The **UNDESERT** project

– from research to action for combating desertification and land degradation in West Africa

Anne Mette Lykke, Karen Hahn, Marco Schmidt, Jørgen Axelsen, Adjima Thiombiano, Yvonne Bachmann and Willie McGhee

Leader of the women's group in Senegal with her newly planted and protected *Tamarindus indica* tree (photo by Anne Mette Lykke).

AARHUS UNIVERSITY
DEPARTMENT OF BIOSCIENCE

undesert

Introduction

Desertification and land degradation occur in arid, semi-arid and dry sub-humid areas and are driven by climatic variations as well as human activity. The result can be degradation of soil and vegetation over billions of hectares of rangeland and cropland (Figure 1). West Africa is a key region to understand these processes driving severe and widespread desertification and land degradation resulting from climate change and human activities.

The UNDESERT project (undesert.neri.dk), an EU-FP7 funded initiative, aimed to provide researchers, policy makers and local people greater insight into desertification and land degradation processes, and their impact on ecosystems and local communities in West Africa. Nine partners from the EU and West Africa worked to investigate the effects of desertification and desertification and to transfer their results into practice. The research approach covered a broad range of biodiversity and environmental factors, however, plant diversity and vegetation and their changes played a major role, because plants and vegetation type best integrate the different environmental changes and impacts over a period of time. The identification of indicator plants provides an easy to communicate criteria for identification and assessment of desertification land degradation.

UNDESERT partners worked in partnership with local people, who observed vegetation changes closely, to learn from their traditional knowledge and to improve practices of managing land in arid environments. UNDESERT also introduced new techniques to restoring ecosystems with communities by planting and regenerating trees, woodland and forests, in part for Payments for Ecosystem Services (PES), specifically carbon sequestration.

UNDESERT also developed an online data platform and decision support tools for natural resource managers, which give easy access to scientific results. Partnerships with local people and natural resource managers were seen as an essential ingredient of this project and the online platform and tools were specifically aimed to provide local benefits from research activities.

UNDESERT was conducted under the thematic area of desertification and land degradation, and as such it has potential relevance to other areas of concern especially food security, biodiversity and poverty reduction.

As the UNDESERT project was multidisciplinary and consisted of both scientific research, including 17 PhD projects, management practices and establishment of an online platform and tools for policy makers and managers, it is not possible to cover all aspects in one publication, but some examples of results and management practices are presented here. More details can be found in eighty already published articles, with more to come this and the next years, and in the PhD reports.

Figure 1. Highly degraded land, called *bowé* in West Africa (photo by Elie Padonou).

Examples of achievements of the project

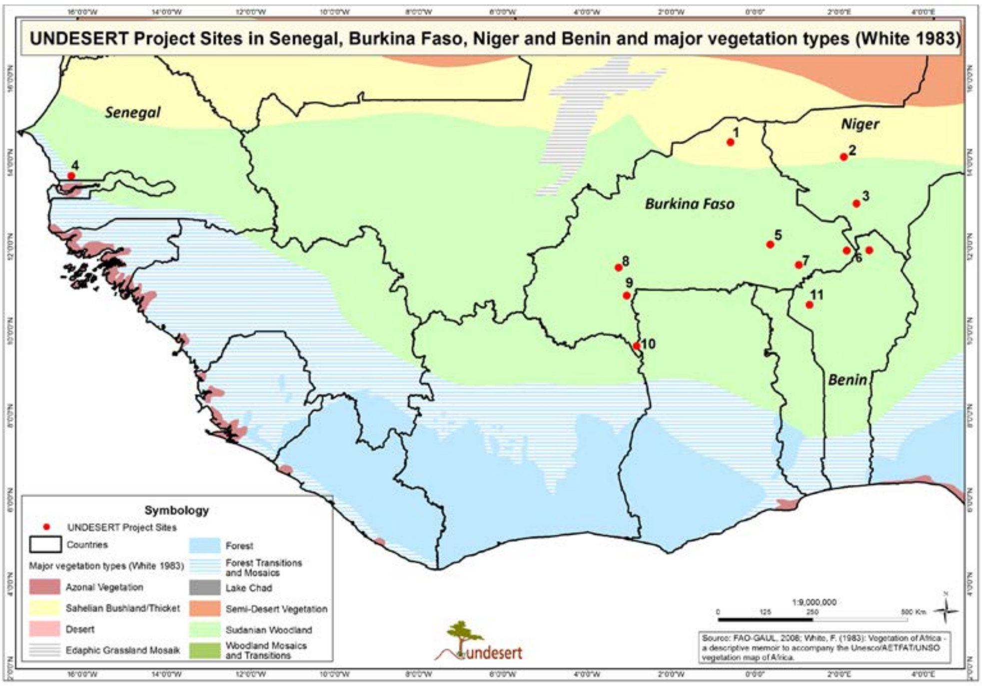


Figure 2. Map of the study region, West Africa, with UNDESERT study sites indicated.

Desertification and degradation processes

UNDESERT aimed at increasing the understanding of how desertification and degradation processes affect biodiversity, soil and human livelihoods in West Africa and at proposing possible mitigation actions. To achieve this, scientific research and management actions were conducted across a climatic and land use gradient from the Sahelian to the Sudanian zone (Figure 2).

As desertification and land degradation are complex processes with various courses, forms and consequences, a compilation of a set of easy to measure and cost-effective desertification and degradation indicators was prepared (Table 1). The eight spatial indicators cover land cover/use change, vegetation indices, human density and fire. The 27 plot-based indicators cover two thematic classes; vegetation/biodiversity and soil/topography. The application of indicators enables improved understanding of the complex relationships between plant distribution, diversity patterns and driving factors such as climate and land use.

Causes and consequences of desertification and degradation processes on vegetation and soils in West African drylands were assessed on various scales. In many cases land use was the main driving factor, especially in the Sudanian zone, but models predict climate to have impact too in the future. Climate change and human impact reinforce each other, and both are important drivers.

Table 1. UNDESERT List of Desertification and Degradation Indicators.

Spatial indicators
• Absolute/percentage land cover and land use change
• Normalized Difference Vegetation Index (NDVI)
• Enhanced Vegetation Index (EVI)
• Population density
• Distance to nearest village
• Land use type
• Fire frequency
• Fire density
Plot-based indicators
• Plant species richness
• Abundance
• Height
• Number of stems
• Number of branches
• Diameter at breast height (DBH)
• Crown diameter
• Life forms index of vegetation disturbance
• Canopy cover
• Ground cover
• Chorological index of vegetation disturbance
• Dispersal types index of vegetation disturbance
• Grazing intensity
• Electrical conductivity (EC) of soils
• Soil organic matter (SOM)
• Extractable phosphorus of soils
• Silt content
• Soil total nitrogen (soil total N)
• Exchangeable potassium in soils
• Soil humidity
• Extent of organic layer
• Compaction of topsoil
• Color of top soil layer
• Occurrence of sheet erosion
• Rill mean cover
• Topographic position
• Slope angle

Species distribution models

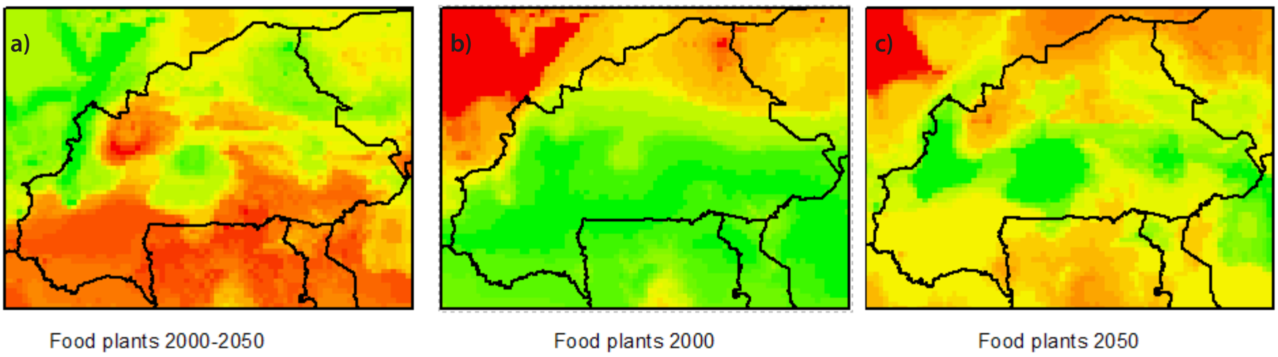
Species distribution models for various species based on the current climate and land use have been compared with the ones for future climate and future land use based on predictions in order to identify and understand future challenges in West Africa. Examples of species models are here summed up in groups of species with different socioeconomic and ecological characteristics. Some examples from Burkina Faso are presented here.

Food plants

After summing up the models of 24 food plants, food plant diversity per pixel ranged between 0 and 24 in 2000 and 2050. In 2000 the highest food species richness was in central and southern Burkina Faso (22-24 species) (dark green areas) (Figure 3b), the lowest in the province of Oudalan in the Sahel (0-15 species) (red and orange) (Figure 3b). By 2050 only central Burkina Faso was predicted to still present comparable high food species richness numbers to the ones in 2000 (Figure 3c). The severest food species richness loss is predicted for southern Burkina Faso and species gains were predicted for some central and Sahel areas (dark green areas) (Figure 3a). This was mainly due to climatic changes scenarios which predict increasing precipitation in some central and Sahelian areas of Burkina Faso.

Trees and shrubs

Trees and shrubs are most diverse in the Sudanian zone as shown in Figure 4b. Between 180 and 298 trees and shrubs were summed up per pixel in the Sudanian zone for 2000. In the Sahelian zone it ranged between 0 and 100 species per pixel (Figure 4b). By 2050 trees and shrubs species richness will be highest in the center-west (Figure 4c). The severest trees and shrubs species richness loss is predicted for southern Burkina Faso (Figure 4a) with 151 species per pixel.



