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Sub-national case studies from Costa Rica and Namibia

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List of abbreviations

CATIE	Centro Agronómico Tropical de Investigación y Enseñanza
CIAT	International Center for Tropical Agriculture
COMDEKS	Community Development and Knowledge Management for the Satoyama Initiative
COP	Conference of Parties
EC	European Commission
ELD	Economics of Land Degradation
ESA	European Space Agency
FAO	Food and Agriculture Organization
FONAFIFO	Fondo de Financiamiento Forestal de Costa Rica
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
ICRAF	World Agroforestry Center
INTA	El Instituto Nacional de Innovación y Transferencia en Tecnología Agropecuaria
IR	Infrared
IRLUP	Integrated Regional Land Use Plan
ISCRIC	The International Soil Reference and Information Centre
JRC	Joint Research Council of the European Commission
LDN	Land Degradation Neutrality
LDSF	Land Degradation Surveillance Framework
LP	Land Productivity
LPD	Land Productivity Dynamics
LUC	Land Use Change
M&E	Monitoring and Evaluation
MINAE	Ministry of Environment and Energy
MODIS	Moderate Resolution Imaging Spectroradiometer
NAMA	Nationally Appropriate Mitigation Action
NASA	National Aeronautics & Space Administration
NDVI	Normalized Difference Vegetation Index
NPP	Net Primary Production
REDD	Reducing Emissions through Degradation and Deforestation
SDG	Sustainable Development Goals
SINAC	Sistema Nacional de Areas de Conservacion
SISLAC	Soil Information System for Latin America
SPOT	Satellite Pour l'Observation de la Terre
SOC	Soil Organic Carbon
SRTM	Shuttle Radar Topography Mission
UNCBD	United Nations Convention on Biological Diversity
UNCCD	United Nations Convention to Combat Desertification

UNEP-WCMC	United Nations Environmental Programme - World Conservation Monitoring Centre
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States Dollars
VI	Vegetation Index

1 Introduction

1.1 Background

Land degradation is a consistent loss of ecosystem functionality due to human and natural processes (Lal et al. 2012), or as defined by the United Nations Convention to Combat Desertification (UNCCD) a "reduction or loss of the biological or economic productivity and complexity of rain fed cropland, irrigated cropland, or range, pasture, forest and woodlands resulting from land uses or from a process or combination of processes arising from human activities" (UNCCD 2015c). Historically, it is a well-documented issue (Grove 1996, Beach et al. 2006, Ellis et al. 2013) and the degree of degradation has forced civilisations to adapt land management practises to the state of the environment, or abandon the landscape altogether (Costanza et al. 2007). Over the last four decades there has been an increase in human-induced land degradation and it is estimated to affect one third of global arable land (UNCCD 2015a, Vlek 2005) and to cost between USD 6.3-10.6 trillion annually or 10-17% of the world's gross domestic product (ELD 2015).

Land degradation affects livelihoods, biodiversity and ecosystem services while it exacerbates climate change and ultimately impacts the well-being of 1.5 billion people globally (Lal et al. 2012, ELD 2015). The impacts are not evenly distributed across the globe, as approximately 40% of all land degradation occurs in the poorest countries, the least capable of mitigating and adapting to the impacts (UNCCD 2015b). Furthermore, as the impacts of land degradation have direct effects on both climate change and biodiversity loss (Lal et al. 2012), they also influence nations' ability to reach the targets set by the United Nations Framework Convention on Climate Change (UNFCCC) and the Convention on Biological Diversity (UNCBD) (Lal et al 2012) (see Figure 1.1). The UNCCD has been actively working to promote synergies between the three conventions, building on common themes such as technology and capacity improvements, financial assets, and awareness raising (Verstraete et al. 2011)(Fig 1.1).

Acknowledging that land degradation is a global challenge and building on the international momentum to restore degraded lands (see for example Initiative 20×20 in Latin America and AFR100 in Africa), the Sustainable Development Goals (SDG) identified Land Degradation Neutrality (LDN) as an important component. While SDG 15 calls for the protection of terrestrial ecosystems and the fight against land degradation in general terms, target 15.3 explicitly formulates the vision of a "land degradation neutral world".

SDG 15.3: By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world

Following the anchoring of LDN in the SDGs, the UNCCD Conference of Parties (COP) in 2015 took the decision to align the implementation of the Convention with SDG 15.3 and invited its Parties to set voluntary LDN targets.

