**Spatial and plot-based desertification and degradation indicators**

**Spatial indicators**

* Absolute/percentage land cover and land use change
* Normalized Diffference 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

**Spatial indicators**

**Name: Absolute/percentage land cover and land use change**

**Brief Definition:** Determination of land cover/use changes in a certain area and period by using remote sensing data

**Keywords:** Land cover, land use, change detection, land degradation, rehabilitation, human impact

**Country:** Common to all countries

**Level:** Spatial

**DPSIR:** Pressure

**Countries where indicator was tested:** Burkina Faso, Niger

**UNDESERT Spatial Scale:** West Africa

**Minimum time scale:** every 2-5 years

**Maximum time scale:** every 2-5 years

**Importance with respect to desertification and degradation:** The absolute and percentage land cover/use change indicators belong to the land-cover change detection approach which helps to determine and map the conditions of the earth’s surface at two or more points in time (Lambin & Strahler 1994; Lillesand et al. 2008). Many studies and projects have assessed land degradation in Africa based on change detection techniques of remote sensing data, for example in South Africa (Ngcofe & Dalithemba 2009), in Ethiopia (Assen 2011) and in all six countries of the FAO-LADA project Argentina, China, Cuba, Senegal, South Africa and Tunisia (DISforLADA DB, http://dis-nrd.uniss.it). Monitoring the dimensions of land cover/use change provides important information for policy makers which serve as a basis for decision making and for the implementation of sustainable land use strategies (Lunetta et al. 2006).

**International conventions and agreements:** The indicator determines position, amount, severity and types of change in land cover/use and indicates the occurrence of vegetation and land degradation. It is therefore directly relevant to the international agreements such as UNCCD, UNCBD and the MDGs.

**Definition and concepts:** Land cover refers to the (bio) physical cover on the surface of the earth. Land cover change is defined as the alteration of the physical or biotic nature of a site, for example the transformation of a forest to a grassland (DIS for LADA). Land use is characterized by the arrangements, activities and inputs people undertake in a certain land cover type to produce, change or maintain it. Land use change may involve alterations in the human management of land, including settlement, cultivation, pasture, rangeland and recreation (DIS for LADA).

Land cover and land use change are the direct and indirect consequences of human actions or climate change. Burning, forest clearing for the establishment of plantations and deforestation represent phenomenon that directly contribute to degradation processes that endanger natural resources and hence man’s livelihood (Ellis & [Pontius](http://www.eoearth.org/profile/Robert.pontius) 2010).

Detection of land cover/use change indicates where transformations of the physical cover of the earth are occur, which cover types are changing and how is the transformation rate. The driving forces and causes of change can often be assessed clearly by integration of local knowledge. Once the trends are understood and projected to the future, sustainable strategies can be developed and set in place (Loveland & Acevedo no year known).

**Methodology**: Three change detection studies were conducted in UNDESERT: One in Niger in the District of Simiri, and two studies in Burkina Faso, in Koulbi Classified Forest and Bontioli Reserve. For each study area two satellite images of different dates (time lag between the two satellite images varied between 20 to 31 years) were acquired. The land cover/use types were classified by by means of supervised classification techniques. For each study area six land cover/land use types were identified. The area of each land cover/use type was calculated on both images per study site and a change matrix was established for the two different dates (absolute change). Furthermore the percentage of change for each land cover/use type was calculated in reference to the entire area (percentage change). The overall accuracies of the supervised classifications were higher than 85% in all three studies. Accuracy assessment was based on 100 randomly distributed points per study. The classification results were assessed with actual field data and existing land cover maps.

**Data needed:** Satellite images of medium to high resolution are needed. For this project Landsat images were used: in Niger two Landsat images of 1975/2006, in Burkina Faso for Koulbi Classified Forest Landsat images of 1986/2006 and for Bontioli Reserve Landsat images of 1984/2010. Reference points for supervised classification and for ground truthing (accuracy assessment) have to be collected. For the verification of the classification results of former satellite images existing land cover/use maps have to be taken into account.

**Limits of the indicator:** The availability and quality of satellite images are limiting factors controlling the selection of the time period and study area under study. For the accuracy assessment the indictor requires field sampling data. The knowledge and experience of the user about and with remote sensing techniques determines the quality of the results.

**Related indicators:** Land use type, NDVI, EVI, grazing intensity, population density

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**Literature:**

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**Project:** UNDESERT

**Date:** October 2012

**Name: Normalized Difference Vegetation Index (NDVI)**

**Brief Definition:** The Normalized Difference Vegetation Index (NDVI) is derived from the red and near-infrared spectral bands of satellite images and is frequently used to assess plant vigor and biomass production.

**Keywords:** Vegetation indices, green biomass, spectral reflectance

**Country:** Common to all countries

**Level:** Spatial

**DPSIR:** State

**Countries where indicator was tested:** Benin, Burkina Faso

**UNDESERT Spatial Scale:** West Africa

**Minimum time scale:** every 1-5 years

**Maximum time scale:** every 1-5 years

**Importance with respect to desertification and degradation:** Spectral vegetation indices are derived from multispectral satellite image data. The Normalized Differenced Vegetation Index (NDVI) is the vegetation index most widely analysed in scientific studies to determine biomass production. NDVI was for example used by Symeonakis & Drake (2004) to monitor desertification and land degradation in Sub-Saharan Africa.

**International conventions and agreements:** The NDVI is directly relevant to the UNCCD as it enables to monitor symptoms of change in biomass over the entire globe.

**Definition and concepts:** Spectral vegetation indices are used in ecology for quantifying plant vigor and biomass production (Kerr & Ostrovsky 2003; Pettorelli et al. 2005; Glenn et al. 2008). In Africa spectral vegetation indices have been used frequently besides climatic data and data on grazing to monitor greening trends in the Sahel (Emeterio et al. 2010; Seaquist et al. 2009; Hickler et al. 2005).

**Methodology:** We tested infour different studies in Burkina Faso and Benin the potential of the NDVI to assess land degradation. Around Pama Fauna Reserve in southern Burkina Faso we assessed by correlation analysis the relationship between species richness (herb and woody species) and the NDVI to determine its potential to predict species richness.

In W-National Park of Burkina Faso species richness was assessed in three land use types. The potential of 26 biotic and abiotic factors to predict species richness was tested in a GLM, amongst them the NDVI.

In the Sahelian zone of Burkina Faso in the Gorouol catchment and in the sub-Sahelian zone in the Faga catchment area localized in Namentenga Province different degradation stages were assessed by using the NDVI and correlation techniques.

In Pendjari National Park in Benin vegetation type-specific NDVI and EVI curves were analysed over a 12 year period. NDVI data were compared with fire events to determine the impact of fire on the long term NDVI trend. A trend analysis was performed on NDVI and EVI values per vegetation type using the Seasonal Decomposition of Time Series (STL) and Breaks for Additive Seasonal and Trend (BFAST) methodologies. In the trend analysis the effect of seasonal climatic variations is reduced. With the Seasonal Decomposition of Time Series (STL) (Cleveland 1990) an accurate and robust estimation of trend and seasonal components is provided. The capacity of the algorithm to deal with outliers or missing values within the time series is high. STL is a non-parametric method which is based on an additive model. It decomposes time series data into three separate components: trend (Zt), seasonal (St) and remainder (et). This type of model implies that the magnitude of fluctuations in the original series resulting from the seasonal pattern and the residual component is not affected by the level of the trend. STL is an iterative procedure that repeatedly uses different types of LOcally wEighted regreSion Smoothers (LOESS) (Cleveland et al. 1990). To evaluate the LOESS fit g(x) at a given x, all data points in the neighbourhood of x are assigned tricubic weights, so that the closer a point is to x, the larger its weight. Weighted least squares are then used to fit a polynomial though the points and g(x) equals the value of the polynomial at x. The parameters to be defined are the size of the neighbourhood and the degree of the polynomial (constant, linear or quadratic).The seasonal component provides the phenology cycle of the local vegetation for the study period while the trend component, modelled by a piecewise linear function, enables determination of the direction of change during the study period by analyzing the slope sign of the trend (Jacquin et al. 2010). Abrupt changes (breakpoints by BFAST) in the trend component often indicate disturbances, for example caused by fires or insects (Verbesselt et al. 2010).

**Data needed:** Satellite image data is needed with spectral information in the red and near-infrared bands. The spatial resolution of the satellite data has to be determined according to the study objective.

**Limits of the indicator**: Application of remote sensing techniques, knowledge and experience are required

**Related indicators:** EVI, land cover/use change

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**Literature:**

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**Project:** UNDESERT

**Date:** October 2012

**Name: Enhanced Vegetation Index (EVI)**

**Brief Definition:** The Enhanced Vegetation Index (EVI) is derived from the red, blue and near-infrared spectral bands of satellite images.

**Keywords:** Vegetation indices, green biomass, spectral reflectance

**Country:** Common to all countries

**Level:** Spatial

**DPSIR:** State

**Countries where indicator was tested:** Benin

**UNDESERT Spatial Scale:** West Africa

**Minimum time scale:** every 1-5 years

**Maximum time scale:** every 1-5 years

**Importance with respect to desertification and degradation:** Spectral vegetation indices are derived from multispectral satellite image data. The Enhanced Vegetation Index (EVI) is used to enhance the vegetation signal with improved sensitivity in high biomass regions and improved vegetation monitoring through a de-coupling of the canopy background signal and a reduction in atmosphere influences

**International conventions and agreements:** The EVI is directly relevant to the UNCCD as it enables to monitor symptoms of change in biomass over the entire globe.

**Definition and concepts:** The EVI is more sensitive than NDVI to canopy structural variations, including [leaf area index](http://en.wikipedia.org/wiki/Leaf_area_index) (LAI), canopy type, plant physiognomy, and canopy architecture. Together with the NDVI it improves the detection of vegetation changes and extraction of canopy biophysical parameters. Spectral vegetation indices are used in ecology for quantifying plant vigor and biomass production (Rouse et al. 1974; Kerr & Ostrovsky 2003; Pettorelli et al. 2005; Glenn et al. 2008). In Africa spectral vegetation indices have been used frequently besides climatic and grazing data to monitor greening trends in the Sahel (Emeterio et al. 2010; Seaquist et al. 2009; Hickler et al. 2005).

**Methodology:** In Pendjari National Park in Benin vegetation type-specific NDVI and EVI curves were analyzed over a 12 year period. EVI data was related to fire events. Trends were calculated and breakpoints to detect abrupt changes. A trend analysis was performed on NDVI and EVI values per vegetation type using the Seasonal Decomposition of Time Series (STL) and Breaks for Additive Seasonal and Trend (BFAST) methodologies. In the trend analysis the effect of seasonal climatic variations is reduced. With the Seasonal Decomposition of Time Series (STL) (Cleveland 1990) an accurate and robust estimation of trend and seasonal components is provided. The capacity of the algorithm to deal with outliers or missing values within the time series is high. STL is a non-parametric method which is based on an additive model. It decomposes time series data into three separate components: trend (Zt), seasonal (St) and remainder (et). This type of model implies that the magnitude of fluctuations in the original series resulting from the seasonal pattern and the residual component is not affected by the level of the trend. STL is an iterative procedure that repeatedly uses different types of LOcally wEighted regreSion Smoothers (LOESS) (Cleveland et al. 1990). To evaluate the LOESS fit g(x) at a given x, all data points in the neighbourhood of x are assigned tricubic weights, so that the closer a point is to x, the larger its weight. Weighted least squares are then used to fit a polynomial though the points and g(x) equals the value of the polynomial at x. The parameters to be defined are the size of the neighbourhood and the degree of the polynomial (constant, linear or quadratic).The seasonal component provides the phenology cycle of the local vegetation for the study period while the trend component, modelled by a piecewise linear function, enables determination of the direction of change during the study period by analyzing the slope sign of the trend (Jacquin et al. 2010). Abrupt changes (breakpoints by BFAST) in the trend component often indicate disturbances, for example caused by fires or insects (Verbesselt et al. 2010).

**Data needed:** Satellite image data is needed that contains spectral information in the red band and near-infrared band. The spatial resolution of the satellite data depends on the study objective.

**Limits of the indicator**: Application of remote sensing techniques requires capacity

**Related indicators:** NDVI, land cover/use change

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Glenn E. P., Huete A. R., Nagler P. L., Nelson S. G. 2008: Relationship between remotely sensed vegetation indices, canopy attributes and plant physiological processes: What vegetation indices can and cannot tell us about landscape. Sensors 8: 2136-2160.

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Pettorelli N., Vik J. O., Mysterud A., Gaillard J.-M., Tucker C. J., Stenseth N. C. 2005. Using satellite-derived NDVI to assess ecological responses to environmental change. Trends in Ecology and Evolution 20: 231-259.

Seaquist J. W., Hickler T., Eklundh L., Ardö J., Heumann B. W. 2009. Disentangling the effects of climate and people on Sahel vegetation dynamics. Biogeosciences 6: 469-477.

**Project:** UNDESERT, **Date:** October 2012

**Name: Population density**

**Brief Definition:** Population per km2

**Keywords:** Human population density, population growth

**Country:** Common to all countries

**Level: S**patial

**DPSIR:** Driving forces

**Countries where indicator was tested:** Burkina Faso

**UNDESERT Spatial Scale:** West Africa

**Minimum time scale:** every 5-10 years

**Maximum time scale:** every 5-10 years

**Importance with respect to desertification and degradation:** In the last decades West Africa has experienced a rapid and constant growth of human population. According to the World’s Population Prospects of the United Nations (2011) the population of West Africa has constantly grown by 2.44-2.79% per year between 1970 and 2010. As a consequence the transformation of natural habitats into agricultural and pastoral areas multiplied and accelerated significantly, resulting in an increased pressure on natural resources, such as vegetation, water, soils and entire ecosystems (Wittig et al. 2007; MEW 1999).

**International conventions and agreements:** The indicator helps to assess the impacts of human pressure on natural ecosystems. It is a driving force for degradation processes. It is relevant for the UNCCD, the MDGs and the TEEB studies. It is directly relevant to the CBD and potentially important in relation to the implementation of rural development policies. In Agenda 21 a specific reference is made to population density in relation to desertification (Chapter 12).

**Definition and concepts:** Population density helps to assess human pressure on the environment. According to the DPSIR framework it describes the interactions between society and ecosystems and clarifies the cause-effect relationships of the interaction of social, economic and environmental systems (Kirstensen 2004; EEA 1999). The indicator is a driving force that causes pressure on the biological, physical and chemical conditions of ecosystems (Kirstensen 2004).