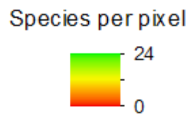
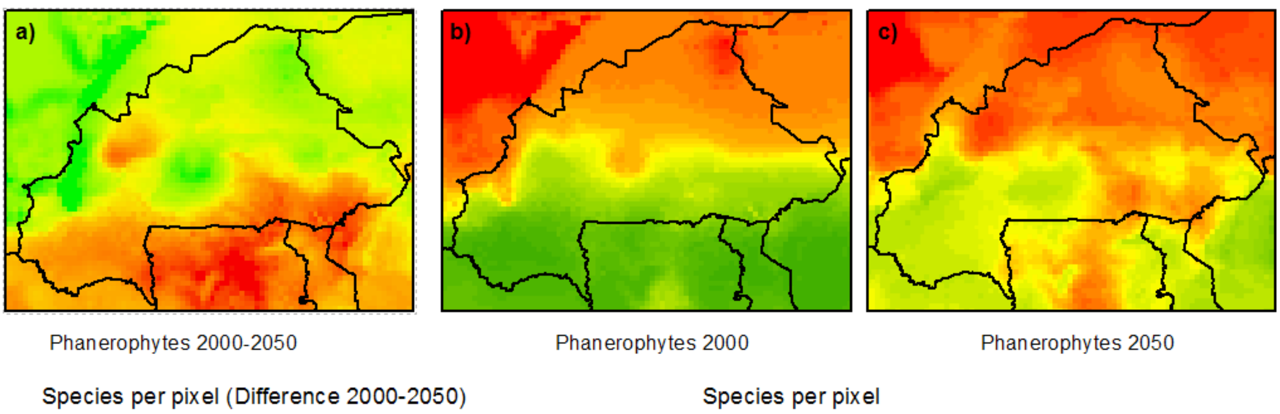


Figure 3. Food plant distribution between 2000 and 2050;
(a) difference, (b) current and (c) future potential spatial distribution.



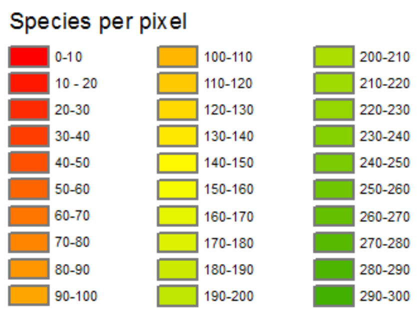


Figure 4. Trees and shrubs between 2000 and2050;
(a) difference, (b) current and (c) future potential spatial distribution.

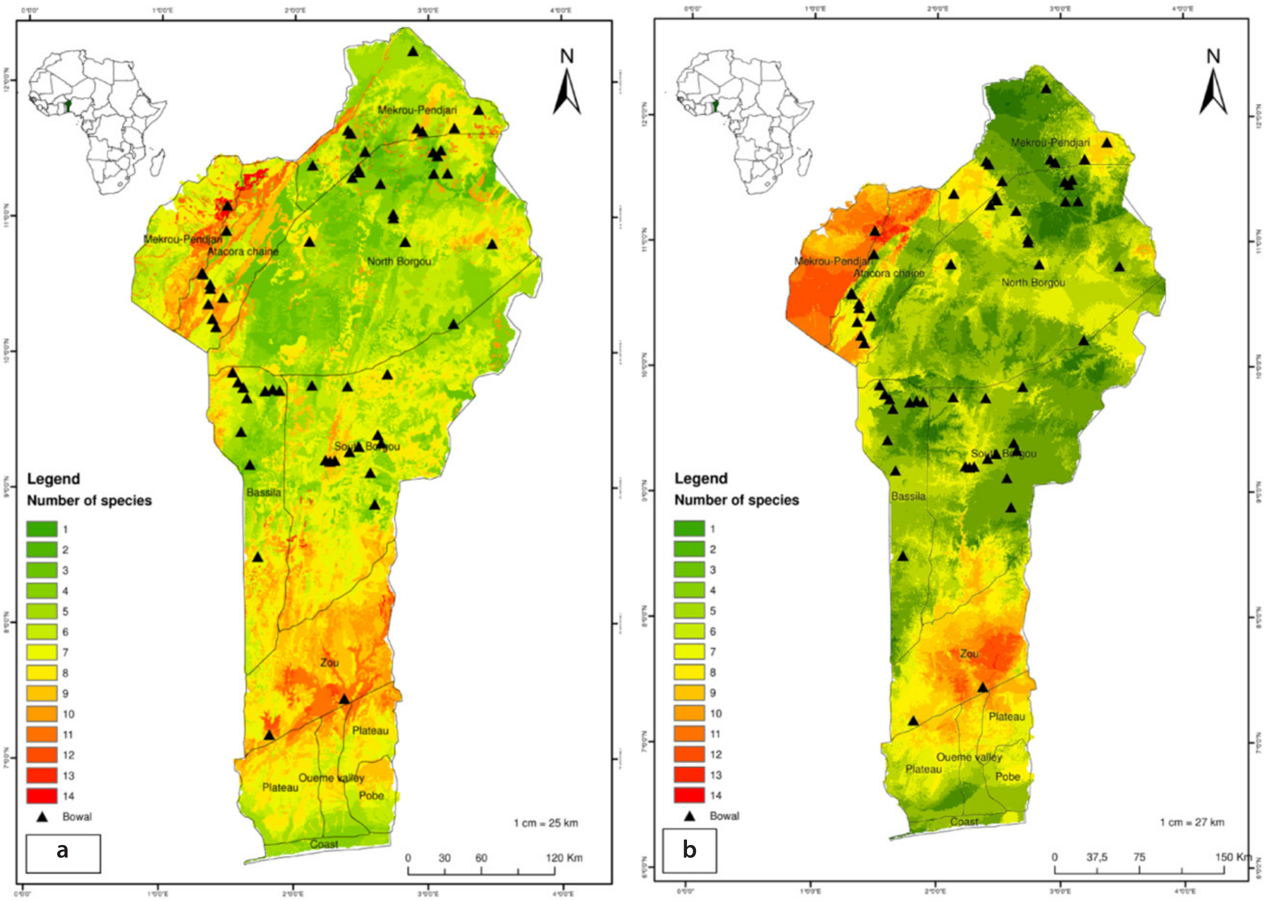


Figure 5. Species distribution maps with (a) current and (b) predicted future distribution of the resilient species that today are adapted to degraded lands, *bowé*.

The results show that West Africa might undergo serious changes within the next decades, and it is of importance to consider these potential changes when planning management practices and natural resource policy actions. In West Africa where the climate zones run in parallel bands, climate change scenarios predict considerable changes for 2050 indicating shifts of these parallel bands. Based on these scenarios the modeling results from UNDESERT show that the West African vegetation might undergo serious changes within the next decades.

Climate change predictions suggest that the Sudanian zone will face high species losses while the center of Burkina Faso was less affected. However, in Senegal the climate change predictions are more widespread as the precipitation is predicted to decline more along the west coast of Africa than in the central parts. The climate predictions for West Africa are still highly unpredictable as they vary from year to year and among predictions.

Species that potentially will increase in the future are the resilient species that today grow in highly degraded land type called bowé. Species distribution models for such species based on the current climate and land use have been compared with the ones for future climate and future land use base on predictions in Benin, which shows that in some areas, particularly in the north-west and in the center resilient species are predicted to increase and thereby replace other species (Figure 5). It is important to consider the socio-economic value of species and not only species numbers in order to understand the impact of future changes on local livelihoods.

Socio-economic values of wild plants

UNDESERT assessed the socio-economic value of wild plants in Senegal, Burkina Faso and Niger. Detailed local knowledge and appreciation of more than 50 of the most useful plant species in each country was assessed using various forms of interviews such as open-ended group interviews and highly structured questionnaires with over 100 informants in each country. The economic value of traditionally used plant species has often been underestimated, although local people have a detailed and profound knowledge and high appreciation for the use of wild plants for food, medicine, construction, firewood and in some cases also spiritual purposes. Local people provide a multitude of information of which a few examples are presented here.

