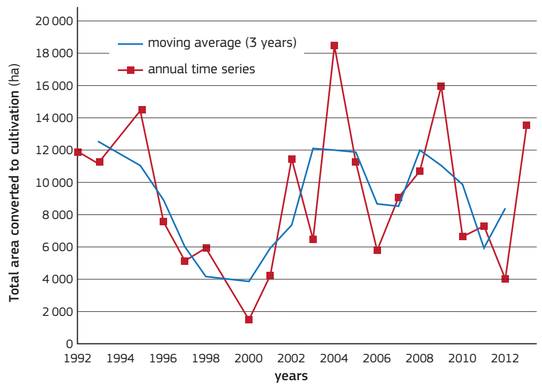
Quantifying choices for the upper Okavango catchment, Angola (cont'd)



Year of forest clearing for agricultural expansion from 1989-2014, with additional close-up looks at the cities of Chitembo, Cuchi and Menongue. The results are based on time series segmentation with LandTrendr on annual Landsat NBR images.
Source: Schneibel, A. et al., 2016[12].

Historical legacy in agricultural dynamics

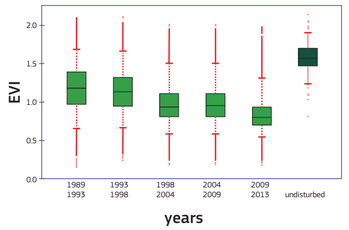
The rate of deforestation in the Cubango catchment has been dynamic and has reflected the relative intensity of historic conflicts. Deforestation for the establishment of fields decreased by more than 70% to 4000ha during the active conflict period (1994-1998) and subsequently tripled to 12000ha per year after the ceasefire in 2002. The rate of deforestation currently remains at a high level of around 10000ha/year. Since under rising land pressure people change to semi-permanent and permanent agriculture, this means that less area returns to fallow, thus providing fewer shrub and forest ecosystems. Regeneration is generally slow, and many fallowed agricultural fields did not reach the pre-disturbance state regarding biomass during the 25 years of observation.



Total area of natural land converted to agriculture (in hectares) on an annual basis (dotted line) and fitted with a moving average filter of 3 years.
Source: Data from: Schneibel, A. et al., 2016[12].

The farming system is changing due to land pressure

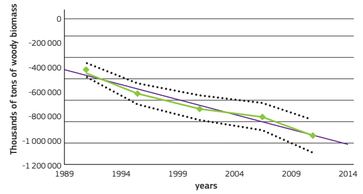
The farming system and the rate of agricultural expansion are closely connected to spatial and temporal drivers like the location and severity of armed conflicts, the resettlement of people, the reconstruction and location of infrastructure and the availability of forested areas. Fields have turned from shifting to semi-permanent farming systems during the last 25 years, especially around cities that are well connected by infrastructure. For those cities that were strongly affected by the civil war this trend is quite recent, starting after the ceasefire in 2002. Cities that were not located close the fighting front show higher land pressure and earlier transition to semi-permanent systems, sometimes since the early 1990s (graph below). However, land pressure is rising, and those cities that were affected by the destruction of fields, the mining of arable land and population movements also show a high deforestation rate since the end of the civil war. This rising land pressure is likely to affect biodiversity, the provision of resources and rural livelihoods in a negative way, and is thus a potential source of conflict, especially since the Miombo forests of the region have been identified as being one of the next tipping points[10].

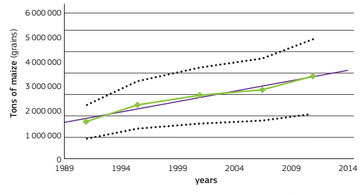


Enhanced vegetation index from 2014 for fields that were established in different periods. The index correlates with green biomass, thus it shows that even fields that are fallow for more than 20 years do not fully recover[12].
Source: Data from: Schneibel, A., et al. 2016[12].

Quantifying the trade-off

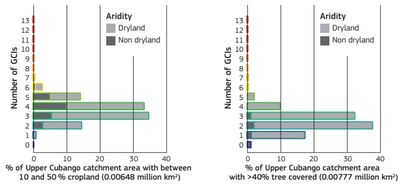
Indicator values based on publications and on household surveys can quantify on one hand the amount of maize grains that can be harvested on the new fields, and on the other hand the woody biomass that is lost due to slash-and-burn agriculture. Depending on different soil types, farming techniques and damage from insects or pests, the rate varies greatly between farmers. While the cutting of forest is a once-only action, fields are used for several years, providing a stable basis for food supply.

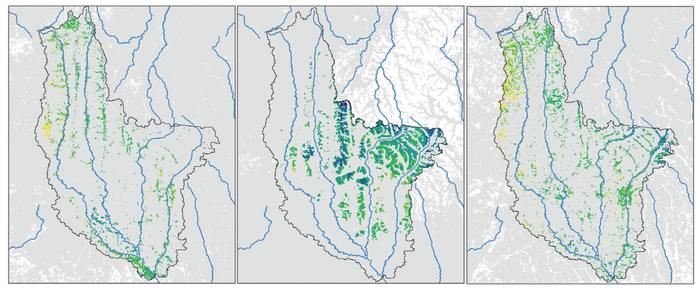


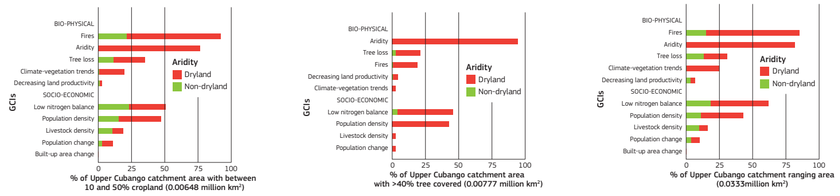


Loss of woody biomass (left) and potential yield of maize grains in tons per year (right). The green line shows the mean, the purple line is the trend line based on the mean values. The dotted black lines show the first standard deviations.
Source: Data from: Schneibel, A. et al., 2016[12].

Although agro-industrial production is emerging in rural Angola (top) and supported by the government, the main agricultural system is still smallholder rainfed agriculture.
Source: top: Stellmes, M.; bottom: Röder, A







Converging evidence from global change issues:
Extensive land changes taking place in this area are driven by increasing population densities, expansion of low-input cultivation and tree loss. As shown on the graphs, these are the main coinciding global change issues (see GCIs, page 144). Not many GCIs coincide, but their impact is notable. The expansion of agriculture is mainly a slash-and-burn practice at the cost of the forest, so the GCIs in both these areas need to be looked at jointly (GCIs in forest on the left and GCIs in agriculture areas in the middle). Being mainly smallholders, low density (mostly 10-50% of the 1 km² pixels is occupied by cultivation) and low input agriculture (defined by nitrogen deficiency) is occurring over more than 50% of the area; this combination is of concern for soil-nutrient depletion. Coinciding with this are high population densities over nearly the same extent. Consequently, tree loss occurs in over 20% of the forest and over 35% of the agricultural area. Slash-and-burn activity is confirmed by the occurrence of fire; this GCI occurs in over 90% of the agricultural area and just under 90% of the rangeland area. Drought conditions affected over 20% of the agricultural area and 35% of the rangelands. The coinciding GCIs mapped at the global scale are confirmed by local knowledge, which allows the correct interpretation of their interaction and impact.
Source: WAD3-JRC, 2018.