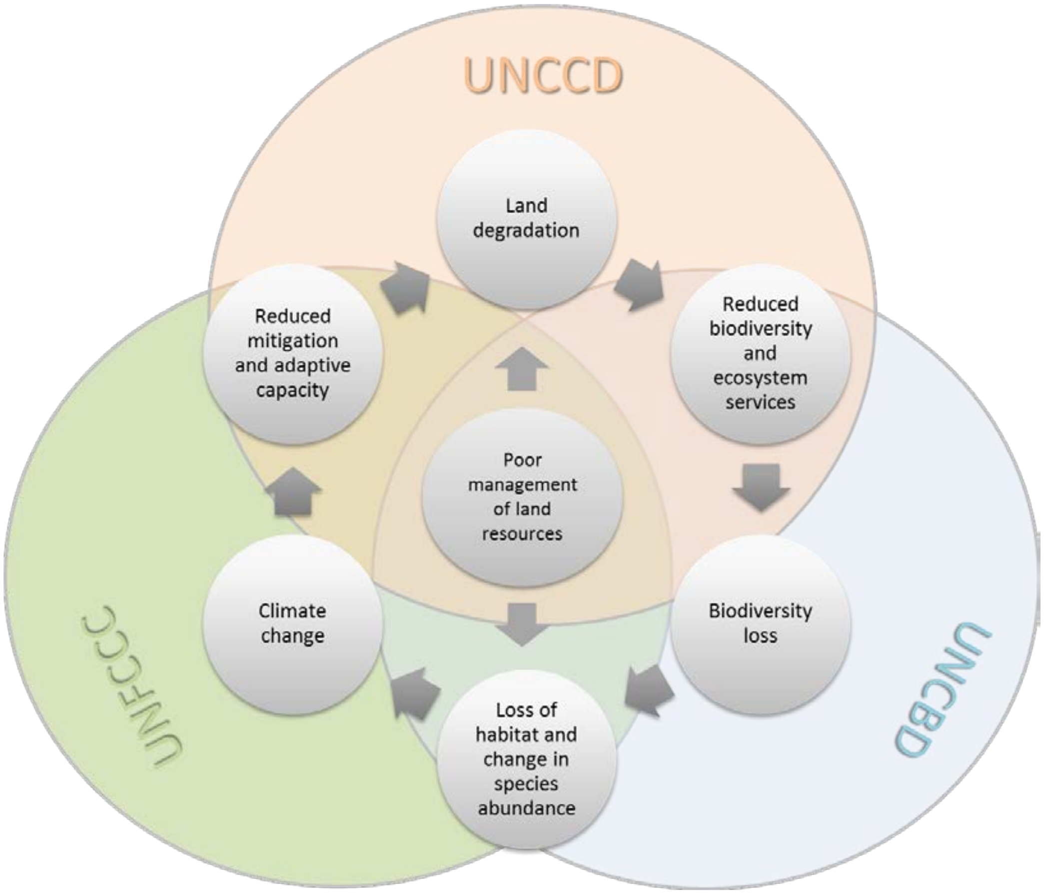

Figure 1.1. Synergies between the three Rio Conventions (adapted from UNCCD 2015b).

After the political establishment of LDN in the context of the SDGs and the UNCCD, the challenge now becomes one of operationalization. First efforts to implement LDN at country level have been initialized already. In 2015, the UNCCD ran a LDN pilot project together with 14 countries [1], which is now being followed by the LDN Target Setting Program (TSP) implemented by the UNCCD´s Global Mechanism. Following the invitation by the UNCCD COP to set voluntary LDN targets, so far more than 100 countries officially expressed their interest to participate in the TSP. The TSP aims at supporting countries in setting LDN targets, identifying strategies and measures to achieve these targets and establishing a corresponding monitoring scheme. It is expected that countries wishing to engage in the LDN process present their targets at COP 13 in late 2017.

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[1] Algeria, Armenia, Belarus, Bhutan, Chad, Chile, Costa Rica, Ethiopia, Grenada, Indonesia, Italy, Namibia, Senegal and Turkey.