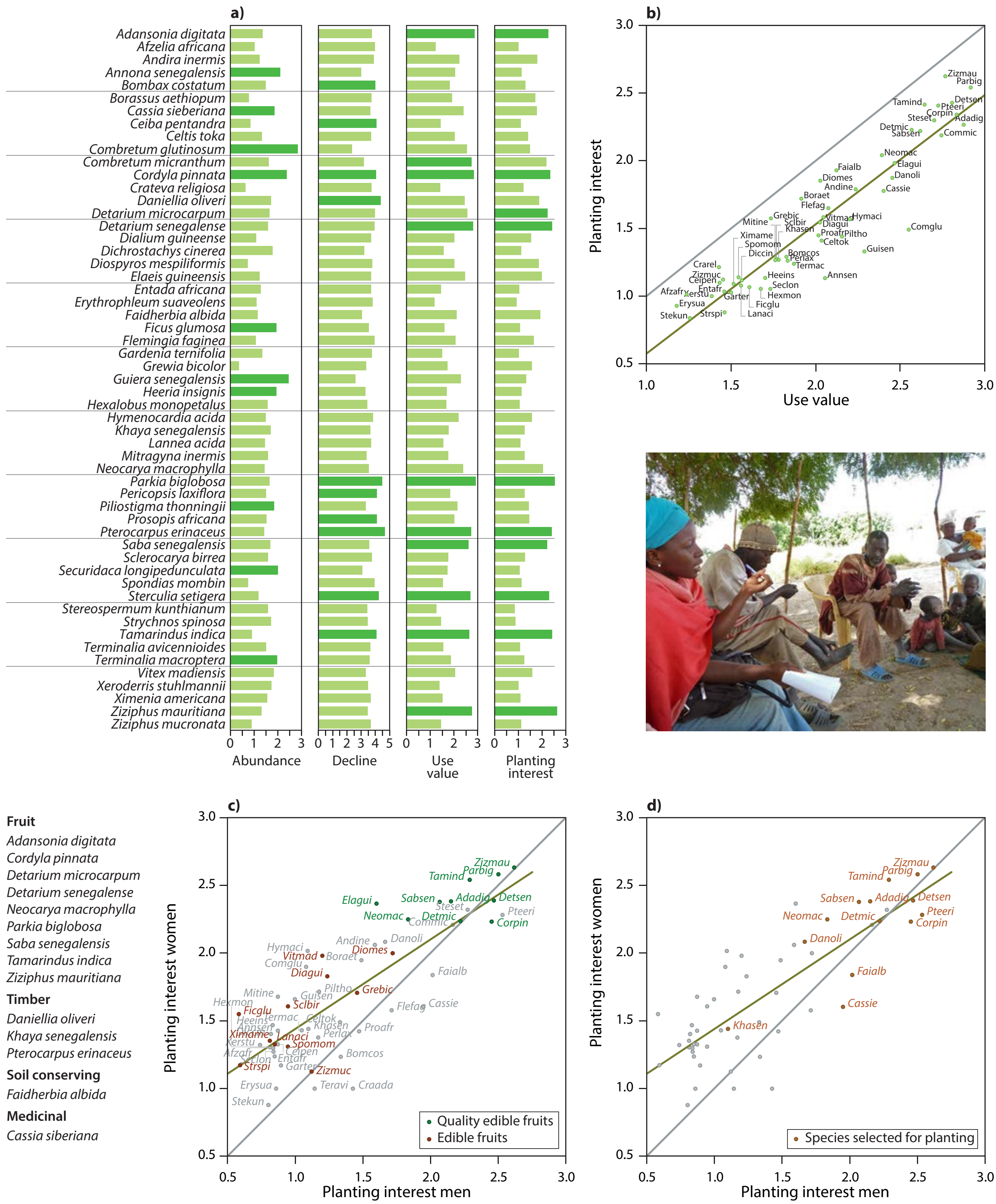


Figure 6. Interviews with local people were conducted on species level. **a)** Average ranking of abundance, decline, use value and planting interest for 55 species based on 120 interviews from Senegal. The higher the value on the x-axis the higher the abundance, decline, use value and planting interest. **b)** Correlation between use value and planting interest, the most useful species are also of highest planting interest. **c)** Correlation between ranking of planting interest by men and women, quality fruit trees are of highest interest for both men and women. **d)** Tree species selected for planting in Senegal (shown in orange colour) are of high local use value and planting interest.

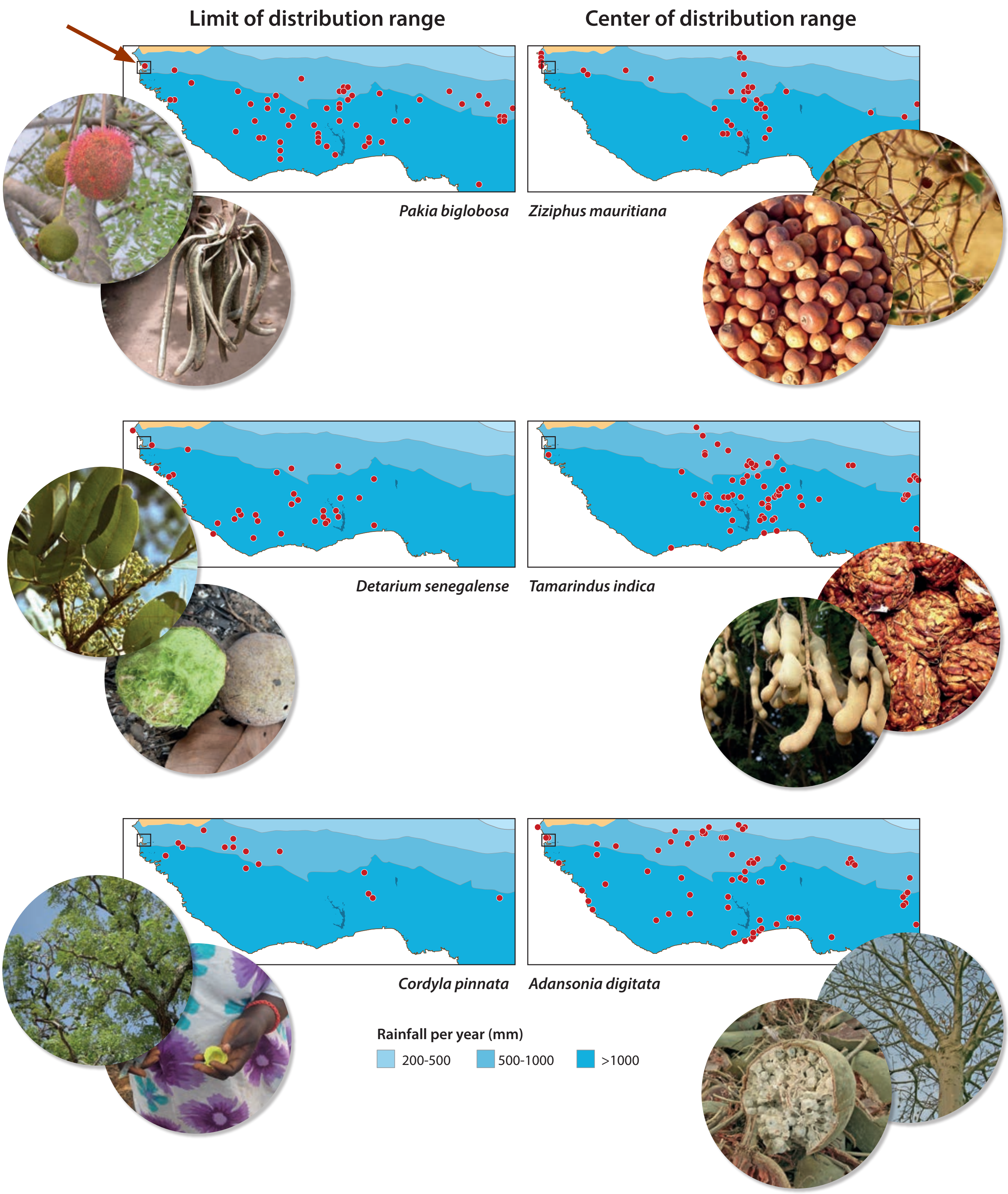


Figure 7. Distribution range (based on GBIF data) of species selected for planting by local people. Species of high local use value and planting interest are often species growing at the dry end of the distribution range. These species will be affected by future climate change, whereas species in the center or humid end of the distribution range will be a safer species choice in regards to persistence under climate change, but are often of lower value.

Local people have good knowledge about abundance, decline and use value of each tree species and clear preference for which species to plant (Figure 6a).

Most species are considered declining to some extent (only a few pioneer species, regenerating in agricultural fields, are not declining). The medium to relatively abundant species are considered most declining and notably many of the highly appreciated species were declining.

Questionnaires on planting interest ensured planting of the most useful species during tree planting activities. The most useful species were also of highest planting interest (Figure 6b) and there was a significant correlation between ranking of planting interest by men and women. Quality fruit trees were of highest interest for both men and women (Figure 6c).

The socio-economic values of a large number of plant species were estimated and several of the most important trees, fx *Parkia biglobosa*, appeared to hold out prospects for economic development if planted in larger extent.

Tree species selected for planting in Senegal were in most cases those of high local use value and planting interest (Figure 6d). Among the tree species finally selected for planting in the Sudanian zone were many fruit trees, eg *Parkia biglobosa, Adansonia digitata, Cordyla pinnata, Detarium senegalense, Tamarindus indica, Ziziphus mauritiana, Detarium microcarpum, Saba senegalensis* and *Neocarya macrophylla*.

The results from Senegal, Burkina Faso and Niger pointed in the same direction. A number of highly appreciated species are undoubtedly declining according to local people. Many valuable wild plants are being lost across the Sahel, for instance in the Niger site, 37 species have become extinct and 68 species are under threat according to local people. Local perceptions of species decline were confirmed by checking current and historic (20 years ago) botanical inventories.

Analysis of selected economically important plant species showed a declining trend for a number of species. One example is *Lannea microcarpa,* a tree with edible fruits and medicinal properties. UNDESERT studies concluded that low-intensity human impact is beneficial for *L. microcarpa* populations, as local users protect this economically important species, whereas in densely populated area, intensive use affects plant populations negatively. This pattern seems typical for quite a number of economically important tree species. Therefore it is often not necessary to prohibit exploitation, but management systems with restricted and sustainable use is indispensable.

Local knowledge ensures high focus on food security and subsistence income and thereby poverty alleviation under the present climate. This is not the case under a dryer climate, however, as most of the tree species preferred by local people presently grow at the dry end of the distribution range (Figure 7). Rural people therefore need advice in order to plant tree species that ensure resistance under future climate change.

We can conclude that a local knowledge based evaluation of species needs in the local area is a very good basis for tree planting projects, practical conservation and sustainable use measures. Local knowledge, however, needs to be supplemented with scientific know-how to ensure sustainable solutions under climate change and also solutions for land use planning in densely populated areas.

Simulation models

Simulation models have been developed to make simulations for the phytogeographical zones Sahel to Sudan in Niger, Benin, Burkina Faso, and Senegal. The models can be used as a basis for management. The models simulate plant/tree growth and human utilization of the species, and model scenarios are tools for finding the optimal or sustainable utilization, thereby addressing the objectives of finding best practices and prevent degradations. The models can simulate selected grasses and trees and provide detailed simulation of roots, trunks, leaves, buds, flowers and fruits. The models can predict how often and how much a species can be exploited to maintain its capacity to grow well, that is to define which are sustainable levels of exploitation for individual species.

The models can simulate the impact of climate change based on ICPP-projections in the years 2025, 2050, 2075 and 2100. One example of the use of simulation modelling was an investigation of seedling productivity of the rare and declining medicinal climbing shrub *Caesalpinia bonduc* in Benin (Figure 8). The model provided an optimal utilization scenario, suggesting how often and how much of a tree part can be harvested.

The models were furthermore equipped with a socio-economic output facility, e.g. by converting biomass of removed grasses (at various grazing pressures) to growth in tropical livestock units (TLUs) and the monetary value of these TLUs. Another example was scenarios of the optimal grazing intensity expressed as the percentage of plant biomass that can be removed by the animals (Figure 9).

When modelling trees the amount of removed firewood were given in biomass, monetary value of firewood and charcoal, and in the number of persons sustained annually by firewood or charcoal.

