Management of soil fertility in smallholder production systems

Recommendations

Smallholders need assistance to achieve sustainability

Crop production by smallholders will likely remain the backbone of rural livelihoods within the Okavango Basin. However, under the current cropping systems, limited land availability results in soil degradation and reduced yields. This may cause households to fall into a poverty trap, a vicious cycle of resource degradation and impoverishment from which they are unable to escape on their own, as they cannot make the investments needed for the adoption of improved farming practices. A major aim for an agricultural reform and awareness campaign should therefore be to increase yields on existing dryland plots with alternative technologies (e. g. conservation agriculture including (organic) fertilization, evaporation control, improved seeds, agro-forestry).

Integrated programs to further develop smallholder-oriented and locally adapted agro-ecological production systems should incorporate:

- Identification of priority areas for agricultural use:
  An identification of the areas with the highest suitability for crop production should be discussed with local communities, the relevant state authorities, and other stakeholders. In case of conflicts with communities' land rights or conservation goals a participatory strategic management-planning process is recommended. Intersectoral integration can help to provide harmonized (dis-)incentives.
- Direct and indirect support:
  For many rural farmers the capacity to invest in improvement of farming practice is limited. Additional support measures should be put into action within the priority areas for agricultural use in order to improve yields and income. Support should include training and empowerment for agricultural extension service officers, and the respective improved extension services for farmers. Additionally, access opportunities for small-scale financial credits should be considered. For the priority areas, the local infrastructure, as a prerequisite for the access to markets, should be improved and maintained.
- Research and development activities:
  As improved and locally adapted farming systems have to be tested before application, agronomic field research incorporating existing institutions should be strongly intensified. Research should include i) small-scale and water-saving irrigation techniques, ii) horticulture (home gardening) concepts focusing on vegetables and fruit trees, iii) pest management even in post-harvest times, iv) use and improved production of manure and organic residues, v) application of pulses like cowpea with bacterial inoculant technology, vi) development of pest-resistant varieties, and vii) combined agro-forestry systems. For the implementation of test sites, cooperation with volunteering farmers from the local villages is recommended. The analysis of farming systems needs to relate the productivity of the fields to the inputs of labour and finances.

Traditional farming and conservation agriculture in comparison.

Disclaimer:
This Policy Brief is based on the joint research results obtained in the research project "The Future Okavango" funded by the German Federal Ministry of Education and Research under Grant No. 01 LL 0912. It is summarizing topic-specific key findings and recommendations; the comprehensive report ‚The Future Okavango – Findings, Scenarios, and Recommendations for action' is available for download on the TFO-website (www.future-okavango.org).

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The focus of the research project 'The Future Okavango' was on sustainable resource management in the Okavango Basin, comprising the adjacent regions of the Okavango River in Angola, Namibia, and Botswana. To enable in-depth analyses four local research sites have been selected representing wider areas and ecosystems within each country: Caiundo, Cusseque (Angola), Mashare (Namibia), and Seronga (Botswana).

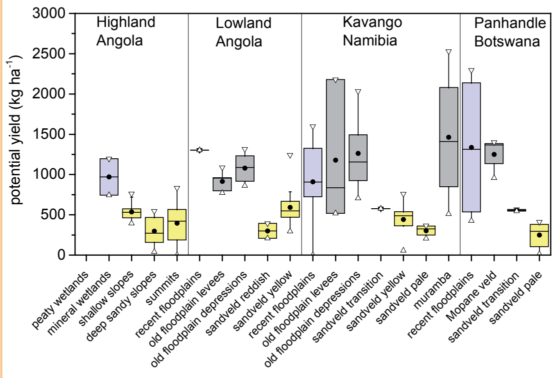
Current challenges

Smallholder subsistence forms of agriculture are the dominant farming systems in the Okavango Basin. They are currently on a pathway towards impoverishment and natural resource degradation.

Key Findings

Due to the sandy and humus-poor character of most soils, natural soil fertility is rather low, restricting potential yields to < 600 kg ha^{-1}. The yields are predominantly nitrogen-controlled

Analysis of soil fertility characteristics and estimation of potential yields revealed that the old floodplains in the central part of the catchment, the dry river beds in the Namibian Kavango regions, and the Mopane veld in North-West Botswana are the preferred landscape units for crop production. Here, based on the natural fertility, potential yields of 800 to 1,200 kg Maize ha^{-1} can be realized. However, these units cover only small parts of the landscape. The units with vast extension (slopes and summits in Angolan highlands and the Arenosol area of the Kalahari) exhibit only very low natural fertility with potential yields varying between 250 and 600 kg maize ha^{-1}. The estimation of the yield potential shows that especially nitrogen is deficient, and at some places also phosphorous. Modelling of soil water dynamics indicated a high proportion of unproductive water losses through evaporation on dryland fields. For details on the respective methodology, please refer to the Synthesis report "The Future Okavango – Findings, Scenarios, and recommendations for Action".



Potential yields (maize) for studied landscape units in the pristine state (left). blue: frequent flooded sites, cropping impossible; grey: preferred sites for agricultural usage; yellow: pure sand sites.

Dark colored soils with higher pH and organic carbon content (top left) and light-colored soils with low pH and carbon content (top right).