1.2 Objective and scope of this study

LDN target setting is a complex process that includes numerous political and technical aspects. The UNCCD´s LDN Technical Guide proposes a step-wise approach to define LDN targets and identify measures to achieve them (UNCCD 2016a). An integral part of any LDN target setting process is the assessment of a baseline, that means taking stock of the current land status. The LDN baseline is the basis for informed target setting and functions as a reference state for future monitoring. First attempts to develop national LDN baselines were undertaken during the LDN pilot phase in 2015.

The objective of this report is to identify entry points and challenges for subnational LDN baselines in order to inform subnational planning processes as potential vehicle for the implementation of LDN targets on the ground. For this purpose two focus regions were chosen within two of the countries – namely Namibia and Costa Rica – that participated in the first LDN pilot phase. The focus areas in Namibia and Costa Rica are the regions of Otjozondjupa and Rio Jesus Maria watershed respectively. Both Namibia and Costa Rica provide interesting case studies given the differences in types of land degradation, national capacities, and land resources.

The selection of methods for baseline assessement will have to take the subsequent monitoring of changes over time and space into consideration, as this is key for the detection of land degradation. Much care must be taken in choosing a methodology that ensure scientific rigor and quality of the assessment. It must quantify the impacts of human activities on the environment, as well as ensure better informed decision making through clear and concise communication of the current state of the land. Box 1 shows a checklist of important criteria for selection of land degradation assessment methodologies (UNCCD 2016a, UBA 2015, LDN Methodological Note [LDN-MN] 2015). These criteria will be explored in the following chapters in an analysis of available methods and data for sub-national baseline assessment.

Box 1: Checklist of criteria for selection of baseline assessment methodologies.

- Ability to assess the indicator of interest at a relevant spatial scale that capture landscape variabilities
- Ability to detect changes in indicators at appropriate spatial scale, and with appropriate temporal resolution
- Cost-effectiveness
- Transparency of methods, high accuracy, consistency, and reliability
- Accessibility, now and in the future, for monitoring and evaluation
- Comparability between regions and nations
- Capacity and acceptance of local and national partners to implement the methodology and integrate with ongoing national processes

The methodological approach for LDN baseline assessment and monitoring is based on the UNCCD´s biophysical progress indicators that were approved by the Parties to the Convention in 2013 (COP 11)[2]:

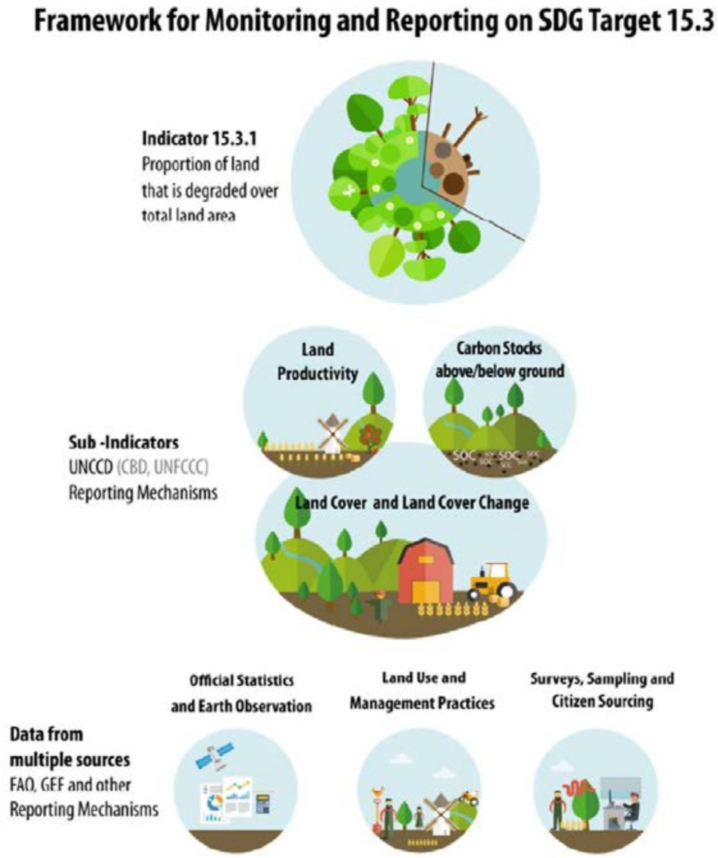


Figure 1.2: The UNCCD indicators for assessing trends in land degradation was agreed upon at the LDN inception meeting. It consists of three indicators that measure trends in land cover as well as the land productivity and carbon stocks associated with the different land covers (UNCCD 2016b).