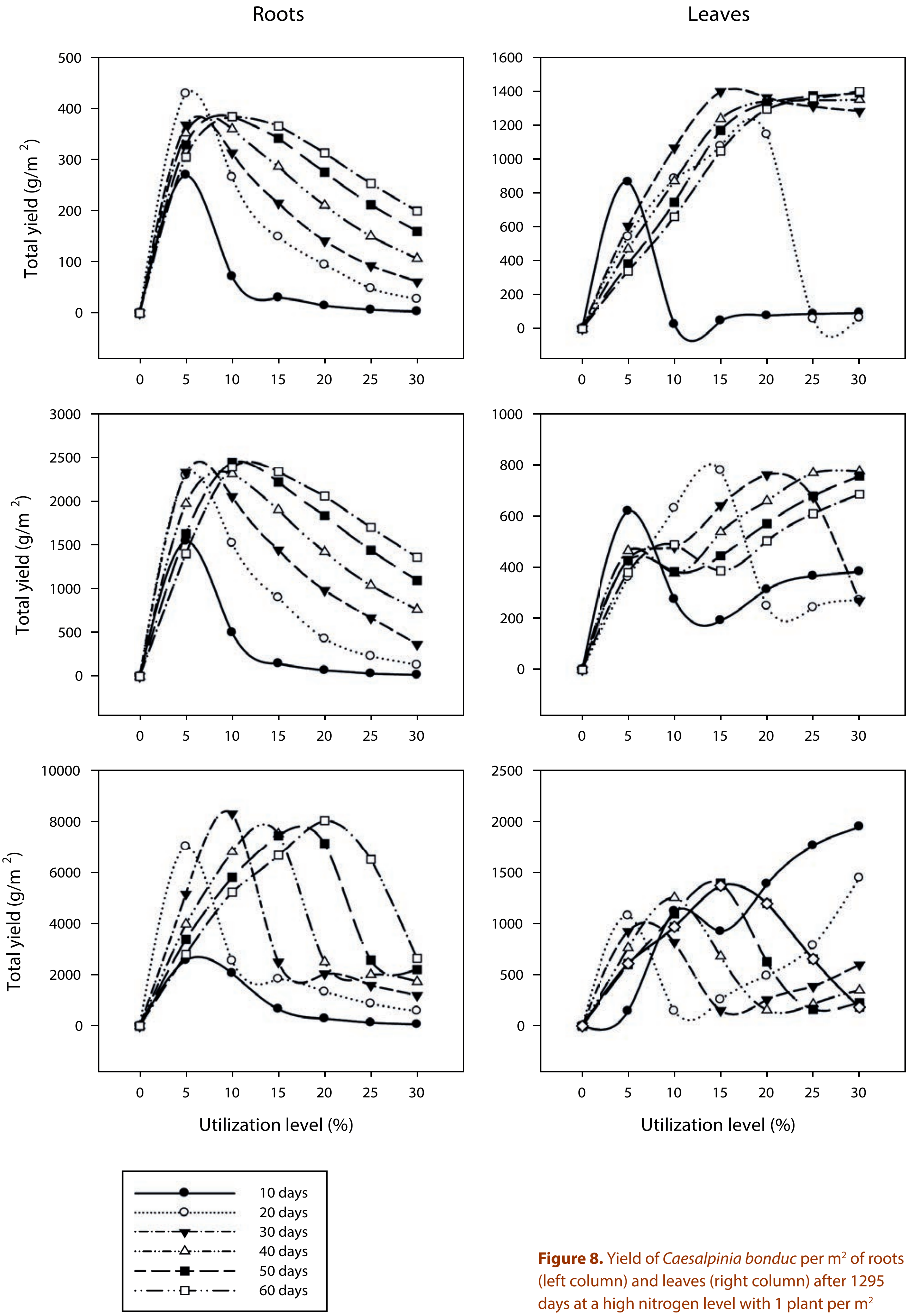


Figure 8. Yield of *Caesalpinia bonduc* per m² of roots (left column) and leaves (right column) after 1295 days at a high nitrogen level with 1 plant per m² (upper row), 5 plants per m² (mid row) and 25 plants per m² (bottom row).

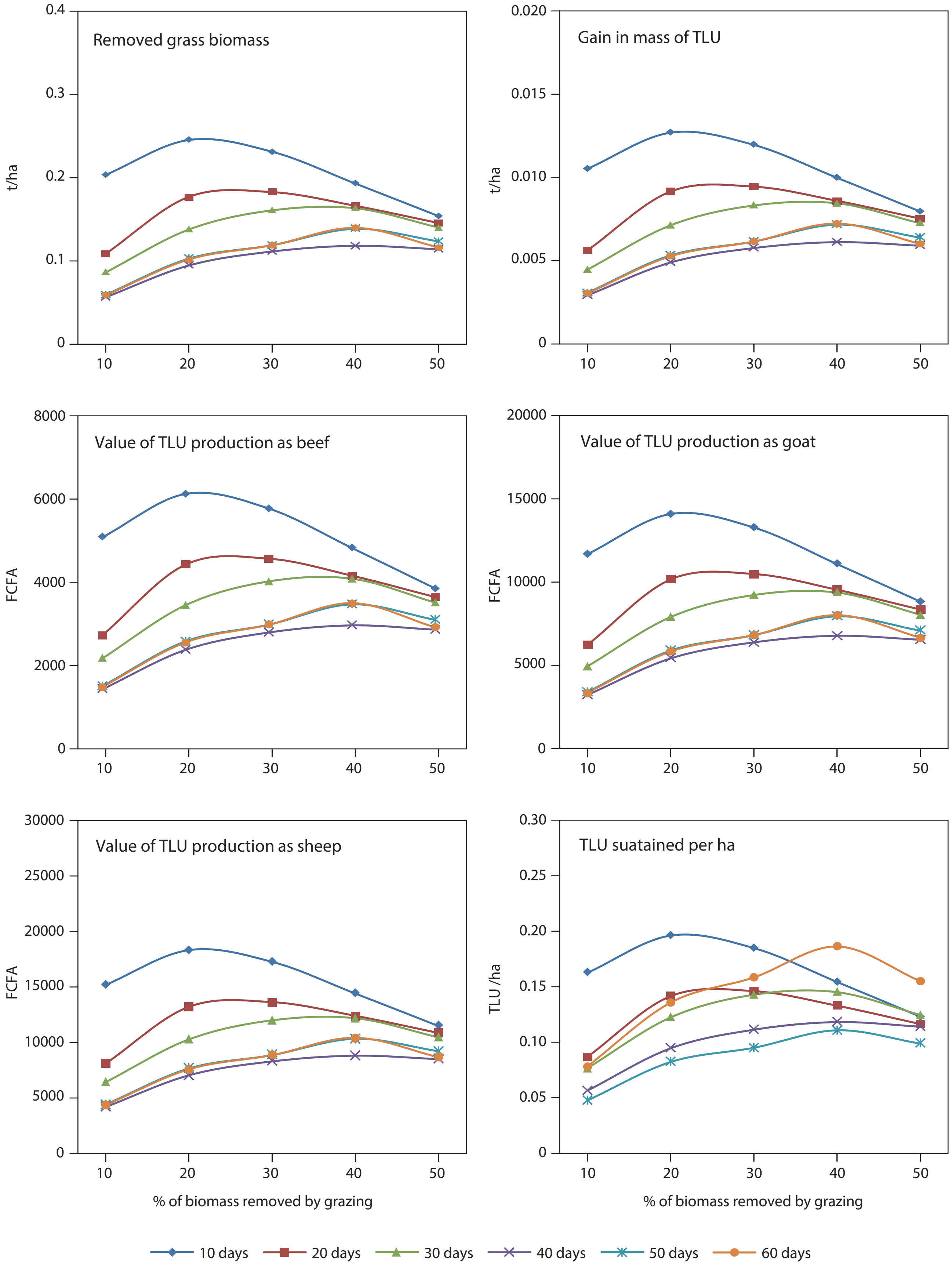


Figure 9. Scenario on grazing intensity measured as % biomass removed at 10 to 60 days intervals. The scenario was made using weather data from the northern Sahel zone of Senegal. The monetary value is expressed in FCFA, the local currency.

Soil

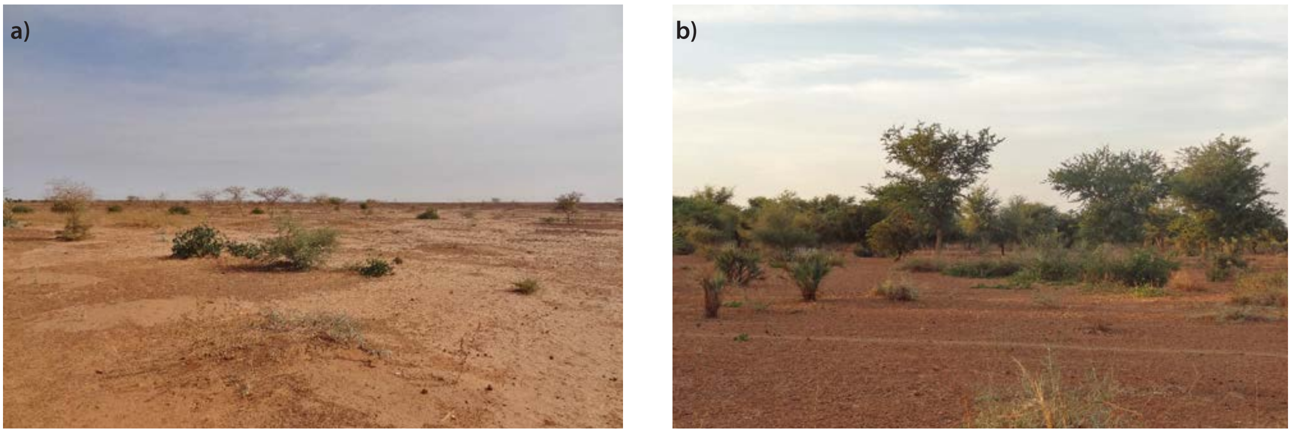


Figure 10. Soil types; (a) degraded and (b) undegraded (photo by Moussa Boubacar).