**Methodology:** In this study SEDAC/Ciesin gridded future estimates of population density with a spatial resolution of 2.5 arc-minutes were used. To assign population values to the grid cells, Ciesin uses a proportional allocation gridding algorithm based on national and sub-national administrative units (SEDAC/Ciesin). The future estimate population values are extrapolated based on a combination of subnational growth rates from census data and national growth rates from the United Nations statistics. The population density grids are derived by dividing the population count grids by the land area grid and represent persons per square kilometer. The population density for the year 2010 was used to assess the impacts on species richness in three land use types in Burkina Faso and the potential of prediction of species richness. A GLM was performed in order to estimate the significance of the relationship between all variables. Population density 2010 as well as distance to village were significant for the indicator species richness.

**Limits of the indicator:** The gridded population density estimates for 2010 are future projections that assume past trends continuing in the future and disregard impacts of external factors, which control population development. Hence they do not necessarily reflect the actual population density. Gridded actual population density are not available.

**Related indicators:** Species richness, distance to villages

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**Project:** UNDESERT

**Date:** October 2012

**Name: Distance to nearest village**

**Brief Definition:** Distance (in m) of phytosociological plot (here we analyzed species richness) to nearest village

**Keywords:** Distance to nearest village, population pressure, human impact

**Country:** Common to all countries

**Level:** Spatial

**DPSIR:** Driving force

**Countries where indicator was tested:** Burkina Faso

**UNDESERT Spatial Scale:** West Africa

**Minimum time scale:** every 3-5 years

**Maximum time scale:** every 3-5 years

**Importance with respect to desertification and degradation:** Distance to villagecontributestogether with population density to identify the fragility of an area on the basis of the human pressure to which it is subjected.

**International conventions and agreements:** The indicator determines the possible pressure of human actions on local ecosystems. It is related to Agenda 21, Chapter 12 – Management of fragile ecosystems. Although humans are a potential risk for natural ecosystems they represent at the same time the key group to prevent degradation processes or induce rehabilitation.

**Definition and concepts:** The indicator distance to villageimplies that human presence represents a potential risk for natural ecosystems. Here we assessed its relationship to species richness of 348 plots in three land use types in and around W-National Park of Burkina Faso. Besides this indicator the potential of 25 other biotic and abiotic factors was tested to predict species richness.

**Methodology:** We used village point data taken by GPS during field work in and around W-National Park of Burkina Faso and the GPS coordinates of the phytosociological relevés (plots with species richness). The distance was calculated in meters in the Geographic Information System ArcGIS10 with the Tool “Nearest Distance”.For each plot with the respective species richness the distance value was added and used in the Generalized Linear Model (GLM).

**Data needed:** Reliable coordinates about the location of villages and the vegetation plots. These data can be captured by GPS at local scale. At regional scale they have to be downloaded from the internet.

**Limits of the indicator:** no limits

**Related indicators:** Population density

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**Literature:**

Nacoulma B. M. I., Schumann K., Traoré S., Bernhardt-Römermann M., Hahn K., Wittig R., Thiombiano A., 2011. Impacts of land-use on West African savanna vegetation: a comparison between protected and communal area in Burkina Faso. Biodiversity and Conservation 20 (14): 3341–3362.

Schumann K., Wittig R., Thiombiano A., Becker U., Hahn K., 2010. Impact of land-use type and bark- and leaf-harvesting on population structure and fruit production of the baobab tree (*Adansonia digitata* L.) in a semi-arid savanna, West Africa. Forest, Ecology and Management 260: 2035-2044.

**Project:** UNDESERT

**Date:** October 2012

**Name: Land use type**

**Brief Definition:** The indicator characterizes here the different land use types around W-National Park Burkina Faso (protected area, buffer area, communal area)

**Keywords:** Land use,protected area, buffer area, communal area

**Country:** Common to all countries

**Level:** Spatial

**DPSIR:** Pressure

**Countries where indicator was tested:** Burkina Faso

**UNDESERT Spatial Scale:** West Africa

**Minimum time scale:** every 5-10 years

**Maximum time scale:** every 5-10 years

**Importance with respect to desertification and degradation:** Land use typeassessesthefragility of an area and characterizes the possible human impact.

**International conventions and agreements:** The indicator determines the possible pressure of human actions on local ecosystems. It is related to Agenda 21, Chapter 12 – Management of fragile ecosystems. Although humans are a potential risk for natural ecosystems they represent at the same time the key group to prevent degradation processes or induce rehabilitation.

**Definition and concepts:** The indicator land use type implies that human presence and activities represent a potential risk for natural ecosystems. Here we assessed the relationship between land use type and species richness for 348 plots in and around W-National Park of Burkina Faso. Land use type was a nominal variable with three characteristics: protected area, buffer area, communal area. Inside the protected area all human activities are forbidden by law. In the buffer area, hunting is allowed. The communal area comprises croplands, fallows of different ages and non-arable savanna sites (Nacoulma et al 2011).

**Methodology:** We added to each of the 348 plots the respective land use type information based on the spatial relationships between the plots and a GIS land use cover of W-National Park Burkina Faso. Woody and herb species richness had been inventoried on 348 plots, 137 of them located in the protected area, 28 in the buffer area and 183 in the communal area. Tukey’s Honestly Significant Difference (HSD) Test proved significant differences between the woody and herb species richness in the protected area, the buffer area and the communal area (F-value 46.91, p < 2e-16). Comparing each of the land use types with another, none of the pairs showed similarities. The differences between all three pairs of land use types were significant. The highest mean woody and herb species richness was found in the buffer area (44.35) followed by the protected area (36.45) and the communal area (27.86). Significant results were also obtained for woody and herb species richness when observed separately.

**Data needed:** As we investigated the relationship between species richness and land use types we needed phytosociological relevés to calculate the species richness per plot, the GPS coordinates of the plots and a GIS land use type cover with the limits of W-National Park Burkina Faso and the buffer areas around it.

**Limits of the indicator:** no limits

**Related indicators:** Population density, distance to village

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**Literature:**

Nacoulma B. M. I., Schumann K., Traoré S., Bernhardt-Römermann M., Hahn K., Wittig R., Thiombiano A., 2011. Impacts of land-use on West African savanna vegetation: a comparison between protected and communal area in Burkina Faso. Biodiversity and Conservation 20 (14): 3341–3362.

Schumann K., Wittig R., Thiombiano A., Becker U., Hahn K., 2010. Impact of land-use type and bark- and leaf-harvesting on population structure and fruit production of the baobab tree (*Adansonia digitata* L.) in a semi-arid savanna, West Africa. Forest, Ecology and Management 260: 2035-2044.

**Project:** UNDESERT

**Date:** October 2012

**Name: Fire frequency**

**Brief Definition:** Number of pixels of a vegetation type burnt during defined time period

**Keywords:** Fire regime, fire density, land degradation, species richness, vegetation, soil

**Country:** Common to all countries

**Level:** Spatial

**DPSIR:** Pressure

**Countries where indicator was tested:** Benin

**UNDESERT Spatial Scale:** West Africa

**Minimum time scale:** every 1-5 years

**Maximum time scale:** every 1-5 years

**Importance with respect to desertification and degradation:** Fires are important in the ecology of African tropical savannas (Zida et al. 2007; Zida et al. 2008; Govender et al. 2006). They are used as a most effective and economic tool for environmental management (e.g. against shrub encroachment), for management of biological resources (e.g. in order to enhance pasture farming, game hunting and harvesting), for prevention and control of fire related damages (e.g. protection of fields and dwellings) and for traditional and socio-cultural practices of the local population (Yameogo 2005). However, burning of areas, particularly indiscriminate bush fires destroy vegetation cover and organic matter that protects soils from erosion. The potential for wind and water erodibility is increased (Nsiah-Gyabaah 1994; Middleton 1987; Le Houerou 1996). In degraded landscapes the impacts of fire, even at modest levels, may be severe (Orr 1995).

**International conventions and agreements:** The indicator determines how often a fire occurs in an ecosystem or vegetation type. In ecosystems which are prone to desertification and in already degraded landscapes frequent fires may cause or accelerate degradation processes. Hence this indicator is relevant for the UNCCD. It is directly relevant to the CBD and potentially important in relation to the implementation of rural development policies.

**Definition and concepts:** Fire frequency quantifies how often fires occur within a defined zone (e. g. protected areas, land cover/land use type) and study period.

**Methodology:** In the UNDESERT study area of Benin, in Pendjari National Park, the “Zone cynégétique” and its surroundings (6,000 km2) fire regimes were analysed for seven vegetation types (see below) on basis of MODIS-data (MOD 13, 16-day time series NDVI/EVI and MOD 14A1, 8-day time series Fire data) for the time period 5/2000 and 7/2012. The seven vegetation types were extracted from a classified Landsat image from 2007. For each of the seven vegetation types 30 1km x 1km squares were digitized. Each square was composed by more than 98% pixels belonging to one vegetation type. The vegetation types are: Woodland savanna (*Burkea africana, Vitellaria paradoxa*), tree savanna 1 (*Crossopteryx febrifuga*), tree savanna 2 (*Terminalia macroptera, Mitragyna inermis*), shrub to grassland savanna, grassland savanna, swamp savanna and rocky savanna. The indicator fire frequency (DPSIR: Pressure) was analysed together with the indicator fire density. Fire frequency was calculated as the quantity of pixels of one vegetation type burnt during the study period. The results were classified according to Devineau et al (2010) in very early fires (JD 241-304), early fires (JD 305-365), late fires (JD 001-064) and very late fires (JD 065-151).

**Data needed:** The analysis was carried out by means of MODIS-data products MOD13Q1 VI 16-day time series and MOD14A1 thermal anomalies 8-day ime series for the time period from 5/2000 to 7/2012.

**Limits of the indicator**: Due to thequality assessment, which is an essential part for analyzing satellite derived data, pixels of low quality of the defined study area were excluded from further analysis. Hence the results are only based on the pixels with sufficiently high quality.

**Related indicators:** Fire density, NDVI, EVI, land cover/use change

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**Literature:**

Bond W. J., Woodward F. I., Midgley G. F. 2005. The global distribution of ecosystems in a world without fire. New Phytologist 165: 525-538.

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**Project:** UNDESERT, **Date:** October 2012

**Name: Fire density**

**Brief Definition:** Number of pixels that burnt per vegetation type and dry season/all dry seasons in relation to all pixels studied of the vegetation type

**Keywords:** Fire regime, fire frequency, land degradation, species richness, vegetation, soil

**Country:** Common to all countries

**Level:** Spatial

**DPSIR:** Pressure

**Countries where indicator was tested:** Benin

**UNDESERT Spatial Scale:** West Africa

**Minimum time scale:** every 1-5 years

**Maximum time scale:** every 1-5 years

**Importance with respect to desertification and degradation:** Fires are important in the ecology of African tropical savannas (Zida et al. 2007; Zida et al. 2008; Govender et al. 2006). They are used as a most effective and economic tool for environmental management (e.g. against shrub encroachment), for management of biological resources (e.g. in order to enhance pasture farming, game hunting and harvesting), for prevention and control of fire related damages (e.g. protection of fields and dwellings) and for traditional and socio-cultural practices of the local population (Yameogo 2005). However, burning of areas, particularly indiscriminate bush fires destroy vegetation cover and organic matter that protects soils from erosion. The potential for wind and water erodibility is increased (Nsiah-Gyabaah 1994; Middleton 1987; Le Houerou 1996). In degraded landscapes the impacts of fire, even at modest levels, may be severe (Orr 1995).

**International conventions and agreements:** The indicator determines how often a fire occurs in an ecosystem or vegetation type related to its size. In ecosystems which are prone to desertification and in already degraded landscapes frequent fires may cause or accelerate degradation processes. Hence this indicator is relevant for the UNCCD. It is directly relevant to the CBD and potentially important in relation to the implementation of rural development policies.

**Definition and concepts:** Fire density quantifies the times a pixel burns related to all pixels studied of this vegetation type during a certain time period. Here the number of pixels that burnt in a vegetation type was related to the total number of pixels studied within this vegetation type.

**Methodology:** In the UNDESERT study area of Benin, in Pendjari National Park, the “Zone cynégétique” and its surroundings (6,000 km2) fire regimes were analysed for seven vegetation types (see below) on basis of MODIS-data (MOD 13, 16-day time series NDVI/EVI and MOD 14A1, 8-day time series Fire data) for the time period 5/2000 and 7/2012. The seven vegetation types were extracted from a classified Landsat image from 2007. For each of the seven vegetation types 30 1km x 1km squares were digitized. Each square was composed by more than 98% pixels belonging to one vegetation type. The vegetation types are: Woodland savanna (*Burkea africana, Vitellaria paradoxa*), tree savanna 1 (*Crossopteryx febrifuga*), tree savanna 2 (*Terminalia macroptera, Mitragyna inermis*), shrub to grassland savanna, grassland savanna, swamp savanna and rocky savanna. The indicator fire density (DPSIR: Pressure) was analysed together with the indicator fire frequency. Fire density was calculated as the number of pixels that burnt per vegetation type and dry season/all dry seasons in relation to all pixels studied of the vegetation type.

**Data needed:** The analysis was carried out by means of MODIS-data products MOD13Q1 VI 16-day-time serried and MOD14A1 thermal anomalies 8-day time series for the time period from 5/2000 to 7/2012. For the classification of the vegetation types Landsat TM of 2007 was used.

**Limits of the indicator**: Due to thequality assessment, which is an essential part for analyzing satellite derived data, pixels of low quality of the defined study area were excluded from further analysis. Hence the results are only based on the pixels with sufficiently high quality.

**Related indicators:** Fire frequency, NDVI, EVI, land cover/use change

**Authors (University/Institute):** Goethe University Frankfurt, Institute of Ecology, Evolution and Diversity

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**Literature:**

Bond W. J., Woodward F. I., Midgley G. F. 2005. The global distribution of ecosystems in a world without fire. New Phytologist 165: 525-538.

Devineau J.-L., Fournier A., Nignan 2010. Savanna fire regimes assessment with MODIS fire data: Their relationship to land cover and plant species distribution in western Burkina Faso (West Africa). Journal of Arid Environments 74: 1092-1101.

Govender N., Trollope, W. S. W., Wilgen van B. 2006. The effect of fire season, fire frequency, rainfall and management on fire intensity in savanna vegetation in South Africa. Journal of Applied Ecology 43: 748-758.

Le Houerou H.N. 1996. Climate change, drought and desertification. Journal of Arid Environments, 34: 133-185

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Nsiah-Gyabaah K. 1994. Environmantal Degradation and Desertification in Ghana: A study of the Upper West Region (Averbury Studies in Green Research). Aldershot, Great Britain.

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Sankaran M., Ratnam J., Hanan N. 2008. Woody cover in African savannas: the role of resources, fire and herbivory. Global Ecology and Biogeography 17: 236-245.