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Key Findings

Under current cropping systems, a decline in land availability leads to a depletion of soil fertility

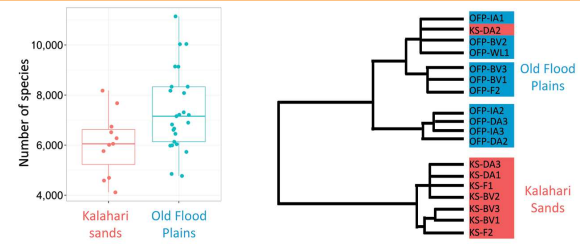
The current traditional cropping systems of shifting cultivation are fairly recent in the mid- and lower basin and were often established by migrants coming from the Northern part (Angola). They depend mainly on fallow as their prime fertility management measure and therefore, the fertility of soils depends directly on the availability of land. However, several factors limit the availability of land, mainly the rising rural population density, the limited availability of fertile soils, and the spatial expansion of cash cropping. Especially in the land-scarce mid-river areas of the basin (e. g. Mashare), farmers are increasingly forced to convert the areas of low soil fertility for crop production. If no additional fertility-management measures are introduced, widespread soil degradation in the form of nutrient losses will occur. Consequently, farmers are trapped in a cycle of poverty and resource degradation, and lack the knowledge and financial means necessary to break the degradation cycle. Thus, acute investment in agricultural knowledge systems adapted for these areas (e. g. conservation agriculture) is needed.

Slash-and-burn agriculture in Angola.

Typical view of a pearl millet field on deep Kalahari sands.

Active microbial communities mediate nutrient release and recovery potential

Soil microorganisms are the key players in the biochemical cycling of carbon, nitrogen, and phosphorus, as they directly affect the degradation of complex soil organic matter, and nutrient release from manure and crop residues: Microorganisms initialize the breakdown of soil organic matter by the secretion of exoenzymes, and mediate the release of ammonium and nitrate from complex nitrogen compounds by ammonification and nitrification. Therefore, nutrient recovery potential in soils is directly affiliated with the activity and population size of soil microbial communities.



Lower species number in nutrient-limited Kalahari sands.

Bacterial communities differ.

Influence of soil type on bacterial diversity in subtropical savannah soils.

High-throughput-sequencing, meta-genomics and multivariate statistical analysis identified representatives of the *Proteobacteria*, *Firmicutes*, *Acidobacteria* and *Actinobacteria* as key organisms of nutrient recovery processes. Especially, certain subdivisions of the phylum *Acidobacteria* and two species of *Aridibacter* have the potential to affect nutrient cycling.

Management of soil fertility in smallholder production systems

Key Findings

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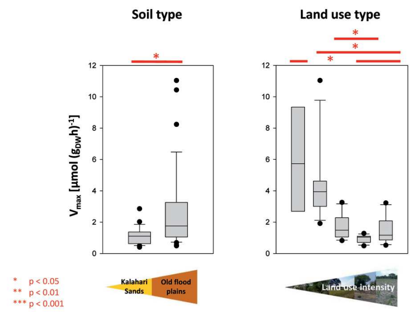
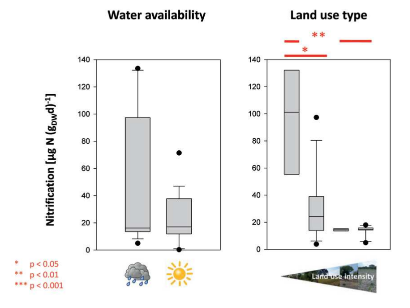
Fertilization and irrigation may counteract the negative effect of tilling on microbial activity and nutrient recovery

The conversion of pristine land to fields for crop production, and especially the frequent tilling, dramatically affects the soil microbial community and thus reduces soil fertility. On intensive used Kalahari sands the microorganisms are much less able to decompose organic matter or to transform nitrogen in a plant-available form than on the bushveld of old floodplains. To counteract the negative effect the addition of manure or crop residues and even a regular irrigation of the fields will improve the microbial activities and therefore soil fertility. Hence, conservation agriculture might support the sustainability of the soil fertility in small holder production systems.



Degradation potential of complex organic compounds in subtropical savannah soils: Comparison between soil types (left) and land use intensity (right).



Nitrogen transformation rates determined in Namibian soils.

Symbiotic nitrogen supply may be enhanced by inoculant application, which increases cowpea and bean yields

Specific bacteria that possess the enzyme nitrogenase are able to fix N_2 from the atmosphere into an utilizable form. Plants of the family *Fabaceaea* (e. g. cowpea, Bambara groundnut, peanuts, common bean) live in symbiosis with these microbes by forming root nodules that deliver nitrogen to the plant. The potential to improve the nitrogen supply by these microbes depends on the intensity of effective nodules. Unfortunately, nodulation with effective nodules was often found to be poor in the Namibian Kavango area and in Cusseque. Novel species of climate adapted symbiotic bacteria belonging mostly to the genus *Bradyrhizobium* have been characterized and deposited at the newly founded Namibian Type Culture Collection of Micro-organisms (NTCCM) centre at UNAM, Windhoek. Pilot field experiments showed 130 – 380 % increased bean yield with rhizobial inoculant in phosphate-fertilized plots in comparison to plants not treated with phosphorous or bacteria.

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