Land degradation can have long lasting effects if it affects the soil. Land degradation is manifested by a decrease in biological activity, organic matter and nitrogen content as well as by compaction of soil particles (figure 10). The physical and chemical soil characteristics were analyzed in order to develop tools for assessment (indicators) of desertification and degradation and to assist managers in their efforts to mitigate impact on biodiversity and ecosystem services. The soil physico-chemical measurements were related to degradation levels; low values of the commonly known fertility indicators carbon, nitrogen, silt, clay, CEC, available potassium and soil organic carbon (SOC) can be used as indicators of degradation, while high values generally are found in un-degraded areas. The suggested indicators of degradation are useful for managers and they only require standard analyses of soil samples that can be made at laboratories in West Africa.

The results of the soil sampling resulted in a hypothesis, that the quotient SOC/(silt+clay) can be used as a degradation indicator. The reasoning behind this indicator is that the silt+clay content defines the potential fertility of a soil, and the SOC content defines to which extend this potential fertility is achieved. This is recommended to make some more tests on the usefulness of this indicator.

In order to monitor changes in restoration areas, annually measured soil physico-chemical parameters from restoration areas were analyzed in relation to the tree species planted and restoration techniques. The results show that an improvement of the soil physico-chemical characteristics was obtained for restoration techniques carried out in both the semi-arid zone of the Sahel and the more humid Sudanian zone. Thus, in the Sahel area restoration by planting of *Guiera senegalensis* and *Acacia seyal* significantly increased soil chemical fertility parameters such as carbon, nitrogen and pH over three years, and in the Sudanian zone stone lines with *Piliostigma thonningii* planting improved the soil fertility significantly.

Model scenarios of soil development and degradation were made in collaboration with the EU-financed project SoilTrEC, which developed a simulation program CAST that is capable of simulating the development in soil carbon and water stable aggregates based on weather and input of organic carbon such as mulch layers. Soil carbon content and water stable aggregates are very important for the soil fertility. The soil physico-chemical measurements from the restoration areas were supplemented with analyses of the content of water stable aggregates and the carbon content of these aggregates and the data from these analyses were used to calibrate the CAST model to simulate soil processes under Sahelian and Sudanian conditions. The simulation results support that stone lines with planting of *P. thonningii* can relatively quickly reduce the degradation level measured in terms of the SOC/(silt+clay) degradation parameter. Furthermore, the CAST model showed that returning the straw from millet as a mulch layer instead of removing it can also reduce the degradation.

Concrete actions on the ground

Desertification and degradation processes are caused by a mixture of climate change and land use factors. In many cases land use is the main factor and so actions can be conducted to restore and reforest the decertified and degraded land.

Tree planting

Restoration measures took place as part of the UNDESRT project using several restoration techniques, such as half-moon, stone line, zaï, agricultural benches and standard plantation, in combination with planting of several species in order to restore degraded lands in Sahel and Sudan areas of West Africa (Figure 11; Figure 12).

The choice of restoration techniques depends on the local environmental conditions (such as soil, topography and climate) and the phytogeographical zone. At the end of the experiments conducted in Burkina Faso, Niger and Senegal, the techniques of half-moons and agricultural benches were found to be the best performing techniques due to their capacity to improve water infiltration, moisture maintenance and soil fertility and thereby improve survival, growth and biomass production of the planted seedlings (Table 2).

Table 2. Recommendations for restoration methods based on experimentation in different phytogeographical zones.

Zone	Method
Sahelian zone (annual rainfall average 600-400 mm)	Half-moon
Northern Sudanian zone (annual rainfall average 600-800 mm)	Half-moon Stone line Agricultural benches
Southern Sudanian zone (annual rainfall average >800 mm)	Stone line

Recommendations for species

Afforestation of bare soils and degraded lands requires a selection of suitable species that present relevant ecosystem services for local communities and at the same time are resistant to the local climate and to future climate.

Based on species performance indicators in plantations (survival rate, growth, adaptation to water stress), socio-economic value (provisioning, regulating, supporting and cultural), biodiversity, including woody species (C3 photosynthetic type), grasses (C4 photosynthetic type) and species with nitrogen fixation (legumes) a number of species are highly recommended for successful restoration of degraded lands (Table 3; Figure 13).

Recommendations depend on soil type, topography and climate, but the results have shown methods with larger holes for the planting of trees, like half-moon and agricultural benches, gave better results than the traditionally used methods with smaller holes, like zaï, and standard plantation. A number of technical manuals describing restoration techniques and recommended species have been prepared as part of the UNDESERT project and the concrete tree planting activities in the field with local communities have widened the eyes of local communities for various new opportunities.

Figure 11 (below). Illustration of plantation techniques.

Figure 12 (right). Plantation areas with tests of different restoration methods. **a)** Before plantation; **b)** After plantation (photos by Philippe Bayen, Abdou Amani, Jerome Yameogo).

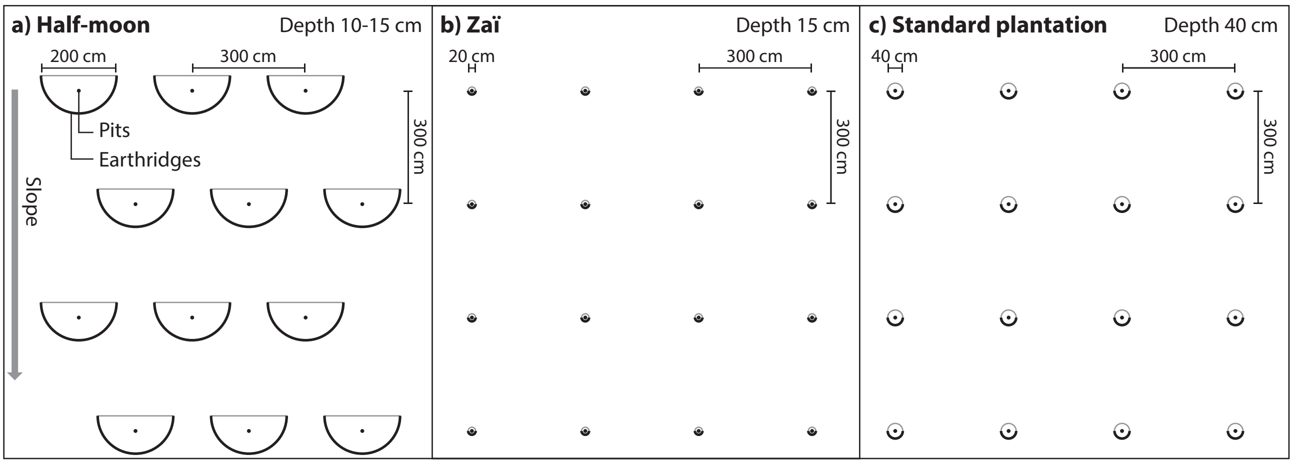
1ab) Half-moon in the northern Sudanian zone of Burkina Faso.

2ab) Zaï in the northern Sudanian zone of Burkina Faso.

3ab) Standard plantation in the northern Sudanian zone of Burkina Faso.

4ab) Agricultural benches in the Sahel of Niger.

5ab) Stone lines in the southern zone of Burkina Faso.




1a) Half-moon


1b)


2a) Zaï


2b)


3a) Standard plantation


3b)


4a) Agricultural benches


4b)


5a) Stone line


5b)

Table 3. Recommendations for species selection in different phytogeographical zones based on restoration experiments in Niger and Burkina Faso.

Zone	Woody species	Perennial grass species	Annual grass species	Herbaceous legumes rich in nitrogen
Sahelian zone (annual rainfall average 600-400 mm):	*Acacia tortilis* *Acacia nilotica* *Guiera senegalensis* *Combretum micranthum* *Combretum glutinosum*	*Cymbopogon schoenanthus* *Androgon gayanus*	*Schoenefeldia gracilis* *Brachiaria lata* *Panicum laetum*	*Alysicarpus ovalifolius* *Zornia glochidiata*
Northern Sudanian zone (annual rainfall average 600-800 mm)	*Acacia gourmaensis* *Acacia dudgeoni* *Sterculia setigera* *Combretum glutinosum* *Combretum micranthum* *Combretum nigricans*	*Cymbopogon schoenanthus* *Andropogon gayanus* *Sporobolis pyramidalis*	*Schoenefeldia gracilis* *Brachiaria lata* *Panicum laetum*	*Alysicarpus ovalifolius* *Zornia glochidiata* *Tephrosia pedicellata*
Southern sudanian zone (annual rainfall average >800 mm)	*Piliostigma thonningii,* *Faidherbia albida,* *Parkia biglobosa*	*Andropogon gayanus* *Schizachyrium sanguineum*	*Pennisetum pedicellatum* *Andropogon fastigiatus*	*Alysicarpus ovalifolius* *Zornia glochidiata*

Figure 13. Plantation of *Combretum glutinosum* in the Sahel of Niger, a species found to perform well in plantations and models shows that it will be well adapted to a possible drier future climate (photo by Abdou Amani).

Payments for Ecosystem Services

One of the major tree planting activities took place in Senegal; a Payments for Ecosystem Services (PES) project that focused on restoring trees around a handful of villages in the Patako region of Senegal. This work took place in a matrix of largely denuded and productively declining agricultural land, mostly growing ground nut cash crops. It was centred on the Patako Forest Reserve, an area of forest gradually being incorporated into agricultural land and degraded through firewood collection and fires.

The Patako carbon PES project has worked with local communities and district authorities to provide women's groups with access to land ownership and women have proven to be successful at establishing trees, employing a mix of new planting and natural regeneration techniques. The collaboration included several village meetings (Figure 14a) and tree planting activities in the field (Figure 14b). The project also established tree nurseries to supply plantations (Figure 14c).

One of the key lessons to come out of the Patako carbon PES project was establishing the baseline social economic context of local people, and how they use their landscape. This is a critical component for developing PES projects and it provided an understanding of the drivers of forest degradation (important in any REDD or PES project) and allowed the project to identify what is possible and feasible in respect of changing land management behaviour.

Much of the forest degradation in Patako forest was a result of land use; land around most villages is largely treeless. As it is women's responsibility to harvest firewood for domestic use (cooking), the UNDESERT project determined that if local women were given control of land, something they have been unable to do until the UNDESERT project, and they were assisted in establishing quick growing, native trees for a woodlot (by natural regeneration or planting), the pressure for firewood collection in neighbouring natural forest would decrease. Not only were women were more motivated in respect of creating new woodland, but they were more successful in establishing trees on previously agricultural/degraded land than men.