Yameogo U.G. 2005. Le feu, un outil d'ingénierie écologique au Ranch de Gibier de Nazinga au Burkina Faso. Doctoral dissertation, Universtité d'Orléans. 268 pp.

Zida D., Sawadogo L., Tigabu M., Tiveau D., Odén P. C. 2007. Dynamics of sapling population in savanna woodlands in Burkina Faso subjected to grazing, early fire and selective tree cutting for a decade. Forest Ecology and Management 243: 102-115.

Zida D., Tigabu M., Sawadogo L., Tiveau D., Odén P. C. 2008. Long-term effects of prescribed early fire, grazing and selective tree cutting on seedling populations in the Sudanian savanna of Burkina Faso. African Journal of Ecology 47: 97-108.

**Project:** UNDESERT, **Date:** October 2012

**Plot-based indicators**

**Name: Plant species richness**

**Brief Definition:** Plant species richness is deﬁned as the total number of plant species occurring per area unit( for example: 30m×30m).

**Keywords**: Plant species richness, total number, species, unit area

**Country:** common to all countries

**Level:** Plot-based

**Position within DPSIR:** State

**Countries where indicator was tested:** Benin

**UNDESERT Spatial Scale:** West Africa

**Minimum time scale:** every 1-5 years

**Maximum time scale:** every 1-5 years

**Importance with respect to desertification and degradation:** Biodiversity plays a crucial role in ecosystem stability and productivity. Tilman and Downing (1994) investigated the relationship between plant species richness and grassland primary productivity; they concluded that conservation of biodiversity is essential to maintain productivity under variable adverse environmental conditions. Biodiversity has several components including the number of species (Reich et al. 2004). Quantitative analysis of ecosystem diversity including species richness, improves the understanding of system stability and resilience in the face of disturbance (e. g. overgrazing, drought or their combination). Quantitative information can help to implement sustainable management strategies for ecosystem resources to mitigate adverse disturbances. These disturbances are serious threats to the ecosystem and may cause irreversible damages (Archer & Stokes 2000). Further, such an understanding will enhance the rehabilitation of degraded ecosystems. Plant species richness is a valuable indicator for assessing land degradation and desertification.

**International conventions and agreements:** The indicator measures the total number of plant species per area unit or a total number of plant species in a region. It is relevant for the UNCCD, the MDGs and the TEEB studies. It is directly relevant to the CBD and potentially important in relation to the implementation of rural development policies

**Definition and concepts:** Plant **s**pecies richness refers to the total number of plant species occurring per area unit (Alhamad 2006) or a total number of plant species in a region (Zipkin et al. 2009). Plant species richness is often used as a tool for prioritizing conservation action (Zipkin et al. 2009). The assessment of plant species richness of an area must not be confused with species diversity measurements that include components of both species richness and the evenness or dominance among the species present (Alhamad 2006). The assessment of plant species richness is closely related to the process of gathering data on the distribution, numbers, and/or composition of species groups and population monitoring. The loss of plant species richness in an area can be used as an indicator for pressures on the environment and can help to define conservation measures and to avoid further damage. Many researches have considered plant species richness as indicator of land degradation and desertification. Tilman et al. (1997) showed that species extinction strongly affects ecosystem processes and services. Hooper and Vitousek (1997) conﬁrmed that species richness is important for maintaining vital ecosystem processes and services. Zhao et al. (2005) and Krogh and Zeisset (2002) also considered plant species richness as indicator of land degradation and desertification.

**Methodology:** Phytosociological relevés (Weber et al. 2000) were carried out in each sample plot of 30m×30m to assess plant characteristics (species richness, discriminant species and life forms). Woody species were collected on the 30m×30m plots while herb species were collected on sub-plots (10m×10m). We visually estimated the cover of each species in each sample according to the Braun-Blanquet cover/abundance scale (Westhoff & van der Maarel 1978): rare (less than 1% cover), 1 (1-5% cover), 2 (5-25% cover), 3 (25-50% cover), 4 (50-75% cover), 5 (75-100% cover).

The matrix of the data of the phytosociological relevés was submitted to Non-metric Multidimensional Scaling (NMS) for ordination. Cluster analysis was performed with flexible beta method based on Sorensen distance. Number of axes for projection of plant communities was retained with stress reduction. Testing for group differences was based on Multi-Response Permutation Procedures (MRPP). Discriminant species analysis of each group was undertaken according to the method of Dufrêne and Legendre (1997). Discriminant values for each species in each group were tested for statistical significance using a randomization technique (Monte Carlo method).

**Data needed:** Information about local flora to assess losses or gains of plant species richness.

**Limits of the indicator:** It should be stressed that plant species richness needs to be used in the context of further indices for biodiversity and changes of biodiversity. Different ecosystems naturally support different numbers of plant species and plant species richness is not necessarily an indicator of high ecological value or stability. It only represents a basic value for each site which can be used for the monitoring of species numbers within the same area or in relation to other variables, e. g. the percentage of threatened plant species on the total number of plant species.

**Related indicators:** Species diversity, vegetation cover

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**Project:** UNDESERT

**Date:** October 2012

**Name: Abundance**

**Brief Definition:** Abundance is an ecological concept referring to the relative representation of a species in a particular ecosystem

**Keywords:** Erosion, species richness, biodiversity

**Country:** common to all countries

**Level:** Plot-based

**DPSIR:** State

**Countries where indicator was tested:** Benin

**UNDESERT Spatial Scale:** West Africa

**Minimum time scale:** every 1-5 years

**Maximum time scale:** every 1-5 years

**Importance with respect to desertification and degradation:** Due to mismanagement of natural resources and overexploitation topsoil erosion is favored and hence productivity of soils reduced. Improper water use results often in salinization. These processes do not only affect crops but also rangelands and their biodiversity. The transformation of rangeland into irrigated cropland usually results in a loss of plant species and fauna associated with them. Later the topsoil is removed and parallel to this the potential for rehabilitating the former biodiversity. Biodiversity is a concept including the concept of abundance. Hence, loss of biodiversity impacts also abundance of species or group of species.

**International conventions and agreements:** The loss of biodiversity often reduces the stability of ecosystems, reducing their ability to provide goods and services that sustain human life. The protection of biodiversity is therefore in mankind's self-interest and has been recognized as a major aspect of sustainable development through the adoption of the Agreed text of the Convention on Biological Diversity at the Nairobi Conference in May of 1992. Furthermore the indicator is related to the MDGs and to the UNCCD.

**Definition and concepts:** Abundance is an ecological concept referring to the relative representation of a species in a particular ecosystem. It is usually measured as the large number of individuals found per sample. How species abundances are distributed within an ecosystem is referred to as relative species abundances. Abundance is contrasted with, but typically correlates to, incidence, which is the frequency with which the species occurs at all in a sample (Bartelt et al. 2001). When high abundance is accompanied by low incidence, it is considered locally or sporadically abundant. A variety of sampling methods are used to measure abundance. In many plant communities the abundances of plant species are measured by plant cover, for example the relative area covered by different plant species in a small plot (Damgaard 2009).

**Methodology:** ACFOR is an acronym for a simple, subjective scale used to describe species abundance within a given area. It is normally used within a sampling quadrat to indicate how many organisms there are in a particular habitat when it would not be practical to count them all. Instead, a smaller representative sample of the population is counted instead. The ACFOR scale is as follows:

 A - The species observed is "Abundant" within the given area.

 C - The species observed is "Common" within the given area.

 F - The species observed is "Frequent" within the given area.

 O - The species observed is "Occasional" within the given area

 R - The species observed is "Rare" within the given area.

This method of sampling is simple and easy to implement, but can be subjective. Species frequency is the number of times a plant species is present in a given number of quadrats of a particular size or at a given number of sample points. Frequency is usually expressed as a percentage and sometimes called a Frequency Index. The concept of frequency refers to the uniformity of a species in its distribution over an area. No counting is involved just a record of species present. Each individual of the species present is recorded, is a more accurate and reliable method of sampling. Relative species abundance is calculated by dividing the number of species from one group by the total number of species from all groups.

**Data needed:** Number of species

**Limits of the indicator:** Measurements for abundance is recommended to do during the wet period when there is a lot of biomass

**Related indicators:** Canopy cover, sheet erosion.

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**Literature:**

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**Project:** UNDESERT, **Date:** October 2012

**Name: Height**

**Brief Definition:** Assessment of the total height of the plant species *Combretum nigricans* on degraded and non-degraded land.

**Keywords**: Total height, *Combretum nigricans*, land degradation

**Country:** common to all countries

**Level:** Plot-based

**Position within DPSIR:** State

**Countries where indicator was tested:** Benin

**UNDESERT Spatial Scale:** West Africa

**Minimum time scale:** every 1-5 years

**Maximum time scale:** every 1-5 years

**Importance with respect to desertification and degradation:** Plant growth is controlled by the content and availability of soil nutrients and physicochemical characteristics of soils. Since land degradation changes soil nutrients and physicochemical characteristics, it also affects plant growth. Hence the total height of plants can be used as an indicator for land degradation.

**Definition and concepts:** Trees show considerable variation and flexibility in their shape and size of crowns, height and trunk diameters (Givnish 2002; Kuppers 1989; Vincent & Harja 2008). These are governed by an inherited developmental tendency, which may in turn be modified by the environment where the tree grows. The total tree height may be defined as the distance along the axis of the bole of the tree from the ground to the uppermost point (tip). In trees with a single, straight stem, this corresponds to the total length of the stem. Total height is a very important tree variable. Tree height is well correlated with other important tree and stand parameters such as tree volume and site. Latter is known as an indicator of environmental conditions persisting in the immediate area. Thus, total tree height is often assessed to provide quantitative information about a tree as well as qualitative information about the local ecosystem.

**International conventions and agreements**: The present indicator contributes to assess desertification and land degradation processes with quantitative information about the plant. It is directly relevant to the UNCCD and potentially important with regard to the implementation of rural development policies.

**Methodology:** The total height of the plant *Combretum nigricans* was measured in the tree savanna on bowe, concretion and sandy-clayish soils. Canonical discriminant analysis and one-way ANOVA were applied to the total height of *C. nigricans* for different soil types (sandy-clayish, concretion and ferricrete soils) using SAS software (SAS 1999) in order to analyze the relationship between soil and the total height of *C. nigricans*.

**Data needed:** In order to understand the effects of land degradation on plant growth and development, an investigation of height data for the species on non-degraded sites is needed.

**Limits of the indicator:** The total height was tested for one plant species only.Differences were found for sandy-clayish, concretion and ferricrete soils.

**Related indicators: N**umber of stems, number of branches, diameter at breast height, crown diameter

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**Literature:**

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**Project:** UNDESERT

**Date:** October 2012

**Name: Number of stems**

**Brief Definition:** Assessment of the total number of stems developed by the plant *Combretum nigricans* on degraded and non-degraded land.

**Keywords**: Total stems, *Combretum nigricans*, land degradation

**Country:** Common to all countries

**Level:** Plot-based

**Position within DPSIR:** State

**Countries where indicator was tested:** Benin

**UNDESERT Spatial Scale:** West Africa

**Minimum time scale:** every 1-5 years

**Maximum time scale:** every 1-5 years

**Importance with respect to desertification and degradation:** Plant growth and development is controlled by the content and availability of soil nutrients and by the physicochemical characteristics of soils. Since land degradation alternates soil nutrient content and availability and hence physicochemical characteristics of soils, it also affects plant growth and development. Hence the total number of stems developed by plants on degraded and non-degraded land is used as an indicator for the land degradation.

**Definition and concepts:** Stem is the main ascending axis of a plant that supports other parts of the tree such as brunches, leafs and fruits. This indicator is usually used with other indicators such as tree height, tree age, stem diameter at breast height and crown diameter in order to analyse their relation by means of regression techniques (Hummel 2000, McElhinny et al. 2005, Hemery et al. 2005). Quantitative information about a tree and qualitative information about the local ecosystem can be obtained.

**International conventions and agreements**: The present indicator contributes to assess desertification and land degradation with quantitative information about the plant. It is directly relevant to the UNCCD and potentially important with regard to the implementation of rural development policies.

**Methodology:** The number of stems for *Combretum nigricans* was measured in the tree savanna on bowe, concretion and sand-clayish soils. Canonical discriminant analysis and one-way ANOVA were applied to the total stems of *C. nigricans* for different soil types (sandy-clayish, concretion and ferricrete soils) using SAS software (SAS 1999) in order to analyze the relationship between soil and the total stems of *C. nigricans*.

**Data needed:** In order to understand the effects of land degradation on stem size and plant growth and development, an investigation of total stem data for *C. nigricans* on non-degraded sites is needed.

**Limits of the indicator: T**he variations of number of stems were tested for one plant species only. Differences were found for sandy-clayish, concretion and ferricrete soils.

**Related indicators:** Total height, numbers of branches, diameter at breast height, crown diameter

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**Project:** UNDESERT

**Date:** October 2012

**Name: Number of branches**

**Brief Definition:** Assessment of the total number of branches developed by the plant *Combretum nigricans* on degraded and non-degraded land.

**Keywords**: Total branches, *Combretum nigricans*, land degradation

**Country:** Common to all countries

**Level:** Plot-based

**Position within DPSIR:** State

**Countries where indicator was tested:** Benin

**UNDESERT Spatial Scale:** West Africa

**Minimum time scale:** every 1-5 years

**Maximum time scale:** every 1-5 years

**Importance with respect to desertification and degradation:** Plant growth and development is controlled by the content and availability of soil nutrients and physiochemical characteristic of soils. Since land degradation affects soil nutrient and soil physicochemical characteristics, it also affects plant growth and development. Hence the number of branches developed by plants on degraded and non-degraded land can be used as an indicator for land degradation.

**Definition and concepts:** Branch is the division of a stem or secondary stem arising from the main stem of a plant. Branch development is essential to quantity and quality of timber produced by plantations (Clark & Saucier 1989; Barbour & Kellogg 1990; Mäkinen & Colin 1999). This indicator is usually used with other indicators such as tree height, tree age, stem diameter at breast height and crown diameter in order to analyse their relation by means of regression techniques (Hummel 2000; McElhinny et al. 2005; Hemery et al. 2005). Quantitative information about a tree and qualitative information about the local ecosystem can be obtained.

**International conventions and agreements**: The present indicator contributes to assess desertification and land degradation with quantitative information about the plant. It is directly relevant to the UNCCD and potentially important with regard to the implementation of rural development policies.

**Methodology:** The number of branches for *Combretum nigricans* was measured in the tree savanna on bowe, concretion and sandy-clayish soils. Canonical discriminant analysis and one-way ANOVA were applied to the total branches of *C. nigricans* for different soil types (sandy-clayish, concretion and ferricrete soils) using SAS software (SAS 1999) in order to analyze the relationship between soil and the total branches of *C. nigricans*.