The indicator ‘Land cover’ is indicative of socio-ecological dynamics of management. Furthermore, this indicator is capable of identifying vulnerable transitions between natural and human-managed land cover classes. The indicators ‘Land productivity’ and ‘Carbon stocks’

[2] Different technological aspects of LDN baseline mapping and monitoring are progressing at a relatively fast pace which resulted in some challenges during the writing of this report. For example, while the methods chapter (2) was completed by February 2016, changes were made in naming of the indicators (e.g. Land Cover / Land Use is now Land Cover) and general framework (e.g. the meaning of “tier” has changed). The authors have attempted to stay abreast of the changes in LDN vocabulary and recommendations regarding new datasets. However, some aspects of this report may become outdated as new datasets are published and improved satellite products become available to the wider public. This progress is a positive sign of the global commitment towards achieving a world that is land degradation neutral.

measure the biophysical state, above ground NPP and below ground organic carbon content, of the different types of land cover. Both land productivity and soil organic carbon (SOC) stocks are directly affected by land management and are vulnerable to land degradation (LDN-MN 2015).[3]

The drivers of land degradation are highly complex socio-ecological processes working on multiple scales both in space and time and there has been debate about the appropriateness of the proposed indicators. Scientific literature supports this, as e.g. Geist and Lambin (2004), Wantzen and Mol (2013), and Sommer et al. (2011) all argue, a single set of cross-scale indicators are highly unlikely to accurately identify land degradation in different locations around the world (see also Box 2). Consequently, given the complexity of land degradation and as well as the range of capacities countries have, the TSP allows for local adaptations of these indicators and encourages the use of additional indicators that are relevant in the specific context (Buenemann et al. 2011, Sommer et al. 2011, LDN-MN 2015). The Technical Guide (UNCCD, 2016) also recommends different tiered datasets for developing LDN baselines and monitoring:

- Tier 1: includes global and regional data (i.e. from earth observation systems)
- Tier 2: refers to data from national statistics or national earth observation systems
- Tier 3: are primary data from field surveys and ground measurements

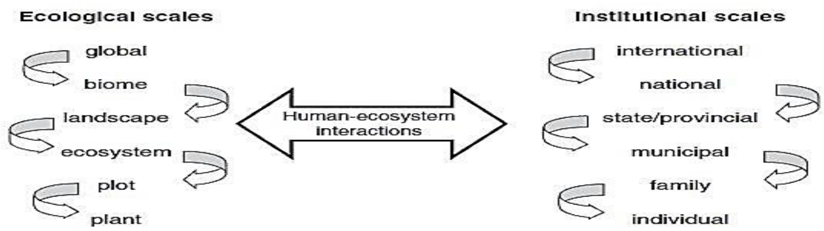
With regard to tier 1, UNCCD (2016a) has defined default global data sources with the aim to provide participating countries with globally available data for their validation and/or use in the absence of national data. These default data sources are included within the following review (chapter 2).

As the word 'trend' implies land degradation monitoring is an analysis of changes over time. It is important to emphasize that in a baseline assessment, no time-series analysis is required as the assessment deals with the current natural resource stocks and state of the land.

The following chapter focuses on available methods and data for assessing LDN baselines at the sub-national scale in Otjozondjupa Region in Namibia and Rio Jesús Maria watershed in Costa Rica, using available Tier 1 data. Chapter 3 will examine what Tier 2 and 3 data are available in the respective sub-national regions, as well as what alternative indicators might apply. It also covers the process of multi-criteria decision making process which was used in stakeholder workshops in both locations, to ensure. Lastly, we present the conclusions in chapter 4.

[3] While the official name of the third indicator is 'Carbon stocks above/ below ground', this report uses the name of the corresponding metric defined by UNCCD, which is 'Soil organic carbon'.

Box 2: Spatial scales of socio-ecologic systems
The terms local, national, regional, and global scales are used throughout this report. The different scales refer to the management/institutional unit or the ecological scale it captures. There is no clear definition of the extent of the different scales, as it is highly contextual. For instance farm sizes vary from thousands of ha in Western Australia (can be captured by coarse scale data) to less than 0.5 ha subsistence farms in Tanzania (needs to be fine scale data to capture changes). The same is evident of municipal and country sizes around the world as well as ecosystem sizes and boundaries. Therefore, the appropriate scale of data reflect the scale of land management and the boundary of the underlying ecosystem (Willemen et al., 2009).