The relationship between a local community and the payments element of a PES project is central to the sustainability of this kind of project. In Patako, payments were distributed as materials in order to avoid conflict, and to provide women with the wherewithal to develop small scale enterprises, without a requirement for cash to pass

Figure 14.

a) Village meeting in Senegal for informing about carbon forestry (photo by Anne Mette Lykke).

b) Tree planting by local women for Payments for Ecosystem Services (PES) project in Senegal (photo by Fatimata Niang-Diop).

c) Caretaking in tree nursery established as part of Payments for Ecosystem Services (PES) project in Senegal (photo by Anne Mette Lykke).

d) Fieldwork for estimation of biomass and carbon sequestration potential of *Combretum nigricans* in the Sahel of Niger (photo by Abdou Amani).

through committees dominated by village elders or chiefs. This is a valuable learning and one applicable to REDD or PES projects across the region. Women in Patako chose to invest in small flour mills, which produce cash from sales, and can be managed cooperatively by women's groups, thus avoiding or reducing elite capture of project resources. They also provide micro credits to members and buy small goods, like chairs, which can be rented out for gatherings and celebrations in the villages. A you-tube video about the project is online (https://www.youtube.com/watch?v=e0gpzL61ZBc).

UNDESERT worked on various methods of establishing trees in Burkina Faso, Niger and Senegal and research has also focused on calculating biomass and carbon stocks of local tree species in order to gain main information about how much carbon a plantation can sequester. The biomass measures, that provide basis data for carbon models, are highly labour demanding and only few have been conducted in West Africa before (Figure 14d). Such measures were used to calculate payment of carbon credits from certified tree planting projects. The work to gather empirical data on tree biomass from different phytogeographical zones in Burkina Faso, Senegal and Niger formed basis for the calculation of a equations that have broadening the knowledge base on carbon sequestration by West African species.

The process of merging academic researchers and practical project work has proven to be a valuable lesson learning experience and has provided pointers for new ecosystem services type projects in West Africa, including REDD+ projects. The project has attracted the attention of a Swedish climate change brokerage firm who are keen to purchase carbon credits from communities in Patako, Senegal.

Decision support for natural resource management and policy making

Besides of highly practical tree planting actions conducted directly with local communities, a contact to natural resource managers is also important to extend the activities to a wider range of areas. Contacts were taken to natural resource managers and politicians in the involved countries and online data portals and decision support tools have been developed to ease the access to scientific data.

Online data portal

The UNDESERT's data portal for biodiversity provides a data exchange mechanism between research and applied use. It is composed of three modules:

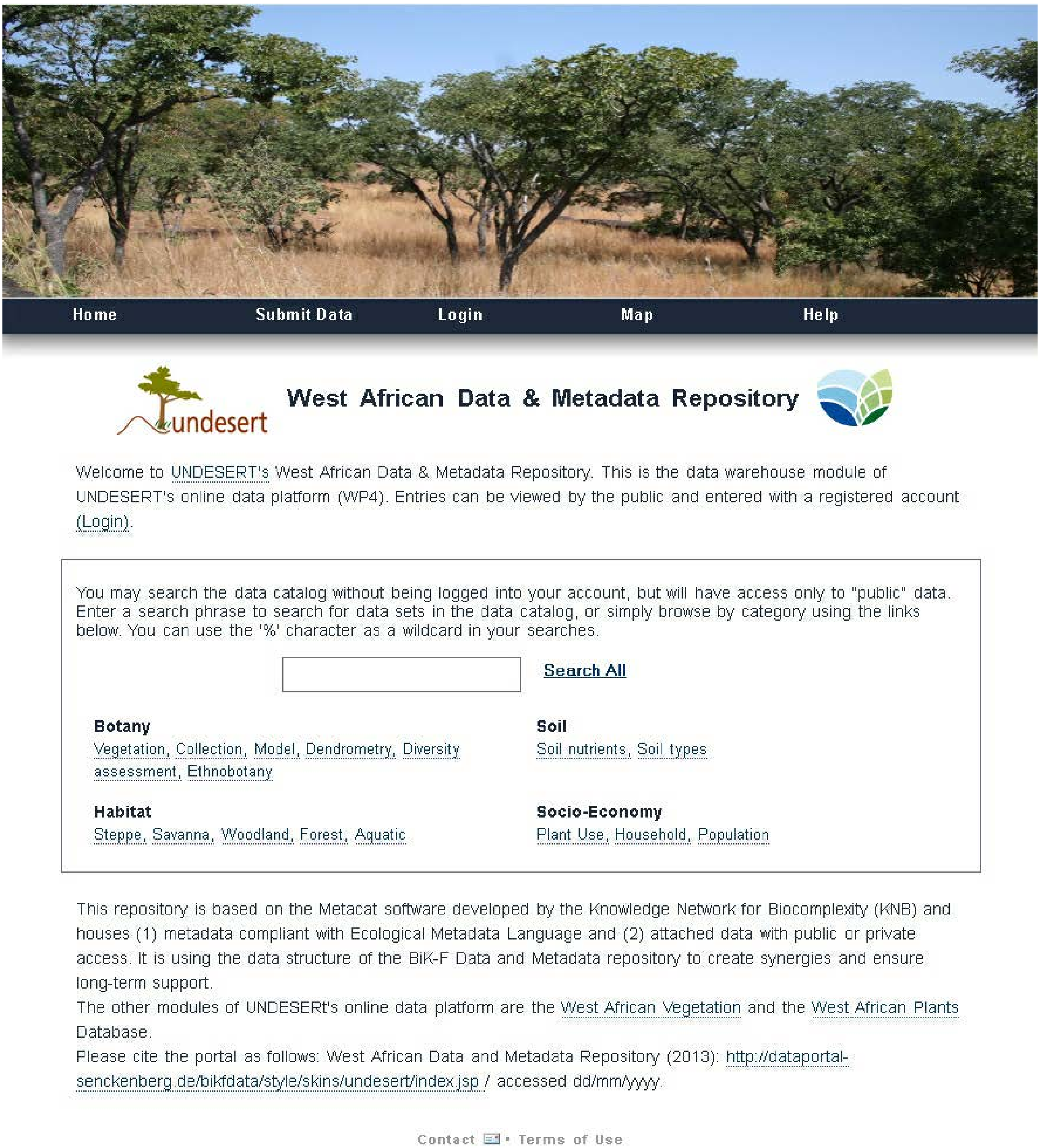


Figure 15. Homepage of the UNDESERT data portal for ecological data.

The West African Data and Metadata Repository (http://westafricandata.senckenberg.de/) is a data warehouse for ecological and socio-economic data (Figure 15). It stores a variety of data, including ethnobotanical assessments of plant use or perceived threats, soil physical and chemical characteristics, modelled distributions of functional plant groups, indicator values, and carbon estimations from biomass and soil. Each dataset is well documented by metadata in EML format.

The West African Vegetation Database (http://westafrican-vegetation.senckenberg.de) gives access to vegetation data which may be used for studies of community composition, vegetation structure, plant distribution, etc. It has become one of the largest vegetation databases in Tropical Africa.

The West African Plant Database (http://www.westafrican-plants.senckenberg.de) is a photo archive and an identification tool for West African plants documenting c. 30% of the West African plant species and most of its savanna species. Besides the photos themselves, it is an important source of occurrence and trait data, has received >300,000 page visits and receives a lot of positive feedback from the public as well as the local scientific community. This database has also very successfully "tapped" an enormous source of expert knowledge from non-professional botanist, who due to long standing field experience, have excellent knowledge of plants, their ecology and distribution. It will be an important issue for the future to make better use of this substantial knowledge available from people like extension workers, foresters, agriculturists, teachers and non-professional botanists.

Data can be easily found within the portal through search options and maps, and 'public' data contributes to international science infrastructure such as the Global Biodiversity Information Facility (GBIF), Map of Life (MoL) or the Encyclopedia of life (EoL).

Online tools are widely accessible and comprises numerous highly detailed data, which are otherwise difficult to access, and this way provides a highly important tool for research, education and management. The collection of extensive botanical and environmental (climate) data and the application of modelling methods allowed for instance a complete conservation assessment for the flora of Burkina Faso based on IUCN criteria. A sound and comprehensive conservation assessment is an important step to conserve the native flora and vegetation and thus, indirectly, contribute to fight desertification and support local livelihoods.