**Data needed:** In order to understand the effects of land degradation on plant growth and development, an investigation of total branch data for other plant species along the gradient of degradation is needed.

**Limits of the indicator:** The variations of total branches were tested for one plant species only.Differences were found for sandy-clayish, concretion and ferricrete soils.

**Related indicators:** Total height, numbers of branches, diameter at breast height, crown diameter

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**Project:** UNDESERT

**Date:** October 2012

**Name: Diameter at breast height (DBH)**

**Brief Definition** Assessment of the diameter of the plant *Combretum nigricans* at 1.3 m height above ground on degraded and non-degraded land.

**Keywords**: Tree diameter at 1.3 m, *Combretum nigricans*, land degradation

**Country:** Common to all countries

**Level:** Plot-based

**Position within DPSIR:** State

**Countries where indicator was tested:** Benin

**UNDESERT Spatial Scale:** West Africa

**Minimum time scale:** every 1-5 years

**Maximum time scale:** every 1-5 years

**Importance with respect to desertification and degradation:** Plant growth and development is controlled by the content and availability of soil nutrients and physicochemical characteristics of soils. Since land degradation alternates soil nutrient and physicochemical characteristics, it also affects plant growth. Hence the plant diameter at breast height on degraded and non-degraded land can be used as an indicator for the land degradation.

**Definition and concepts:** Trees show considerable variation and flexibility in their shape and size of crowns, height and trunk diameters (Givnish 2002, Kuppers 1989, Vincent & Harja 2008). These are governed by an inherited developmental tendency, which may in turn be modified by the environment where the tree grows. The plant diameter at breast height (DBH) is measured at 1.3 m height above ground. In many circumstances, the height of 1.3 m above the ground may not be clearly recognised or tree measurements at this height may be unrepresentative. DBH helps to determine growth, volume, yield and forest potential. DBH is a very important tree variable. It is well correlated with other important tree and stand parameters such as tree volume and site - an indicator of the environmental conditions that persists in the area. Thus, DBH is often measured to provide quantitative information about a tree as well as qualitative information about the local ecosystem.

**International conventions and agreements**: The present indicator contributes to assess desertification and land degradation with quantitative information about the plant. It is directly relevant to the UNCCD and potentially important with regard to the implementation of rural development policies.

**Methodology:** The total height of the plant *Combretum nigricans* was measured in the tree savanna on bowe, concretion and sandy-clayish soils. Canonical discriminant analysis and one-way ANOVA were applied to DBH of *C. nigricans* for different soil types (sandy-clayey, concretion and ferricrete soils) using SAS software (SAS 1999) in order to analyze the relationship between soil and the DBH of *C. nigricans*.

**Data needed:** In order to understand the effects of land degradation on plant growth and development, an investigation of DBH data for *C. nigricans* on non-degraded sites is needed.

**Limits of the indicator:** DBH was tested for one species only.Differences were found for sandy-clayish, concretion and ferricrete soils.

**Related indicators: Height:** Total height, numbers of stems, number of branches, crown diameter

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**Literature:**

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**Project:** UNDESERT

**Date:** October 2012

**Name: Crown diameter**

**Brief Definition:** The parameter represents thediameter of the crown of the plant (*Combretum nigricans*) on degraded land and non-degraded land.

**Keywords**: Diameter, crown, *Combretum nigricans*, land degradation

**Country:** Common to all countries

**Level:** Plot-based

**Position within DPSIR:** State

**Countries where indicator was tested:** Benin

**UNDESERT Spatial Scale:** West Africa

**Minimum time scale:** every 1-5 years

**Maximum time scale:** every 1-5 years

**Importance with respect to desertification and degradation:** Plant growth and development is controlled by the content and availability of soil nutrients and physicochemical characteristics of soils. Since land degradation alternates soil nutrient and physicochemical characteristics, it also affects plant growth. Hence the crown diameter of plants on degraded and non-degraded land can be used as an indicator for the land degradation.

**Definition and concepts:** Trees show considerable variation and flexibility in their shape and size of crowns, height and trunk diameters (Givnish 2002, Kuppers 1989, Vincent & Harja 2008). These are governed by an inherited developmental tendency, which may in turn be modified by the environment where the tree grows. The size of a tree canopy and its height above the ground is significant for a tree as it determines the total amount of light that the tree intercepts for photosynthesis (Midgley 2003, Russel et al. 1989). Thus, the size of a tree crown has a considerable importance and is strongly correlated with the growth of the tree and its different parts. The crown diameter can be assessed from the ground or from aerial photographs. The ground measurement is carried out by projecting the edges of the crown vertically to ground using a plumb bob, a crownometer and an optical prism. For the measurements of crown diameter by means of aerial photographs, the accuracy is dependent on image scale, film resolution and individual skills. The crown diameter is strongly correlated with DBH and is used to assess the tree volume. Crown diameter provides quantitative information about a tree and qualitative information about the local ecosystem.

**International conventions and agreements**: The present indicator, as a contributing indicator to assess desertification and land degradation with quantitative information about the tree, is directly relevant to the UNCCD and potentially important in relation to the implementation of rural development policies.

**Methodology:** The crown diameter of the plant (here: *Combretum nigricans*) was measured in the tree savanna on bowe, concretion and sandy-clayish soils. Canonical discriminant analysis and one-way ANOVA were applied to the crown diameter values of *C. nigricans* in different soil conditions (sandy-clayish, concretion and ferricrete soil) using SAS software (SAS 1999). The objective was to analyze the relationship between soil and crown diameter of *C. nigricans*.

**Data needed:** In order to understand the effects of land degradation on plant growth and development, an investigation of crown diameter values for the plant under study has to be made on degraded and non-degraded sites.

**Limits of the indicator:** The crown diameter was only assessed for one species (*C. nigricans*). Differences were found between sandy-clayish, concretion and ferricrete soils.

**Related indicators:** Height, numbers of stems, number of branches, diameter at breast height

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**Project:** UNDESERT

**Date:** October 2012

**Name: Life forms index of vegetation disturbance**

**Brief Definition:** The degree of disturbance of vegetation communities due to land degradation, based on the relative evolution of the number of therophytes and phanerophytes

**Keywords:** Erosion, disturbance, vegetation communities, life forms

**Country:** common to all countries

**Level:** Plot-based

**DPSIR:** State

**Countries where indicator was tested:** Benin

**UNDESERT Spatial Scale:** West Africa

**Minimum time scale:** every 1-5 years

**Maximum time scale:** every 1-5 years

**Importance with respect to desertification and degradation:** The state of a nation’s ‘‘biodiversity’’ has emerged as an increasingly important indicator of environmental health (Wilson 1988). The subject of biodiversity loss has been so critical in the past 100 years that it has been considered as a global change in its own right (Walker & Steffen 1996). Land use activities are seen as the major cause of land degradation and biodiversity loss (Stocking & Murnaghan 2000; Foley et al. 2005; Yeo et al. 2010; Boardmana et al. 2003). The impact of land use change is likely to become by 2100 a more important threat for biodiversity than climate change, nitrogen deposition, species introductions and changing atmospheric concentrations of carbon dioxide at global scales (Chapin et al. 2000; Sala et al. 2000). Balmford et al. (2005) suggest that by 2050 the impact of agricultural conversion on biodiversity at global scale will be as signiﬁcant as the effects of other drivers such as population size or per capita consumption. This assertion is confirmed by many studies which try to model future trends (Tilman et al. 2001; OECD 2008). Species composition, species diversity, coverage, structure and life-form of vegetation are altered by land degradation due mainly to land use (Li et al. 2006). One of the immediate causes of land degradation is inappropriate land use, including overgrazing, excessive irrigation, and intensive tillage and cropping. Increasing comprehension of relationships between land degradation and biodiversity is fundamental to understanding the links between people and their environment and to develop more comprehensive monitoring systems, and more sophisticated modeling and scenario tools.

**International conventions and agreements:** The indicator gives information about the type of life form prevailing on differently degraded sites. The loss of biodiversity often reduces the stability of ecosystems, reducing their ability to provide goods and services that sustain human life. The protection of biodiversity is therefore in mankind's self-interest and has been recognized as a major aspect of sustainable development through the adoption of the Agreed text of the Convention on Biological Diversity at the Nairobi Conference in May of 1992. Furthermore the indicator is related to the MDGs and to the UNCCD.

**Definition and concepts:** Life forms index of vegetation disturbance is based on the biodiversity’s indicators of disturbance and shows the relative evolution (number or cover) of therophytes and phanerophytes. Along successional stages there are two major types of life forms whose evolution (in terms of number or cover) are negatively correlated. Therophytes are supposed to be more abundant/dominant in pioneer stages (more disturbed). This trend decreases while reaching less disturbed stages. On the contrary, the number/cover of phanerophytes is supposed to increase from disturbed to stable communities (Pidwirny & Jones 2010; Bangirinama 2009; Djego 2006). The spatial and temporal comparison of the evolution of the two groups is expressed in terms of ratio or relative frequency. This method was inspired by Adomou et al.(2005). They used ratio to compute the phytogeographical index (*Ip*) which made it possible to compare and to classify different plant communities according to their level of affinity to the Sudanian or Guineo-Congolian region.

**Methodology:** Data about species was collected by phytosociological relevés according to Braun-Blanquet (1932) within nested sample plots (30m x 30m for the woody layer and 10m x 10m for the herbaceous layer). After their identification, the life form of each species was noted. Afterwards the index was computed as:



where *IL* is the life forms index, Ph is the frequency of Phanerophytes and Th is the frequency of Therophytes.

**Data needed:** Frequency of life form type of species collected

**Limits of the indicator:** Species composition can change in time, especially in grasslands or annual vegetation. Collection of species compositon should be undertaken during the wet period when biomass production is at its maximum and soil erosion occurs

**Related indicators: S**heet erosion, soil sealing and crusting, change in colour, armour layer, canopy cover, ground cover

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**Project:** UNDESERT

**Date:** October2012

**Name: Canopy cover**

**Brief Definition:** The degree of protection afforded by vegetation against the action of different erosive agents

**Keywords:** Erosion, plant, soil protection

**Country:** Common to all countries

**Level:** Plot-based

**DPSIR:** Pressure

**Countries where indicator was tested:** Benin

**UNDESERT Spatial Scale:** West Africa

**Minimum time scale:** every 1-5 years

**Maximum time scale:** every 1-5 years

**Importance with respect to desertification and degradation:** One of the immediate causes of land degradation is inappropriate land use, including overgrazing, excessive irrigation, and intensive tillage and cropping. The resulting degradation affects ecosystem structures and functions in general and vegetation cover/canopy cover in particular. Canopy is defined as the cover formed by the leafy upper branches of the trees in a forest. Canopy cover is then a key factor on land degradation. Reduction in the perennial cover is regarded as an important indicator of the onset of desertification. Canopy cover plays a very important role on protecting the soil surface from raindrop splashing, increasing soil organic matter, soil aggregate stability, water holding capacity, hydraulic conductivity, retarding and reducing surface water runoff, etc.. Many authors demonstrated that in a wide range of environments, both water run-off and soil sediment loss decrease exponentially as the percentage of canopy cover increases. Moreover, canopy cover is closely related to annual rainfall and soil depth. As rainfall and soil depth decrease, vegetation cover decreases.

**International conventions and agreements:** The UNCCD states that soil erosion is one of the main causes of land degradation. "Land degradation means reduction or loss, in arid, semi-arid and dry sub-humid areas, of the biological or economic productivity and complexity of rainfed cropland, irrigated cropland, or range, pasture, forest and woodlands resulting from land uses or from a process or combination of processes, including processes arising from human activities and habitation patterns". As canopy cover has a direct influence on soil erosion this indicator is related to the UNCCD.

**Definition and concepts:** Many authors demonstrated that in a wide range of environments, both run-off and sediment loss decrease exponentially as the percentage of plant cover increases. It has been known at least since 1916 ([Kiesselbach, 1916](#_ENREF_3)) that plants intercept and transmit rainwater down their stems and at least since 1948 that vegetation canopies change the drop-size distribution of rain and that splash detachment under canopies is different from that on a bare soil ([Chapman, 1948](#_ENREF_2)). Plant and litter cover also lower evapotranspiration rates of soil and prevent higher soil temperatures, thus working as an “air-conditioner” (Molinar et al. 2001; Kohutiar 2008). This indicator is suggested by the Desertlink project and is included in the Desertification Indicator System for Mediterranean Europe (DIS4ME). Moreover the Land Degradation Assessment in Drylands (LADA) project suggested vegetation cover decrease as an indicator of biological degradation of land (FAO 2003).

**Methodology:** The canopy cover was assessed with the Cc factor. Cc is a one of the sub-factors of the cover-management factor (C) which represents the effects of vegetation, management, and erosion-control practices on soil loss in the Revised Universal Soil Loss Equation (Bie de 2005; Jakubíková et al. 2006). Canopy cover protects bare soil against soil loss. The protection offered by the foliage decreases in the direction of higher layers in the canopy. Since the canopy cover factor for a specific vegetation type must take this into account, it depends on the “effective canopy cover” and the “effective canopy height”.

Assuming a random distribution of basal cover and a non-random positioning of successive canopy layers, the “effective canopy cover” by layer (Bie de 2005) is (all fractions):

1st layer = (canopy cover‑basal cover).

2nd layer = 2nd canopy cover\*(1‑1st layer).

3rd layer = 3rd canopy cover\*(1‑2nd layer)\*(1‑1st layer).

Figure 1 shows the diagram for “effective canopy height” (EH) determination. The “effective canopy height” is computed (Bie de 2005; Jakubíková et al. 2006) as:

CH = Ht – FH = 2/3 (Ht– Hl)

Top height Ht

Height of the lower layer H­l

Effective fall height FH

Effective canopy height EH

Figure1: Determination of the effective canopy height for the cylindrical shape of the plant body.

FH is defined as the average path of the raindrop falling from the plant on which it was previously intercepted. FH = 1/3 (Ht – Hl) + Hl (Jakubíková et al. 2006).

Cc is computed layer by layer according to Figure 2 (Wischmeier & Smith 1978; Kooiman 1987; Palmer 1989). Cc was computed by summing all (X) layer-specific Cc factors as [(Cc,1+Cc,2+…+Cc,X)‑(X‑1)]. Lower values of Cc correspond with good canopy cover and then, less soil loss (de Bie 2005).

Figure 2: CC factor assessment

The Cc figure presents [1‑ ((1‑ ((37.13H‑4.02H2+0.146H3)/100))\*C)], where C is the “effective canopy cover” (%) and H the “effective canopy height” (m).