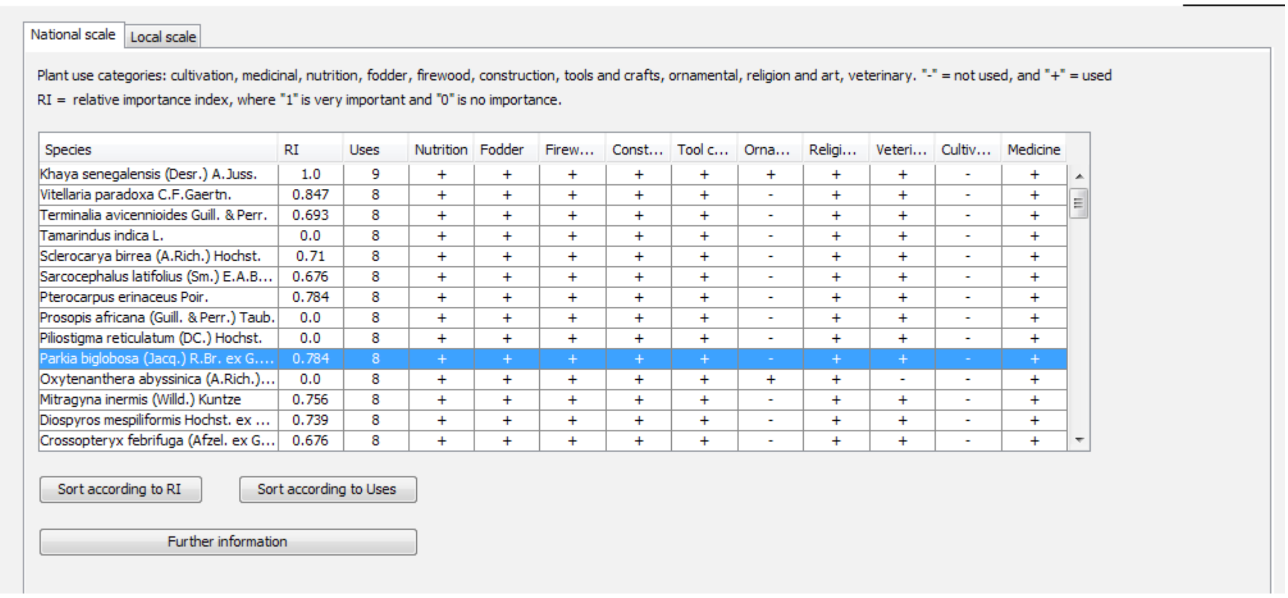
Decision support

A computer based decision support system was programmed as a dissemination platform for UNDESERT. It was designed to let the user extract information from UNDESERT research results that can help the user to take decisions on ecosystem management. The DSS includes the modules: 'Vegetation', 'Degradation', 'Restoration', 'Socio-economy', 'Climate change', Plant growth modeling', 'Carbon sequestration', and 'Land use'. The system has been designed having different questions or question series that may be asked be people dealing with ecosystem management in mind. By helping answering these questions, the decision support system will be a strong tool in the hands of ecosystem managers or people involved in development projects in West Africa. The DSS is available for download from the UNDESERT homepage (undesert.neri.dk). We here provide an example of how it may be used, an example demonstrating how the use of different modules can be combined for taking scientifically founded decisions.

Example:
A series of questions asked by for instance a development project worker in southern Burkina Faso:

1. Which tree species do I have to plant to enhance livelihood in a given area?
2. In which area are these species found?
3. How do we optimize the growth of these species?
4. How can the species be expected to react to climate change?

The user must start out with the Socio-economy module, which provides a list of important species that may be used and the user may for instance choose *Parkia biglobosa* (Figure 16). Second step is to get information on the geographic distribution of the species from the Vegetation module (Figure 17). Here the development project worker learns that the species is naturally occurring in southern Burkina Faso. Third step is to get information on how to utilize them best from the Restoration Module (Figure 18 and Figure 19), and finally before deciding on which species to plant it will be relevant to know how the possible species can be expected to react to climate change, which comes from the climate change module (Figure 20). Here the user learns that the species can be expected to be capable of growing in southern Burkin Faso also in year 2050.



Species	RI	Uses	Nutrition	Fodder	Firew...	Const...	Tool c...	Orna...	Religi...	Veteri...	Cultiv...	Medicine
Khaya senegalensis (Desr.) A.Juss.	1.0	9	+	+	+	+	+	+	+	+	-	+
Vitellaria paradoxa C.F.Gaertn.	0.847	8	+	+	+	+	+	-	+	+	-	+
Terminalia avicennioides Guill. & Perr.	0.693	8	+	+	+	+	+	-	+	+	-	+
Tamarindus indica L.	0.0	8	+	+	+	+	+	-	+	+	-	+
Sclerocarya birrea (A.Rich.) Hochst.	0.71	8	+	+	+	+	+	-	+	+	-	+
Sarcocephalus latifolius (Sm.) E.A.B...	0.676	8	+	+	+	+	+	-	+	+	-	+
Pterocarpus erinaceus Poir.	0.784	8	+	+	+	+	+	-	+	+	-	+
Prosopis africana (Guill. & Perr.) Taub.	0.0	8	+	+	+	+	+	-	+	+	-	+
Piliostigma reticulatum (DC.) Hochst.	0.0	8	+	+	+	+	+	-	+	+	-	+
Parkia biglobosa (Jacq.) R.Br. ex G....	0.784	8	+	+	+	+	+	-	+	+	-	+
Oxytenanthera abyssinica (A.Rich.)...	0.0	8	+	+	+	+	+	+	+	-	-	+
Mitragyna inermis (Willd.) Kuntze	0.756	8	+	+	+	+	+	-	+	+	-	+
Diospyros mespiliformis Hochst. ex ...	0.739	8	+	+	+	+	+	-	+	+	-	+
Crossopteryx febrifuga (Afzel. ex G...	0.676	8	+	+	+	+	+	-	+	+	-	+

Figure 16. The list of species that are important to people and their possible uses. The user has highlighted *Parkia biglobosa* which is being used for 8 different purposes, and has a high relative importance index.

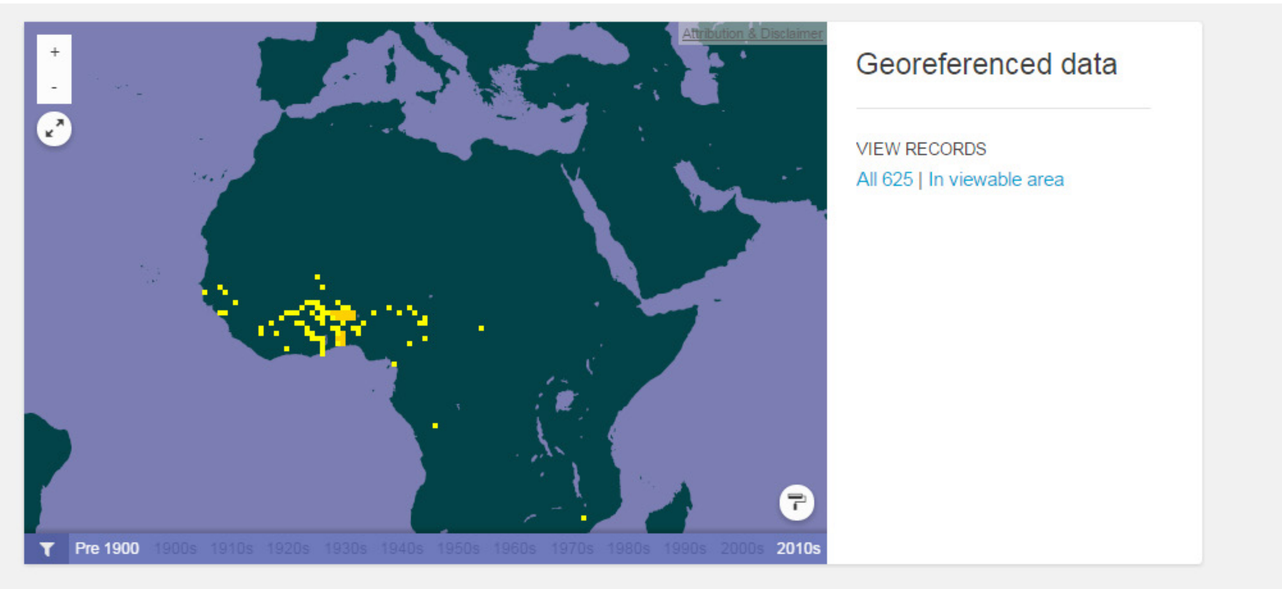


Figure 17. The distribution of *Parkia biglobosa* showing that the species has it main occurrence in southern Burkina Faso.

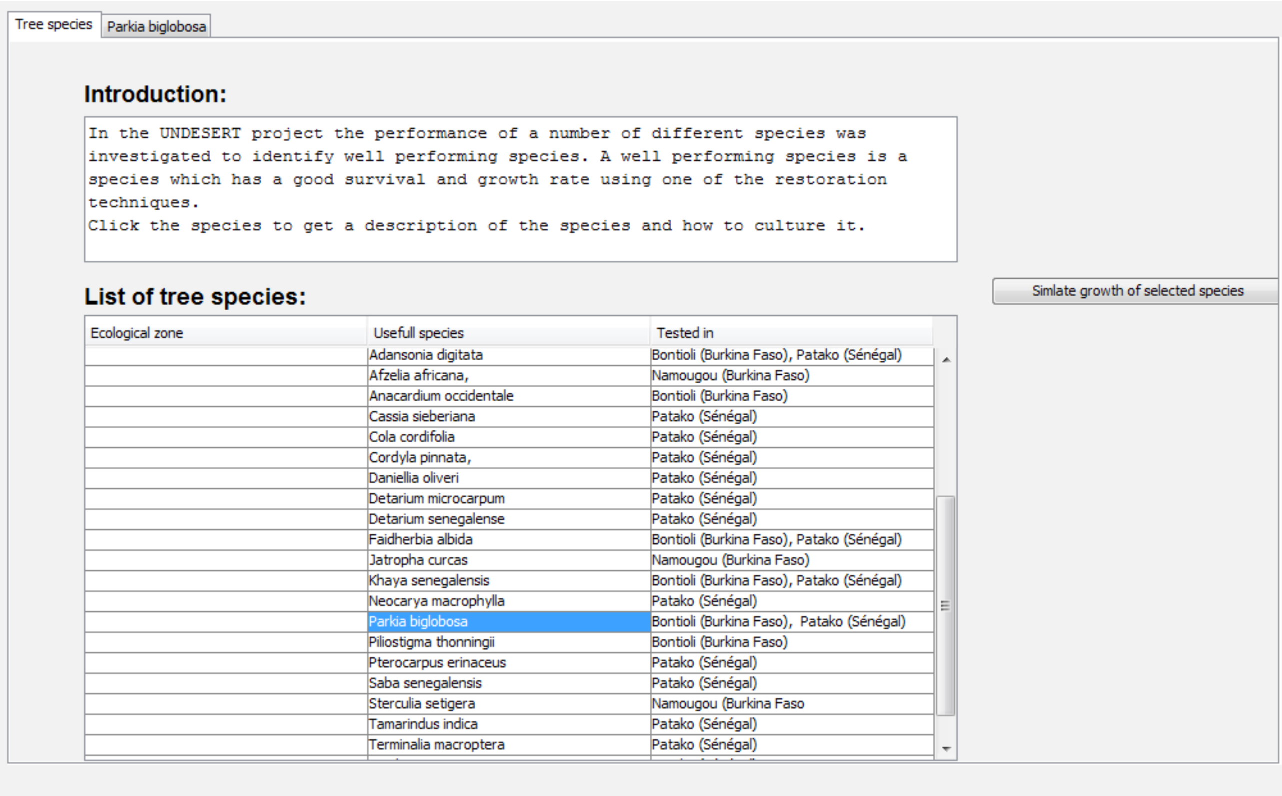


Figure 18. The user can select *Parkia biglobosa* from the list of "restoration" trees in the Restoration module and get a PDF-viewer showing the instructions on how to grow the species.