**Data needed:** Canopy cover assessed by using Braun-Blanquet (1932) cover/abundance scale : rare (less than 1% cover), 1 (1-5% cover), 2 (5-25% cover) , 3 (25-50% cover), 4 (50-75% cover), 5 (75-100% cover).

**Limits of the indicator:** Canopy cover can be altered with time especially for perennial deciduous plants or annual vegetation. Measurements for canopy cover are especially important during the wet period when soil erosion occurs.

**Related indicators:** Sheet erosion, rills, colour change.

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**Project:** UNDESERT

**Date:** October2012

**Name: Ground cover**

**Brief Definition:** The degree of protection offered by litter and stones against different erosive agents

**Keywords:** Erosion, soil protection, litter, stones

**Country:** Common to all countries

**Level:** Plot-based

**DPSIR:** Pressure

**Countries where indicator was tested:** Benin

**UNDESERT Spatial Scale:** West Africa

**Minimum time scale:** every 1-5 years

**Maximum time scale:** every 1-5 years

**Importance with respect to desertification and degradation:** One of the immediate causes of land degradation is inappropriate land use, including overgrazing, excessive irrigation, and intensive tillage and cropping. The resulting degradation induces the removal of vegetation and all protection of soil by litter and stones. Ground cover is key factor on land degradation. Removal or decrease of ground cover leaves soil bare, without protection, vulnerable to erosion. Stones and litter play an important role on protecting the soil surface from raindrop splashing, increasing soil organic matter, soil aggregate stability, water holding capacity, hydraulic conductivity, and retarding and reducing surface water runoff.

**International conventions and agreements:** The indicator represents ground cover. Ground cover has an impact on wind and water erosion of soils as it favors these processes. The UNCCD states that soil erosion is one of the main causes of land degradation. "Land degradation means reduction or loss, in arid, semi-arid and dry sub-humid areas, of the biological or economic productivity and complexity of rainfed cropland, irrigated cropland, or range, pasture, forest and woodlands resulting from land uses or from a process or combination of processes, including processes arising from human activities and habitation patterns".

**Definition and concepts:** Many authors have demonstrated that in a wide range of environments, both run-off and sediment loss decrease as the percentage of ground cover increases. Litter and stone protect soils from raindrop impact and splash, tend to slow down the movement of surface runoff and increase the infiltration rate and water holding capacity of the soil (Molinar et al. 2001; Bonan 2002). According to Bonan ([2002](#_ENREF_1)), the erosion factor used to estimate total erosion losses in forests, drops from 0.36 on soils with no to 0.003 with 100% litter coverage. The coverage of litter also lowers evapotranspiration rates of soils and prevents soils from high temperatures, thus working as an “air-conditioner” (Kohutiar 2008; Molinar et al. 2001). The Land Degradation Assessment in Drylands (LADA) project suggested percentage of ground cover decrease as an indicator of biological degradation of land (FAO 2003).

**Methodology:** The ground cover factor is assessed with the Cc factor. Cc is a one of the sub-factors of the cover-management factor (C) which represents the effects of vegetation, management, and erosion-control practices on soil loss in the Revised Universal Soil Loss Equation (Bie de 2005; Jakubíkovká et al. 2006). Soil loss decreases sharply as sparse ground cover becomes denser. CG is computed by cover type using [e-(b\*Ground Cover (%))], where b is the ground surface roughness. Ground cover (%) is computed as [%litter+%basal cover+%stones] (de Bie 2005). A value of 0.05 was taken as ground surface roughness factor (b) for rough field surfaces and 0.04 for smooth field surfaces. CG values were calculated for each plot (Figure 1). The equations were adapted from de Bie (2005), USDA ([1991](#_ENREF_3)) and Renard et al.([1994](#_ENREF_2)).

**Figure 1: CG factor assessment**

The CG figure is defined by [e‑(b\*Ground Cover (%))],where b is the surface roughness.

**Data needed:** Ground cover assessed by using Braun-Blanquet (1932) cover/abundance scale: rare (less than 1% cover), 1 (1-5% cover), 2 (5-25% cover), 3 (25-50% cover), 4 (50-75% cover), 5 (75-100% cover).

**Limits of the indicator:** During rainy season, ground cover is difficult to be assessed because of the biomass that covers it. Sample plots have to be cleaned or the assessment has to be made during a period of low vegetation.

**Related indicators:** Sheet erosion, soil sealing and crusting, armour layer, change in colour, canopy cover.

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**Literature:**

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**Project:** UNDESERT

**Date:** October 2012

**Name: Chorological index of vegetation disturbance**

**Brief Definition:** The degree of disturbance of vegetation communities due to land degradation, based on the relative evolution of the number of species with wide distribution and regional species

**Keywords:** Erosion, disturbance, vegetation communities, chorological types

**Country:** Common to all countries

**Level:** Plot-based

**DPSIR:** State

**Countries where indicator was tested:** Benin

**UNDESERT Spatial Scale:** West Africa

**Minimum time scale:** every 1-5 years

**Maximum time scale:** every 1-5 years

**Importance with respect to desertification and degradation:** The state of a nation’s biodiversity has emerged as an increasingly important indicator of environmental health (Wilson 1988). Indeed, the issue of biodiversity loss has been so critical in the past 100 years that it has been considered as a global change (Walker & Steffen 1996). Land use activities are seen as the major cause of land degradation and biodiversity loss (Stocking & Murnaghan 2000; Foley et al. 2005; Yeo et al. 2010; Boardmana et al. 2003). The impact of land use change is likely to become by 2100 a more important threat on biodiversity than climate change, nitrogen deposition, species introduction and changing atmospheric concentrations of carbon dioxide at global scales (Chapin et al. 2000; Sala et al. 2000). In the same way, Balmford et al. (2005) suggest that by 2050, the impact of agricultural conversion on biodiversity at global scales, should be as signiﬁcant as the effects of other drivers such as population size or per capita consumption. This assertion is confirmed by many studies which try to model future trends (Tilman et al. 2001; OECD 2008). Species composition, species diversity, coverage, structure and life-form of vegetation are altered by land degradation due mainly to land use (Li et al. 2006). One of the immediate causes of land degradation is inappropriate land use, including overgrazing, excessive irrigation, and intensive tillage and cropping. Then, natural vegetation could be considered as the first and major component affected by land degradation. Increasing comprehension of relationships between land degradation and biodiversity is fundamental to understanding the links between people and their environment and to develop more comprehensive monitoring systems, and more sophisticated modeling and scenario tools.

**International conventions and agreements:** The indicator gives information about the degree of disturbance of vegetation communities due to land degradation, based on the relative evolution of the number of species with wide distribution and regional species. The loss of biodiversity often reduces the stability of ecosystems, reducing their ability to provide goods and services that sustain human life. The protection of biodiversity is therefore in mankind's self-interest and has been recognized as a major aspect of sustainable development through the adoption of the Agreed text of the Convention on Biological Diversity at the Nairobi Conference in May of 1992. Furthermore the indicator is related to the MDGs and to the UNCCD.

**Definition and concepts:** The chorological index of vegetation disturbance is based on the biodiversity’s indicators of disturbance and shows the relative evolution (number or cover) of species with wide distribution and regional species. Along successional stages (along a gradient of disturbance), there are two major groups of chorological types of species which evolutions (in terms of number or cover) are negatively correlated. Species with wide distributions are supposed to be more abundant/dominant in pioneer stages (more disturbed sites). This trend decreases while one reaches less disturbed stages. On the contrary, the number/cover of regional species is supposed to increase from disturbed to stable communities (Djego 2006; Bangirinama et al. 2009; Pidwirny & Jones 2010). Moreover, in order to allow spatial and temporal comparison of the evolution of the two groups named above is expressed in terms of ratio or relative frequency. This method was inspired by Adomou et al.([2005](#_ENREF_1)). They used the ratio to compute the phytogeographical index (*Ip*) which made it possible to compare and to classify different plant communities according to their level of affinity to the Sudanian or Guineo-Congolian region.

**Methodology:** Data about species is collected by phytosociological relevés according to Braun-Blanquet ([1932](#_ENREF_2)) within nested sample plots (30mx30m for the woody layer and 10mx10m for the herbaceous layer). After their identification, the chorological types of each species are noted. Afterwards, the index is computed as:

where *IC* is the chorological index and S, SZ, SG, Pt, PAL, AA, TA, PRA are respectively the frequency of Sudanian, Sudano-Zambezian, Sudano-Guinean, Pantropical, Paleotropical, Afro-American, Tropical Africa and Pluri Regional in Africa species.

**Data needed:** Frequency of chorological types of species collected

**Limits of the indicator:** Species composition can be altered with time especially in grasslands or annual vegetation ytpes. Measurements for species composition are especially important during the wet period when biomass production is maximal and soil erosion occurs.

**Related indicators:** Sheet erosion, soil sealing and crusting, change in colour, canopy cover, ground cover.

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**Project:** UNDESERT

**Date: October** 2012

**Name: Dispersal types index of vegetation disturbance**

**Brief Definition:** The degree of disturbance of vegetation communities due to land degradation, based on the relative evolution of the number of sclerochory and sarcochory

**Keywords:** Erosion, disturbance, vegetation communities, dispersal types

**Country:** common to all countries

**Level:** Plot-based

**DPSIR:** State

**Countries where indicator was tested:** Benin

**UNDESERT Spatial Scale:** West Africa

**Minimum time scale:** every 1-5 years

**Maximum time scale:** every 1-5 years

**Importance with respect to desertification and degradation:** Land use activities are seen as the major cause of land degradation and biodiversity loss (Stocking & Murnaghan 2000; Foley et al. 2005; Yeo et al. 2010; Boardmana et al. 2003). The impact of land use change on biodiversity is likely to become by 2100 a more important threat than climate change, nitrogen deposition, species introductions and changing atmospheric concentrations of carbon dioxide at global scales (Chapin et al. 2000; Sala et al. 2000). In the same way Balmford et al. (2005) suggest that by 2050 the impact of agricultural conversion on biodiversity at global scales will be as signiﬁcant as the effects of other drivers such as population size or per capita consumption. This assertion is confirmed by many studies which model future trends (Tilman et al. 2001; OECD 2008). Species composition, species diversity, coverage, structure and life-form of vegetation are altered by land degradation due mainly to land use (Li et al. 2006). One of the immediate causes of land degradation is inappropriate land use, including overgrazing, excessive irrigation, and intensive tillage and cropping. A profound comprehension of relationships between land degradation and biodiversity is fundamental for understanding the links between people and their environment and for developing more comprehensive monitoring systems, and more sophisticated modeling tools and scenarios.

**International conventions and agreements:** The indicator represents the degree of disturbance of vegetation communities due to land degradation, based on the relative evolution of the number of sclerochory and sarcochory. It is directly relevant to the UNCCD.

**Definition and concepts:** The dispersal type index of vegetation disturbance is based on the biodiversity’s indicator of disturbance and shows the relative evolution (number or cover) of sclerochory and sarcochory. Along successional stages there are two major of species life forms whose evolutions (in terms of number/cover) are negatively correlated. Sclerochory is supposed to be more abundant/dominant in pioneer stages (more disturbed). This trend decreases while reaching less disturbed stages. On the contrary, the number/cover of sarcochory is supposed to increase from disturbed to stable communities (Pidwirny & Jones 2010; Bangirinama 2009; Djego 2006). Moreover, in order to allow spatial and temporal comparison the evolution of the two groups is expressed in term of ratio or relative frequency. This method was inspired by Adomou et al.(2005). They used ratio to compute the phytogeographical index (*Ip*) which made it possible to compare and to classify different plant communities according to their level of affinity to the Sudanian or Guineo-Congolian region.

**Methodology:** Data about species is collected by phytosociological relevés according to Braun-Blanquet (1932) within nested sample plots (30m x 30m for the woody layer and 10m x 10m for the herbaceous layer). After their identification, the life form of each species is noted. Afterwards the index is computed as:



where *ID* is the dispersal types index, Sarco is the frequency of Sarcochory and Sclero is the frequency of Sclerochory.

**Data needed:** Frequency of dispersal types of species collected

**Limits of the indicator:** Species composition can change, especially in grasslands or annual vegetation. Observation of species composition should be made during the wet period when biomass production is at its maximum and soil erosion occurs

**Related indicators:** Sheet erosion, soil sealing and crusting, change in colour, canopy cover, ground cover

**Authors (University/Institute):** University of Abomey Calavi/ Laboratory of Applied Ecology

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**Literature:**

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**Project:** UNDESERT

**Date:** October 2012

**Name: Grazing intensity**

**Brief Definition:** The degree of disturbance of vegetation communities due to grazing and trampling of cattle

**Keywords:** Disturbance, grazing, vegetation communities, trampling, cattle

**Country:** Common to all countries

**Level:** Plot-based

**DPSIR:** Pressure

**Countries where indicator was tested:** Burkina Faso

**UNDESERT Spatial Scale:** West Africa

**Minimum time scale:** every 1-3 years

**Maximum time scale:** every 1-3 years

**Importance with respect to desertification and degradation:** Grazing is known as one of the principal human economic activities that cause desertification and degradation of land in Africa (Zhao et al. 2005).

**International conventions and agreements:** The indicator assesses the degree of disturbance of vegetation communities and soils due to grazing activities and trampling. The loss of biodiversity and compaction of soils reduce the stability of ecosystem and their ability to provide goods and services that sustain human life. The protection of biodiversity is a mankind's self-interest and has been recognized as a major aspect of sustainable development through the adoption of the Agreed text of the Convention on Biological Diversity at the Nairobi Conference in May of 1992. Furthermore the indicator is related to the MDGs and to the UNCCD.

**Definition and concepts:** The compaction of the soils by cattle trampling changes their biological and physical-chemical characteristics and subsequently vegetation composition and species patterns change. Around Pama Fauna Reserve in southern Burkina Faso the effect of grazing intensity was assessed on species richness and woody/herb cover and the density of woody species.

Methodology: In total 214 phytosociological relevés were sampled in the North-Sudanian zone (119) and in the South-Sudanian zone (95). Woody plants were sampled on 1,000 m2 plots and herbaceous plants on 100 m2 plots. The classification of the grazing intensity was based on presence of animal tracks and shrubs (stratum of very dense shrub cover). Four grazing intensities were differentiated: PP (peu piétiné/pâturé, little trampled/grazed), MP (moyennement piétiné/pâturé, medium trampled/grazed), TP (très piétiné/pâturé, very trampled/grazed), FTP (fortement piétiné/pâturé, heavily trampled/grazed).

Tukey’s Honestly Significant Difference (HSD) Test proved significant differences between the total species richness along the gradient of grazing (F-value 15.79, p < 0.001). Calculated separately for herb species richness, HSD was highly significant along the gradient of grazing (F-value 25.08, p < 0.001) (Table 4). The lowest total species richness was observed on heavily trampled/grazed sites (FTP, 24) and so were herb species richness (14.5) and woody species richness (9.5) separatedly. These results are congruent with Holechek et al. (1999) who defined that severe grazing or overgrazing impedes forage species to maintain themselves. This can lead to degradation of plants and soils and the loss of species richness (Keya 1998).

Woody species density per ha was highest on medium trampled/grazed land (624.2) and it was lowest on heavily trampled/grazed land (275).

**Data needed:** Grazing intensities based on expert opinion of each field plot

**Limits of the indicator:** Subjective assessment of the sites

**Related indicators: Authors (University/Institute):** University of Ouagadougou

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**Literature:**

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**Project:** UNDESERT

**Date: October** 2012

**Name: Electrical conductivity (EC) of soils**

**Brief Definition:** Determination of the degree of salinization in the soil

**Keywords:** Electrical conductivity, soil, salinization

**Country:** common to all countries

**Level:** Plot-based

**Position within DPSIR:** State

**Countries where indicator was tested:** Benin

**UNDESERT Spatial Scale:** West Africa

**Minimum time scale:** every 1-5 years

**Maximum time scale:** every 1-5 years

**Importance with respect to desertification and degradation:** Electrical conductivity measure the degree of salinization of soil, which is an important cause of land degradation. Salinization is responsible for the formation of Solontschaks. Here the presence of free salts makes the soil highly breakable, structure less and uniform (Paton & Humphreys 2007). It becomes useless for cultivation as the quantity of available nutrients is poor.

**International conventions and agreements:** The indicator measures the degree of salinization in soils and contributes to determine the provisioning and supporting services of an ecosystem. The degree of salinization of soil is a key factor in accelerating soil erosion and thus for irreversible land degradation and desertification. It is therefore directly relevant to the international agreements such as UNCCD and the MDGs.

**Definition and concepts:** Soil electrical conductivity measures the ability soil water has to conduct an electric current. All the important nutrients for plants growth take either the form of cations or anions and are dissolved in the soil water. They carry electrical charge and determine the electrical conductivity of the soil. Thus, the indicator is a good measure of the degree of salinization. Electrical conductivity is denoted by the Greek letter σ (Sigma). Its SI unit (Système international d'unités) is siemens per metre (S/m-1).

In the DESIRE project, electrical conductivity of the soil is considered as main cause of land degradation and is used to define desertification risks in the Environmentally Sensitive Areas (ESA). In DESIRE soil electrical conductivity was used mainly in plain areas where the main process of desertification consist in soil salinization. Soil electrical conductivity was also considered in the LADA project as indicator of land degradation. It has also been used in several scientific researches as an indicator of land degradation and desertification in different countries of the world (Lavee et al. 1998; Muukkonen et al. 2009;Bockheim & Gennadiyev 2009; Khresa et al. 1998; Mills and Fey 2004; Yüksek & Yüksek 2011; Emadi et al. 2009).

**Methodology:** In our study in Benin nine topsoil sample pairs were taken on bowal plots (degraded land) and non-bowal plots (forest soil for control). We used a soil auger to a depth of 10 cm. The composite topsoil samples were dried at 105°C in the laboratory, crushed and sieved through a 2 mm screenThe electrical conductivity of the material was measured in a 1:5 soil extract (Rhoades 1982). T-tests were made to investigate the differences of the soil electrical conductivity of these topsoils between bowal plots and non-bowal plots (forest soil).

**Data required:** Collection of soil samples on differently degraded sites and analysis in the laboratory, a classification of the level of degradation of bowal according to electrical conductivity.

**Limits of the indicator:** Soil electrical conductivity measure the degree of soil salinization, important cause of soil degradation. This indicator has no limit as indicator of land degradation.

**Related indicators:** extractable phosphorus, total N, exchangeable potassium, species richness, soil organic matter, soil texture, plant cover

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**Project:** UNDESERT

**Date:** October 2012

**Name: Soil organic matter (SOM)**

**Brief Definition:** The soil organic matter (SOM) is a solid phase component which is the nutrient storehouse of vegetation

**Keywords** Soil, organic matter, nutrient, vegetation

**Country:** common to all countries

**Level:** Plot-based

**DPSIR:** State

**Countries where indicator was tested:** Benin

**UNDESERT Spatial Scale:** West Africa

**Minimum time scale:** every 1-5 years

**Maximum time scale:** every 1-5 years

**Importance with respect to desertification and degradation:** Soil degradation is an important contributor to land degradation. The loss of organic material leads to a decline in quality and productivity of a soil.

**International conventions and agreements:** The UNCCD emphasizes the fact that combating desertification must be tackled within the general framework of actions to promote sustainable development. Decrease of organic matter is a key factor in accelerating soil erosion and thus for irreversible land degradation and desertification.

**Broad definition and concepts:** The soil organic matter (SOM) is a solid phase component which is the nutrient storehouse of vegetation (Wang et al., 2010). Soil organic matter does not only provide the nutrients for plants but also improves the physical conditions and temperature of a soil. Soil organic matter is one of the most important parameters of soil fertility (Wang et al. 2010). The loss of organic material in soil is an indicator of land degradation and decline in productivity. Land use change affects organic matter content and aggregate stability in a significant way (Kosmas et al. 1999). In many deserted areas, the loss of vegetation cover brings out a reduction of soil organic matter (DESERTLINKS 2005). This reduction has a direct effect on soil structure as soil aggregates are weakened. The degradation of the soil structure on the surface has a negative effect on the biomass productivity of the soil by reducing the water availability for plants and hampering the regeneration of vegetation cover. This indicator of land degradation and desertification was also used in projects like the MEDALUS project, the DESERTLINKS project, the DESIRE project and other scientific research projects on land degradation (Zhao et al. 2005; Wang et al. 2010; FAO 2003; Lavee et al. 1997; Lal 2006; Zhao et al. 2010)

**Methodology:** In our study we used ninetopsoil sample pairs taken on bowe (degraded land) and non-bowe plots (forest soil for control). We used a soil auger to a depth of 10 cm. The composite topsoil samples were dried at 105°C in the laboratory, crushed and sieved through a 2 mm screen. The following soil analyses were undertaken. The soil organic matter (SOM) was taken by the K2Cr2O7 method. T-tests were made to investigate on the differences of the soil organic matter of topsoils on bowe and forest plots.

**Data needed:** Soil samples are needed and a reference system of land degradation classes regarding soil organic matter content are needed for West Africa.

**Limits of the indicator:** no limit as indicator of land degradation and desertification

**Related indicators: e**xtractable phosphorus, total N, exchangeable potassium, species richness, electrical conductivity, soil texture, plant cover, soil organic carbon

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**Literature:**

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**Project:** UNDESERT

**Date:** October 2012

**Name: Extractable phosphorus of soils**

**Brief Definition:** Determination ofextractable phosphorus in the soil

**Keywords**: Extractable phosphorus, concentration, soil, land degradation

**Country:** common to all countries

**Level:** Plot-based

**Position within DPSIR:** State

**Countries where indicator was tested:** Benin

**UNDESERT Spatial Scale:** West Africa

**Minimum time scale:** every 1-5 years

**Maximum time scale:** every 1-5 years

**Importance with respect to desertification and degradation:** Extractable phosphorus is an indispensable nutrient for plant growth. A reduced content of extractable phosphorus implies an increased risk of desertification. Therefore soil extractable phosphorus is a good indicator for assessing land degradation and desertification.

**International conventions and agreements:** The indicator measures the amount of extractable phosphorus available for plant growth and contributes to determine the provisioning and supporting services of an ecosystem. It is therefore directly relevant to the international agreements such as UNCCD and the MDGs.

**Definition and concepts:** Traditionally, extractable phosphorus has been used to describe the amount of phosphorus in soils that are available for crop uptake. Furthermore it has been used to determine the probability of crop response to added phosphorus, and thereby the requirements of fertilization. Bioavailable phosphorus is often used to describe phosphorus in soils or sediments that is available for uptake by algae or macrophytes in surface waters. To some extent, bioavailable phosphorus is also used to describe the availability of soil phosphorus to plants (Barber 1995). Extractable phosphorus has been applied in many studies to assess land degradation and desertification. In northeastern Tanzania, desertiﬁed landscapes showed overall losses of soil extractable phosphorus compared to non-desertified landscapes (Oba et al. 2008). The small concentrations of extractable phosphorus in desertiﬁed landscapes are consistent with reported effects of land degradation on soil nutrients (Palumbo et al. 2004). The reduced amount of soil nutrients such as extractable phosphorus implies an increased risk of desertiﬁcation (Wang et al. 2004). According to Martinez-Mena et al. (2002) and Su et al. (2004) desertiﬁed landscapes have most probably been stripped of nutrients. Khresat et al. (1998) and Lafleur et al. (2005) considered extractable phosphorus as a valuable indicator of land degradation in South Africa and Jordan.

**Methodology:** In our study in Benin we took ninetopsoil sample pairs on bowal plots (degraded land) and non-bowal plots (forest soil for control). We used a soil auger to a depth of 10 cm. The composite topsoil samples were dried at 105°C in the laboratory, crushed and sieved through a 2 mm screen. The following soil analyses were undertaken. The extractable Phosphorus was analyzed by using a Bray-2 extract as described by Bray and Kurtz (1945). T-tests were made to investigate the differences of the soil extractable phosphorus of topsoils on bowal and on forest plots.

**Data required:** Collection of soil samples on differently degraded sites and analysis in the laboratory.

**Limits of the indicator:** Soil extractable phosphorus is an important nutrient for plant growth. When the amount in the soil decreases, the risk of land degradation and desertification increases. This indicator has no limit as indicator of land degradation.

**Related indicators:** extractable phosphorus, total N, exchangeable potassium, species richness organic matter, soil texture, plant cover

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**Project:** UNDESERT

**Date:** October, 2012

**Name: Silt content**

**Brief Definition:** Determination of silt content in the soil

**Keywords:** Silt content, land degradation

**Country:** common to all countries

**Level:** Plot-based

**DPSIR:** State

**Countries where indicator was tested:** Benin

**UNDESERT Spatial Scale:** West Africa

**Minimum time scale:** every 1-5 years

**Maximum time scale:** every 1-5 years

**Importance with respect to desertification and degradation:** A change in silt content represents a change in soil particle distribution (such as due to soil loss). It induces alteration of the soil texture and structure and causes compaction and physical degradation of the soil.

**International conventions and agreements:** The UNCCD emphasizes the fact that combating desertification must be tackled within the general framework of actions to promote sustainable development. Decrease of silt content in soil is a key factor in accelerating soil erosion and thus for irreversible land degradation and desertification.

**Definition and concepts:** Silt (particles in the soil ≤ 75 micrometers in diameter) content is determined by measuring the portion of dry aggregate material that passes through a 200-mesh screen. The size of eroding aggregates is influenced by the silt content of the soil (Couper 2003; Opara 2009). Various scientific researchers have considered silt content as indicator of land degradation. Omuto (2008) found in Kenya that the majority of correctly identiﬁed degraded plots had high bulk density, high proportion of silt, and very low inﬁltration characteristics. The aggregate stability of some Mediterranean soils is positively correlated with the silt content (Boix-Fayos et al. 2001). Silt content of soils has also been recognized to favor fluvial erosion and mass failures (Wolman 1959; Schumm 1960a, b; Walker et al. 1987). Silt was also considered in the LADA-project for calculating the soil fertility index. Siltation is one of the effects of off-site degradation (WOCAT 2008).

**Methodology:** In our study nine topsoil sample pairs were taken on bowal (degraded land) and non-bowal plots (forest soil for control). We used a soil auger to a depth of 10 cm. The composite topsoil samples were dried at 105°C in the laboratory and, lastly, crushed and sieved through a 2 mm screen. Silt content was measured by the pipette method (Loveland & Whalley 1991). T-tests were made to investigate on the differences of the silt content of topsoils on bowal and forest plots.

**Data needed:** Soil samples are needed and a classification system to determine the degree of degradation.

**Limits of the indicator**: In our case, degraded land had a lower silt content than non-degradaded land. When using silt content as indicator of land degradation, the position must be clarified.

**Related indicators**: extractable phosphorus, total N, exchangeable potassium, species richness, soil organic matter, soil texture, plant cover

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**Project**: UNDESERT

**Date**: October 2012

**Name: Soil total nitrogen (soil total N)**

**Brief Definition:** Determination of soil total N

**Keywords** Total N, soil, land degradation and desertification

**Country:** common to all countries

**Level:** Plot-based

**DPSIR:** State

**Countries where indicator was tested:** Benin

**UNDESERT Spatial Scale:** West Africa

**Minimum time scale:** every 1-5 years

**Maximum time scale:** every 1-5 years

**Importance with respect to desertification and degradation:** Land degradation and desertification is one of the major processes affecting the soil total N (total N). Total N is concentrated in soil surface horizons and is an important determinant of soil quality, agricultural productivity, water quality and global climate (Lal et al. 1998, Post & Kwon 2000, Reicosky 2001, Ingestad 1981). The loss of total N is usually followed by a deﬁciency of plant nutrients, a deterioration of soil structure, a reduced soil workability and a lower water-holding capacity (Frye 1987, Batie et al. 1993, Richter 1999, Gilly et al. 1997, Kimble et al. 2001, Dabney et al. 1999).

**International conventions and agreements:** The present indicator helps to determine land and soil productivity. It can also be used to assess the effects of climate change due to Greenhouse gases. It is directly relevant to the UNCCD and UNFCCC and potentially important in relation to the implementation of rural development policies.

**Definition and concepts:** Land degradation and desertification do not onlyresult in soil degradation and severe decrease in land productivity (Gad & Abdel 2000). They also promote the emission of soil N into the atmosphere where it acts as a greenhouse gas. Thus, the effects of desertification on soil N contents have become a concern in recent years (Dale & Peter 2001, Breuer et al. 2006). Total N in topsoil is removed by soil erosion. Intensive soil erosion results in a significant decrease of total N amounts. Total N in soils is mainly associated with the ﬁne particles, and its amount decreases significantly with land degradation. Total N was also considered in the LADA project as an indicator of land degradation and in several research papers (Bewket & Stroosnijder 2003, Zhao et al. 2010, Mills & Fey 2004, McDonald et al. 2002, Lal 2006, Zhao et al. 2005, Zhao et al. 2009, Guoxiao et al. 2008, Wang et al. 2009).