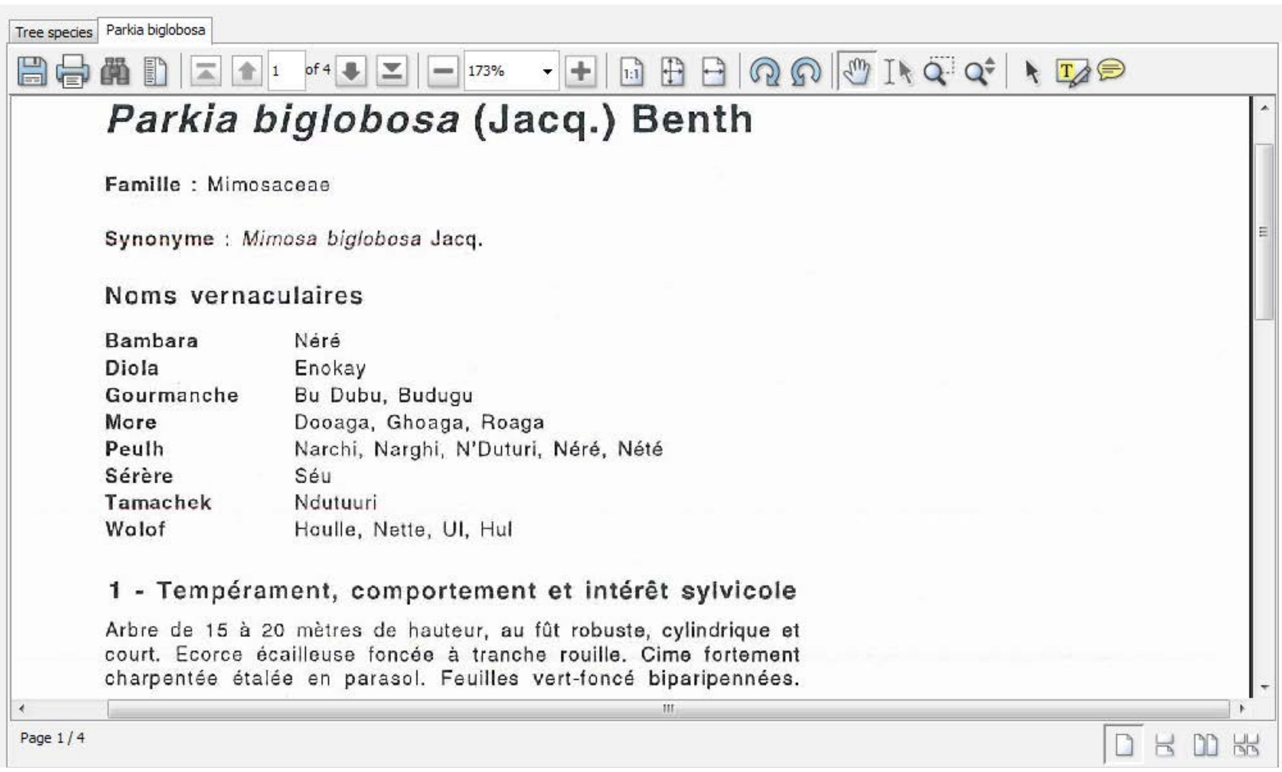


Figure 19. The instructions on how to grow *Parkia biglobosa* in a PDF-viewer, where the following pages come when clicking the arrow down.

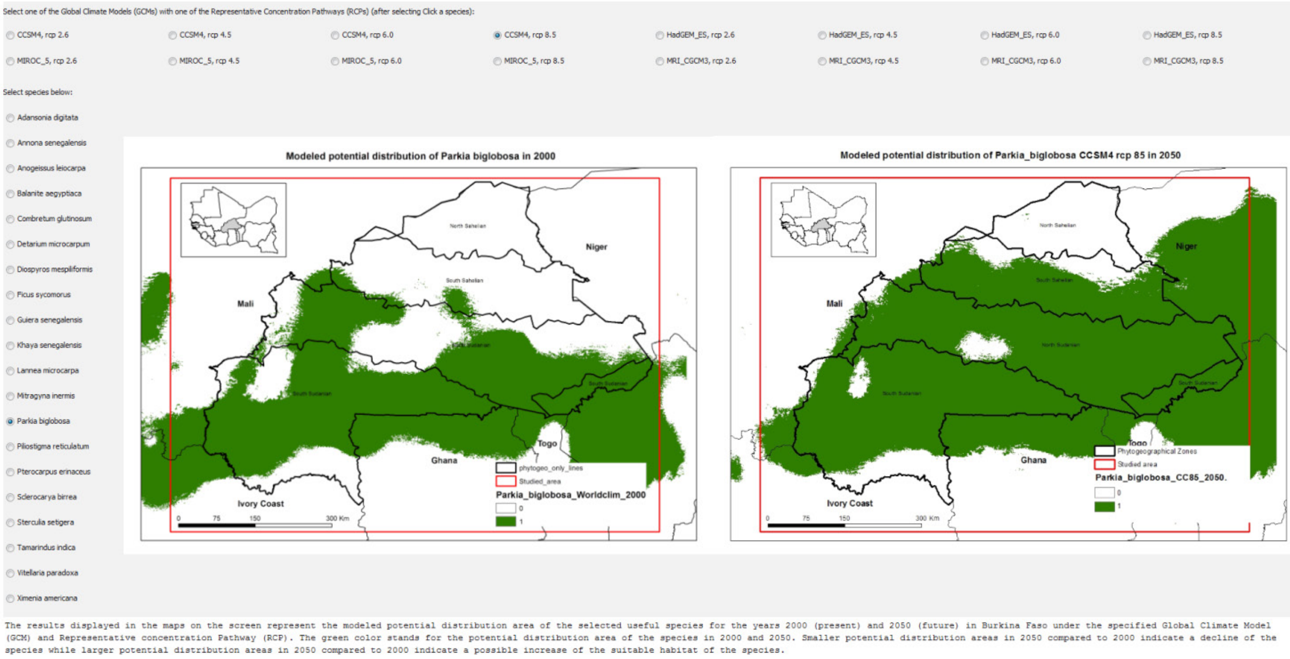


Figure 20. Potential distribution of *Parkia biglobosa* in Burkina Faso in 2000 and predicted potential distribution in 2050.

Suggestions for the future

Local communities and natural resource managers in West Africa have very good knowledge concerning desertification and degradation processes, and local knowledge is particularly important to gain an understanding of the historical changes in vegetation and in soil, and thereby their livelihood. Plants as indicators for desertification play a much more important role than soil parameters, for the former are generally are much better known by local people than soil parameters.

Local knowledge, however, falls short when it comes to future climate change and problems related to severe demographic increase. Naturally local people cannot have knowledge about future climate changes and furthermore, local traditions were developed under a low population density and therefore do not have traditions for active tree planting and protection. Here scientists can support local people and managers to find solutions. Local knowledge needs to be supplemented with scientific know-how to ensure sustainable solutions under climate change and also solutions for land use planning in densely populated areas.

The selection of species for forest carbon projects creates a dilemma of choice between locally prioritized species vs climate change resistant species, because many of the locally prioritized tree species grow at the edge of their distribution in the areas where they are selected. The best practices for tree species selection in Payments for Ecosystem Services (PES) projects have to be carefully discussed among scientists and rural people. With the right species selection, forest carbon projects offer great hope for simple solutions for restoring degraded lands.

Climate models are useful to predict scenarios for the future, but they are still quite variable and have high uncertainties particularly for West Africa. This presents a challenge when the models have to be used in practice to propose the right methods and species for tree planting projects. In contrast to Burkina Faso, where precipitation might increase in some parts, the precipitation is predicted to decrease in most of Senegal. More precise climate models are to be wished for in order to plan management practices and natural resource policy.

The practical actions showed that women were more motivated than men in respect of creating nurseries and tree planting, and they were more successful in establishing trees on previously degraded land than men. They also succeeded more to invest the money in sustainable activities. It is suggested that future tree planting projects in Africa should focus on female stakeholders to achieve maximum benefit. And the projects should focus on solving the problem of woman's lack of rights to land. It is important to plan payment without a requirement for cash to pass through committees dominated by village elders or chiefs to make sure that the payment goes directly to the women.

Combatting desertification and land degradation requires capacity building of local people, who are the most affected and in place to take action. One cornerstone of UNDESERT, the process of merging academic researchers and practical project work, has proven to be a valuable lesson learning experience and has provided pointers for new ecosystem services type projects in West Africa, including REDD+ projects, which could be a next step recommended based on the present work.

In several cases it was found that total protection of tree species is not necessary to achieve sustainable use, but restrictions on the use are indispensable. A recommendation for future projects would be to focus on protection of already existing natural resources in close collaboration with local communities through improved sustainable management systems, fx REDD+ or related projects.

The integration of a high number of PhD students in applied research projects is recommended, as the PhD students can engage themselves full time and obtain the sound data from the field that are labour intensive to get. The inclusion of PhD students is of high value, but it is also requires a high input from senior researchers to ensure that the PhD projects are carried out in the best way. PhD students can acquire good relations and maintain constant contact to local communities by living with them during field work. Finally an education of a new generation of scientists in Africa is necessary to cope with the problems of desertification and degradation in combination with climate change and increased human populations.

Research results are often lacking behind in West Africa, but the knowledge is sufficient for creating practical actions based on available research results. Future projects, however, should sign contracts with students and researchers to transfer data to an online data portal, to a decision support tool and to national research and policy managers in the expectation that they will prove useful for strategic and programmatic development. Many research results are available, but not exploited to a sufficient extent, as they are difficult to access. The online data portal and the decision support tool are valuable tools and it is important that the new generation of researchers continue to upload data and continuously develop and disseminate the tools to policy makers in the future.

Acknowledgements

The UNDESERT project has been funded by the Environment Programme, Management of Natural Resources, DG Research and Innovation (project no. 243906).