**Methodology:** In our study in Benin nine topsoil sample pairs were taken on bowe (degraded land) and non-bowe plots (forest soil for control). We used a soil auger to a depth of 10 cm. The composite topsoil samples were dried at 105°C in the laboratory, crushed and sieved through a 2 mm screen. The following soil analyses were undertaken. The total N was extracted by using a Kjeldahl System 1026 distilling unit. T-tests were made to investigate on the differences of the soil total N of topsoils on bowe and forest plots.

**Data needed:** Collection of soil samples on differently degraded sites and analysis in the laboratory, a classification of the level of degradation of bowe according to soil total N.

**Limits of the indicator:** No limit as indicator of land degradation and desertification

**Related indicators:** extractable phosphorus, soil organic matter, soil organic carbon, exchangeable potassium, species richness, electrical conductivity, soil texture, plant cover

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**Project:** UNDESERT

**Date:** October 2012

**Name: Exchangeable potassium in soils**

**Brief Definition:** Determination of quantity of potassium in the soil

**Keywords**: Exchangeable potassium, soil, land degradation

**Country:** Common to all countries

**Level:** Plot-based

**Position within DPSIR:** State

**Countries where indicator was tested:** Benin

**UNDESERT Spatial Scale:** West Africa

**Minimum time scale:** every 1-5 years

**Maximum time scale:** every 1-5 years

**Importance with respect to desertification and degradation:** Exchangeable potassiumis an indispensable nutrient for plant growth. However, large quantity of exchangeable potassium in soils raises the potential erodibility of the ground and increases the risks of land degradation and desertification. Thus, soil exchangeable potassium is a good indicator for assessing land degradation and desertification processes.

**International conventions and agreements:** The indicator measures the quantity of exchangeable potassium in soils and contributes to determine the provisioning and supporting services of an ecosystem. An increase of exchangeable potassium in soils is a key factor for the acceleration of soil erosion and thus for irreversible land degradation and desertification. It is therefore directly relevant to the international agreements such as UNCCD and the MDGs.

**Definition and concepts:** Large quantities of exchangeable potassium in soils are considered to degrade the soil structure and to increase the risk of erosion. A high content of potassium increases the percentage of exchangeable potassium and causes dispersion (Auerswald et al. 1996; Baver et al. 1972; Quirk 1978; Shainberg et al. 1981; Shainberg & Letey 1984; Shainberg et al. 1987a; Keren 1991). The hydraulic properties of the soil are influenced, crusts are built, runoff and soil erosion are facilitated (Agassi et al. 1981; Gerits et al. 1987; Ahuja 1990; Lavee et al. 1991).

**Methodology**: In our study in Benin we took ninetopsoil sample pairs on bowe plots (degraded land) and non-bowe plots (forest soil for control). We used a soil auger to a depth of 10 cm. The composite topsoil samples were dried at 105°C in the laboratory, crushed and sieved through a 2 mm screen. The exchangeable potassium was determined after extraction of the ammonium acetate-extractable cations (centrifuge procedure described by Thomas 1982) using atomic absorption spectrometry. T-tests were made to investigate on the differences of the soil exchangeable potassium of topsoils on bowal and forest plots.

**Data required:** Collection of soil samples on differently degraded sites and analysis in the laboratory.

**Limits of the indicator:** No limits

**Related indicators:** Extractable phosphorus, total N, exchangeable potassium, species richness organic matter, soil texture, plant cover

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**Project:** UNDESERT

**Date:** October 2012

**Name: Soil humidity**

**Brief Definition:** The occurrence of flooding

**Keywords:** Erosion, compaction of soil, flooding, crusting, sealing.

**Country:** common to all countries

**Level:** Plot-based

**Position within DPSIR:** State

**Countries where indicator was tested:** Benin

**UNDESERT Spatial Scale:** West Africa

**Minimum time scale:** every 1-5 years

**Maximum time scale:** every 1-5 years

**Importance with respect to desertification and degradation:** The UN Convention to Combat Desertification defines desertification as "land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities“. Nowadays, land degradation is increasing in extent and severity in many parts of the world (Adams & Eswaran 2000; Bai et al. 2008; Kapalanga 2008). Erosion is recognized as the main process of land/soil degradation and modifies the soil structure. Compaction is an important type of physical soil degradation. Compaction and soil surface sealing reduce infiltration and hydraulic conductivity. Surface water runoff volumes are increased (Frisby & Pfost 1993; Horton et al. 1994; Radcliffe & Rasmussen 2000) and runoff periods get longer (Hinckley et al. 1983). Compaction reduces the water retention of the soil and alters the good development of root-system of plants. The decrease of infiltration induces flooding which can be permanent or temporary according to the degree of compaction, degree of crusting or degree of soil sealing.

**International conventions and agreements:** Soil surface sealing due to erosion, reduces the infiltration capacity and the occurrence of flooding increases. Hence, occurrence of flooding is related to the UNCCD which states that soil erosion is one of the main causes of land degradation. Moreover, the UNCCD emphasizes the fact that combating desertification must be tackled within the general framework of actions to promote sustainable development. Within Agenda 21 infiltration capacity is relevant to Chapter 12 - Management of fragile ecosystems: combating desertification and drought.

**Definition and concepts:** Flooding could be defined as the saturation of the pores of soil due to a decrease of the capacity of retention and a low infiltration rate. Water stays on the surface and inundates the area. Its root causes are high intensities of rainfall, soil sealing and crusting. The latter are defined as clogging of the pores with fine soil material and development of thin impervious layers at the soil surface obstructing the infiltration of rainwater. The Land Degradation Assessment in Drylands (LADA) project pointed out that soil humidity or flooding are appropriate indicators of physical soil degradation due to erosion (FAO 2003).

**Methodology:** Humidityof soil was assessed visually. The indicator was assessed within sample plots of 30m x 30m. Each plot was classified according to the occurrences of flooding: Dried station or temporary flooded (during rainy season only).

**Data needed:** Occurrence of flooding

**Limits of the indicator:** No limits

**Related indicators:** Rills and gullies, tree-root, soil sealing and crusting, armour layer, change in colour

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**Project:** UNDESERT

**Date:** October2012

**Name: Extent of organic layer**

**Brief Definition:** Organic matter of soil estimated by the extent of organic layer (A)

**Keywords:** Erosion, organic layer, organic matter, spot method, loss of topsoil

**Country:** Common to all countries

**Level:** Plot-based

**DPSIR:** State

**Countries where indicator was tested:** Benin

**UNDESERT Spatial Scale:** West Africa

**Minimum time scale:** every 1-5 years

**Maximum time scale:** every 1-5 years

**Importance with respect to desertification and degradation:** The UN Convention to Combat Desertification defines desertification as "land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities“. Land degradation is increasing in severity and extent in many parts of the world, with more than 20% of all cultivated areas, 30% of forests and 10% of grasslands undergoing degradation processes (Bai et al. 2008. Millions of hectares of land are degrading in all climatic regions per year. It is estimated that 2.6 billion people are affected by land degradation and desertification in more than a hundred countries, influencing over 33% of the earth´s land surface (Adams & Eswaran 2000). This global development was treated in the United Nations Convention to Combat Desertification, the Convention on Biodiversity, the Kyoto Protocol on Global Climate Change and the Millenium Development Goals (UNEP 2008). Land degradation impacts three main components of landscape i.e. vegetation, soil and water. It refers to five main processes i. e. vegetation degradation, water erosion, wind erosion, salinization and waterlogging, and soil crusting and compaction. Each year, 75 billion metric tons of soil are removed from the land worldwide, by wind and water erosion, with most coming from agricultural land (Pimentel et al 1995). Erosion induces the removal of the soil fertile layer (A) rich in humus and organic matter. Various important soil characteristics concerning the nutrient budget are determined through soil organic matter, such as the cation exchange capacity, soil acidity, the capacity of binding organic chemicals (pesticides, herbicides, fertilizer, etc.), the release and sequestration of N, P, and S during decomposition of soil organic matter, and nutrient availability for soil microorganisms (Volk & Loeppert 1982). Loss of fertile topsoil induces reduction of soil fertility and productivity and may lead to an irreversible loss of natural farmland on shallow soils. Crops yield and animal productivity are negatively impacted as also biodiversity.

**International conventions and agreements:** The UNCCD emphasizes the fact that combating desertification must be tackled within the general framework of actions to promote sustainable development. Decrease of soil organic matter is a key factor for accelerating soil erosion and thus for irreversible land degradation and desertification. The UNCCD emphasizes the role that soil organic matters plays in the context of global carbon balance.

**Definition and concepts:** Loss of topsoil through erosion is the process of topsoil removal leaving unproductive subsoils. Reduction of the extent of topsoil means intensification of erosion. It implies that top-dark soils, organic layer (A) are removed partly or totally by runoff. The indicator was used as an indicator of severely eroded soils by the Assessment of the Status of Human-Induced Soil Degradation (ASSOD) (Kapalanga 2008), LADA, WOCAT, DESIRE (CDE/WOCAT, FAO/LADA, ISRIC, 2008). Moreover this indicator is used by local population to assess land degradation by erosion (Saïdou et al 2004; Okoba 2005)

**Methodology:** This indicator of soil erosion was assessed by dropping vertically a metal rod on the ground and noting the nature of the substrate touched (dark topsoil or red sub-surface soil). The metal rod was dropped each meter in 8 directions (4 half diagonal and 4 half median) until reaching a distance of 15 m from the center of the plot (Figure 8.1). This methodology was also used to assess the dynamics of grasslands by Daget and Poissonnet (1971). The percentage of contact-spots with the dark topsoil layer was computed as the average extent of the organic layer (A) on the site.

15 m

30 m

**Rod contacts**

**Figure8.1: Sample units for organic layer extent assessment**

**Data needed:** Contact-points of a metal rod with the dark topsoil at plot level (30m x 30m)

**Limits of the indicator:** The indicator gives only an approximate and qualitative idea of the severity of topsoil loss. The assessment is time-consuming, but low cost and can easily be incorporated in the sampling of phytosociological relevés.

**Related indicators:** Sheet erosion, rills, color change, compaction, tree-root, rock and armour layer exposure, decline in soil productivity

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**Literature:**

Adams C. R., Eswaran H. (eds.) 2000. Global land resources in the context of food and environmental security. Soil Conservation Society of India. New Delhi.

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**Project:** UNDESERT

**Date:** October 2012

**Name: Compaction of topsoil**

**Brief Definition:** Disruption of topsoil structure caused by compacting processes or erosion with a reduction of porosity and infiltration

**Keywords:** Water erosion, soil structure, infiltration

**Country:** Common to all countries

**Level:** Plot-based

**DPSIR:** State

**Countries where indicator was tested:** Benin

**UNDESERT Spatial Scale:** West Africa

**Minimum time scale:** every 1-5 years

**Maximum time scale:** every 1-5 years

**Importance with respect to desertification and degradation:** Erosion is recognized as the main process of land/soil degradation. Erosion modifies the structure of the soil. Compaction is one type of physical soil degradation. Compaction and soil surface sealing reduce infiltration and hydraulic conductivity while surface water runoff volumes increase (Frisby & Pfost 1993; Horton et al. 1994; Radcliffe & Rasmussen 2000) and runoff periods get longer (Hinckley et al. 1983). Compaction reduces the water retention capacity of the soil and alters the good development of the root-system of plants. It is important to assess the level of soil compaction in order to have an idea about the ecosystem-stability.

**International conventions and agreements:** Compaction contributes to the reduction of infiltration and hydraulic conductivity of soil. It gives an idea of the state of soil structure modified by water and wind erosion. Hence, it is related to the UNCCD which states that soil erosion is one of the main causes of land degradation. Moreover, the UNCCD emphasizes the fact that combating desertification must be tackled within the general framework of actions to promote sustainable development. Within Agenda 21 infiltration capacity is relevant to Chapter 12 - Management of fragile ecosystems: combating desertification and drought.

**Definition and concepts:** Compaction could be defined as a disruption of soil structure caused by compacting processes with a reduction of porosity and then infiltration. It favors and is directly related to soil sealing and crusting which is defined as the clogging of pores with fine soil material and development of a thin impervious layer at the soil surface obstructing the infiltration of rainwater. The Land Degradation Assessment in Drylands (LADA) project selected compaction of soil (occurrence and severity) as an indicator of physical soil degradation due to erosion (FAO 2003). Soil compaction is often assessed through bulk density which is an expensive method.

**Methodology:** Compaction of soil was assessed visually. The indicator was assessed within sample plots of 30m x 30m. Each plot was classified according to its level of compaction of the topsoil layer, defined as “movable”, “compact”, “very compact” and “hard”. The assessment of this indicator is very low-cost, low-time consuming and is easy for local people.

**Data needed:** State of degradation of topsoil

**Limits of the indicator:** The indicator gives only an approximate and qualitative idea of the level of compaction of soil

**Related indicators:** Rills and gullies, tree-root, soil sealing and crusting, change in colour

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**Literature:**

Adams C. R., Eswaran H. (eds.) 2000. Global land resources in the context of food and environmental security. Soil Conservation Society of India. New Delhi.

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**Project:** UNDESERT

**Date:** October 2012

**Name: Color of top soil layer**

**Brief Definition:** Colour of remaining topsoil, turning from dark to red

**Keywords:** Erosion, organic matter, color change, loss of top soil

**Country: C**ommon to all countries

**Level:** Plot-based

**DPSIR:** State

**Countries where indicator was tested:** Benin

**UNDESERT Spatial Scale:** West Africa

**Minimum time scale:** every 1-5 years

**Maximum time scale:** every 1-5 years

**Importance with respect to desertification and degradation:** Erosion is one of the main processes of land degradation. But field measurements of soil erosion can be expensive and in many cases impractical. Surrogate, simpler to measure variables, may be used instead to predict erosion risk. As soil structural stability is influenced by a number of soil properties. Erosion risk surrogate variables should encompass a number of these influential soil properties. Soil color encompasses many basic soil properties. Soil colour as a function of parent material, may also encompass properties such as texture, mineralogy and iron content (Romkens et al. 1977; Trott & Singer 1983; Schwertmann 1993). Change in color from dark to red is often correlated with a decrease of organic matter, a decrease of fertility and productivity of soil and a decrease of yield of crops.

**International conventions and agreements:** The indicator represents soil colour. Colour change of topsoil is a very good indicator of ongoing erosion processes, of decrease of soil organic matter, fertility and productivity of soil. The UNCCD states that soil erosion is one of the main causes of land degradation. “Land degradation means reduction or loss, in arid, semi-arid and dry sub-humid areas, of the biological or economic productivity and complexity of rainfed cropland, irrigated cropland, or range, pasture, forest and woodlands resulting from land uses or from a process or combination of processes, including processes arising from human activities and habitation patterns". Thus, the indicator is directly related to the UNCCD.

**Definition and concepts:** This indicator describes the colour of the remaining soil after water erosion has removed the topsoil. The colours range from dark to red. Local population, in particular farmers, refer to such soils as infertile or had grown “old”. This means that topsoil has been removed leaving sub-surface soil layers, which do not longer produce high yields (Saïdou et al. 2004; Okoba 2005). LADA suggested soil colour change as a field indicator of soil loss, productivity change and biological degradation of soil at farm or village-level (FAO 2003). In the study by Berry et al. ([2003](#_ENREF_1)) in Chile to assess the extent, cost and impact of land degradation, soil erosion was assessed in the field by means of expert protocols, using 5 degrees of erosion). The strong/severe degree of erosion was characterized by change in colour of topsoil. Moreover Hearman & Hinz ([2004](#_ENREF_2)), have shown a significant relationships between soil colour and iron, sand and rock content. They explained why soil colour has a great potential to be used as a predictor for soil stability and why it can be used as a powerful management tool.

**Methodology:** Colour of soil is assessed visually. Two main variables are often observed. Topsoil varies between black and red. The transition from black to red indicates that dark topsoil has been removed by water leaving sub-surface soil layers. The indicator is assessed within sample plots of 30m x 30m. The assessment of this indicator is very low-cost, low-time consuming and used by local people.

**Data needed:** Colour of the top layer of soil

**Limits of the indicator:** The indicator gives only an approximate qualitative idea of severity of top soil loss

**Related indicators:** Soil productivity decline, nutrient mining, lighter structure and weak aggregation, sheet erosion, extent of organic layer, compaction

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**Project:** UNDESERT

**Date:** October 2012

**Name: Occurrence of sheet erosion**

**Brief Definition:** Occurrence of flat areas with a smoothed micro-relief with (often-parallel) linear flow marks or sediments

**Keywords:** Water erosion, flow surfaces, sediments

**Country:** common to all countries

**Level:** Plot-based

**Position within DPSIR:** State

**Countries where indicator was tested:** Benin

**UNDESERT Spatial Scale:** West Africa

**Minimum time scale:** every 1-5 years

**Maximum time scale:** every 1-5 years

**Importance with respect to desertification and degradation:** The UN Convention to Combat Desertification defines desertification as "land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities“. Nowadays, land degradation is increasing in extent and severity in many parts of the world (Adams & Eswaran 2000; Bai et al 2008; Kapalanga 2008). The loss of soil on the land surface by wind and water erosion has been identified as a major constraint in generating enough food to feed the world’s escalating population (Pimentel 2006). Erosion has caused substantially reduced crop yields in Africa (Corvalan et al. 2005). Areas with high rates of soil erosion can cause large hydrologic modifications and though resulting in negative social and economic consequences (i.e. flooding, construction and plant damages and loss of agricultural land etc.) (Pimentel 2000). In addition, soil erosion is attributed to the partial loss of agricultural land through continuous decrease in fertility (i.e. loss of the soil chemical and physical characteristics that support the fertility of the land and keep it in an acceptable productive level). Then there is a narrow link between the intensity of water erosion and the stability of ecosystems. Erosion in general and water erosion in particular is one of the main processes of land degradation. Water erosion assessment is a key goal in the design of land/soil degradation mitigation policies. But field measurements of soil erosion can be expensive and in many cases impractical. The use of low-cost and low time-consuming indicators such as flow surfaces or sheet erosion is interesting.

**International conventions and agreements: I**ndicator measures occurrence of sheet erosion. It is especially relevant to the UNCCD as in the convention soil erosion is one of the main causes of land degradation.

**Definition and concepts:** Bergsma ([1992](#_ENREF_1)) and Bergsma and Kwaad ([1992](#_ENREF_2)) defined different types of soil surfaces for undertaking an evaluation of erosion hazard. The erosion type of sheet erosion occurs on flat areas with a smoothed micro-relief with (often-parallel) linear flow marks or sediments, partly eroded by shallow non-concentrated flows. In other words, sheet erosion is the removal of a fairy uniform layer of soil from the surface, marked by runoff flow leaving a smoothened surface that shows the direction of the flow. The LADA project suggested this indicator for assessment of the loss of topsoil (FAO 2003). This indicator was used by de Bie ([2005](#_ENREF_3)), to monitor the cumulative effect of erosion between tillage/weeding and harvesting. Moreover it is one of the most often observed indicators of farmers in the central highlands of Kenya (Okoba 2005). This indicator refers to an ongoing water erosion process and is assessed visually in terms of presence-absence.

**Methodology:** Sheet erosion was assessed visually. The presence-absence of this indicator was noted on sample plots of 30m x 30m. The assessment of this indicator is very low-cost, low-time consuming and known by local people.

**Data needed:** Presence-absence of flow surfaces on plots

**Limits of the indicator:** The indicator gives only an approximate qualitative idea of severity of topsoil loss

**Related indicators:** Rills and gullies, tree-root, rock, armour layer exposure, change in colour

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Adams C. R., Eswaran H. (ed.) 2000. Global land resources in the context of food and environmental security. Soil Conservation Society of India. New Delhi.

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**Project:** UNDESERT

**Date:** October 2012

**Name: Rill mean cover**

**Brief Definition:** Shallow channels (3–5 cm deep) cut by concentrated flows, slightly concave and not part of the micro-drainage system of the area

**Keywords:** Water erosion, flow surfaces, topsoil removal

**Country:** common to all countries

**Level:** Plot-based

**Position within DPSIR:** State

**Countries where indicator was tested:** Benin

**UNDESERT Spatial Scale:** West Africa

**Minimum time scale:** every 1-5 years

**Maximum time scale:** every 1-5 years

**Importance with respect to desertification and degradation:** The UN Convention to Combat Desertification defines desertification as "land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities“. Nowadays, land degradation is increasing in extent and severity in many parts of the world (Adams & Eswaran 2000; Bai et al. 2008; Kapalanga 2008). Erosion is recognized as the main process of land/soil degradation. Rill cover on micro topography is assessed for erosion hazard evaluations (Bergsma 1992; Bergsma & Kwaad 1992). Rills are very good indicator of many cumulative effects of erosion and well-related to soil erodibility and to soil loss (Bie de 2005).

**International conventions and agreements:** The indicator refers to rill mean cover. The UNCCD states that soil erosion is one of the main causes of land degradation. "Land degradation means reduction or loss, in arid, semi-arid and dry sub-humid areas, of the biological or economic productivity and complexity of rainfed cropland, irrigated cropland, or range, pasture, forest and woodlands resulting from land uses or from a process or combination of processes, including processes arising from human activities and habitation patterns". Thus the indicator is related to the UNCCD.

**Definition and concepts:** Rills are shallow channels (3–5 cm deep) cut by concentrated flows, slightly concave and not part of the micro-drainage system of the area. De Bie ([2005](#_ENREF_1)) demonstrated that in the maize agro-systems in Kenya, fewer rills indicate high groundcover, dense plant cover and a non-sandy topsoil. Thus, the detachment of soil particles is less, and soil and water conservation practices such as weeding end late. There is a shorter period for rill formation. Control of slope length, slope gradient and intercropping with vegetables become possible. The Land Degradation Assessment in Drylands (LADA) project suggested rill cover as a field indicator of soil loss (FAO 2003).

**Methodology:** This indicator of erosion was visually assessed according to the Braun-Blanquet (1932) cover/abundance scale: rare (less than 1% cover), 1 (1-5% cover), 2 (5-25% cover), 3 (25-50% cover), 4 (50-75% cover), 5 (75-100% cover). The indicator was assessed in terms of mean cover within sample plots of 30m x 30m.

**Data needed:** Mean cover of rills within sample plots of 30m x 30m

**Limits of the indicator:** The indicator gives only an approximate and qualitative idea of the intensity of erosion

**Related indicators:** Sheet erosion, tree-root, soil sealing and crusting, armour layer, change in colour

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Bergsma E., Kwaad J. F. P. M. 1992. Rain erosion hazard evaluation from soil loss as well as from soil surface features. Paper presented at the 7th International ISCO Conference, Sydney. 25– 35.

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**Project:** UNDESERT

**Date:** October 2012

**Name: Topographic position**

**Brief Definition:** Topographic position combination of specific slope angle, slope position, aspect or elevation and refers to the location of the plot on the earth’s surface

**Keywords:** Erosion, compaction of soil, flooding, crusting, sealing.

**Country:** common to all countries

**Level:** Plot-based

**Position within DPSIR:** Pressure

**Countries where indicator was tested:** Benin

**UNDESERT Spatial Scale:** West Africa

**Minimum time scale:** every 1-5 years

**Maximum time scale:** every 1-5 years

**Importance for land degradation:** Vegetation patterns are affected by interacting responses to environmental gradients, disturbance, competition and herbivory (Stohlgren et al. 1998). Environmental gradients of factors such as elevation, moisture, edaphic factors and topographic position are the primary determinants of plant species distributions (Whittaker 1956). Vegetation is composed of an organized series of topo-communities that is determined principally by topographic habitats. These habitats correlate with variations in soil conditions and relative light intensity, and these govern seedling establishment and physiological performance of the trees (Tang & Ohsawa 2002). Indeed topographic position is a combination of specific slope angle, slope position, aspect or elevation. There is a narrow link between hillslope position, hydrologic condition and erosion process and then, runoff and sediment productions from a hillslope segment are highly variable, both spatially and temporally (C. Huang et al. 2001). Hence, erosion and vegetation are related by the environmental factor which is topographic position.

**International conventions and agreements:** The UNCCD states that soil erosion is one of the main causes of land degradation. "Land degradation means reduction or loss, in arid, semi-arid and dry sub-humid areas, of the biological or economic productivity and complexity of rainfed cropland, irrigated cropland, or range, pasture, forest and woodlands resulting from land uses or from a process or combination of processes, including processes arising from human activities and habitation patterns". The topographic position influences the severity erosion processes can have.

**Definition and concepts:** The topographic position is defined as the position of a point of interest on the earth’s surface. This position could be the summit, middleslope or downslope. Huang et al. 2001 designed a conceptual hillslope model showing interactions between hillslope position, hydrologic condition and erosion processes (Figure 8.2).



**Figure 8.2: Conceptual hillslope model showing interactions between hillslope position, hydrologic condition and erosion processes**

**Methodology:** The topographic position can be easily assessed visually., classes are defined. The indicator is a qualitative indicator.

**Data needed:** Topographic map

**Limits of the indicator:** The quality of the indicator depends on the scale of measurement.

**Related indicators:** Topography, sheet erosion, canopy cover, ground cover

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**Literature:**

Huang C., Gascuel-Odoux C., Cros-Cayot S. 2001. Hillslope topographic and hydrologic effects on overland flow and erosion. CATENA 46: 177-188.

Stohlgren T. J., Bachand R. R., Onami Y., Binkley D. 1998. Species-environment relationships and vegetation patterns: effects of spatial scale and tree life-stage. Plant Ecology135: 215-228.

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Whittaker R. H. 1956. Vegetation of the Great Smoky Mountains. Ecological Monographs 26: 1-80.

**Project:** UNDESERT

**Date:** October 2012

**Name: Slope angle**

**Brief Definition:** The slope of a topographic landform refers to the inclination of that surface to the horizontal

**Keywords:** Erosion, compaction of soil, flooding, crusting, sealing

**Country:** common to all countries

**Level:** Plot-based

**DPSIR:** Pressure

**Countries where indicator was tested:** Benin

**UNDESERT Spatial Scale:** West Africa

**Minimum time scale:** every 1-5 years

**Maximum time scale:** every 1-5 years

**Importance with respect to desertification and degradation:** The UN Convention to Combat Desertification defines desertification as "land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities“. Nowadays, land degradation is increasing in extent and severity in many parts of the world (Adams & Eswaran 2000; Bai et al. 2008; Kapalanga 2008). Erosion is recognized as the main process of land degradation and desertification in hilly and mountainous areas. Generally speaking, soil sediment loss can be estimated by the product of the amount of surface water run-off times the slope gradient times a constant related to soil surface characteristics. As the slope becomes steeper, the runoff coefficient increases, the kinetic energy and carrying capacity of surface water flow becomes greater, soil stability and slope stability decreases, soil sediment loss increase. Therefore, slope gradient is undoubtedly considered as one of the most important determinants of soil erosion and desertification.

**International conventions and agreements:** Indicator refers to the slope gradient. Slope is directly related to soil erosion and therefore to the UNCCD.

**Definition and concepts:** Slope greatly affects the amount of surface water run-off and soil sediment loss. A soil erosion rate becomes acute when slope angle exceeds a critical value and then increases logarithmically. The slope gradient can have variable effects in different climatic zones, depending mainly on the annual rainfall. Measurements conducted in different areas with natural vegetation in the Atacora mountains (Benin) show that there are more important soil losses upslope than downslope and that the severity of soil loss increases on ploughed areas (Tente & sinsin 2005). De Bie ([2005](#_ENREF_1)) reported that soil loss was considered variable between plots due to differences in surface soil, land cover, infrastructure, crop management, slope, and map unit. Slope is a very important factor so that it is integrated in many models of erosion and soil loss assessment such as USLE, RUSLE and CORINE (Kapalanga 2008).

The amount of sediments transported after each rainfall event is a function of climate, vegetation, topography and soil which can be estimated by the equation:

S=kq(\*\*m) L (\*\*n)

where: S is the sediment loss (t ha-1), k is soil erodibility, q is overland flow discharge per unit width, L is local slope gradient, and m, n, are empirical exponents to be determined. Except slope gradient, slope length is also important affecting soil loss due to surface water runoff. Tillage erosion caused by tillage implements is greatly affected by slope gradient. As the following equation shows, soil erosion is proportionally related to slope gradient. The flux of soil in the direction of ploughing (Qs, in kg m-1) per tillage operation can be determined by the equation:

Qs = D\*BD\*G\*B

Where: D is the ploughing depth (m), BD is the bulk density of the soil (kg m-3), G is slope gradient (tan), and B is coefficient, corresponding to plough depth D. The Land Degradation Assessment in Drylands (LADA) project (Argentina, China and Senegal) ([FAO, 2003](#_ENREF_2)), the DESERTLINK project, LADA, WOCAT, DESIRE (CDE/WOCAT, FAO/LADA, ISRIC, 2008), point out slope as an indicator of erosion risk.

**Methodology:** Slope gradient can be measured (a) by using topographic maps, and (b) in the field by using a clinometer or by rough estimation.

**Data needed:** Topographic map or field measurement

**Limits of the indicator:** The quality of the indicator depends on the scale of measurement

**Related indicators:** Topography, sheet erosion, canopy cover, ground cover

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