2 Review of existing frameworks, methods and data for assessment of LDN baselines for Tier 1 data

This chapter gives an overview of remote sensing data sources and examines existing methodologies and datasets that can be used for developing baselines for LDN at subregional level using Tier 1 global datasets selected in accordance with the abovementioned checklist in Box 1.

2.1 Overview of remote sensing data sources

Land degradation assessments generally have been completed using several approaches, or combination of approaches (Sommer et al. 2010, Reed et al. 2011), including expert opinions (qualitative), land users' (or stakeholders') opinions (qualitative), field monitoring (observations and measurements), modelling (e.g. for estimates of productivity changes or SOC) and remote sensing (e.g. NOAA-AVHRR, MODIS, Landsat, Sentinel-2). Remote sensing has become one of the most important tools for many different types of assessments and other monitoring efforts. It will play a central role in an LDN baseline, and therefore it is shortly presented in this chapter.

Remote sensing is based on satellite sensors which collect a large amount of data at various spatial and temporal resolutions, and can be classified into passive (e.g. optical, thermal) and active (radar and LiDAR) systems. Optical sensors such as Landsat (NASA), Moderate Resolution Imaging Spectroradiometer/ MODIS (NASA), Sentinel-2A (ESA), as well as the commercial sensors RapidEye (PlanetLabs) and WorldView (Digital Globe) are widely used in assessing and monitoring land processes, including vegetation cover, biodiversity, urbanization, soil properties, and soil erosion, to mention some examples. Active systems like radar are gaining ground because they can be applied in areas with high cloud cover where radar waves are not restricted and they provide additional valuable information like surface roughness. However, few baselines exist, there is less expertise available in the land cover community, and passive optical systems are still the most widely used.

The increased quality and availability of remote sensing data, including free satellite imagery such as MODIS and Landsat (e.g. the archives of the University of Maryland Global Land Cover Facility), and more recently Sentinel-2 of ESA's Copernicus program have opened a range of new possibilities for the application of remote sensing in the operational assessment of land degradation processes. The most commonly used free remote sensing sensors are listed below

Table 2.1. Overview of the most common free multispectral remote sensing sensors used in the assessment of land resources and land degradation.

Sensor	Spatial resolution	Temporal resolution	Spectral bands	Launch
NOAA-AVHRR	8km	1 day	6	1982
MODIS	250m, 500m and 1km	1 day	7	2000
Landsat 5	30m, 60m	16 days	7	1982
Landsat 7	15m, 30m, 60m	16 days	7	1999
Landsat 8	15m, 30m, 60m	16 days	11	2013
Sentinel-2A	10m, 20m, 60m	10 days	13	2015
SPOT 5	2.5m, 5m, 10m	2-3 days	5	2002
SPOT 6	1.5m, 6m	1 day	4	2012
SPOT 7	1.5m	1 day	4	2014

The explanatory value of remote sensing data can be increased by different modelling techniques. Modelling involves mathematical changes to values of the original data in order to capture features that are not directly measured by the data available, e.g. turning the points of soil samples into a continuous map, or when various remote sensing data layers are comprised into one map with multiple features.

It might be necessary, for instance, to combine remote sensing data with field observations, or to improve on spatial and temporal resolution with ancillary remote sensing images (Congalton et al. 2014). MODIS of NASA's Terra and Aqua satellites, for example, produces a number of bands of different wavelengths that can detect multiple changes in the landscape with a high temporal resolution (see Table 2.1). However, many of these derived products are still only available at a coarse scale (500m and 1km), which challenges the assessment of land degradation because it often takes place at a finer scale.

It is likewise possible to combine multiple remote sensing data into one analysis. For example, MODIS can provide a high temporal resolution, time series, allowing for analysis of seasonal patterns and phenology, while Landsat can provide better granularity to identify what processes and land uses underlie the situation. Remote sensing has been applied for the assessment of land degradation in several different contexts, most commonly for analysis of land cover and productivity, but also for assessing SOC and soil erosion prevalence in landscapes (see e.g. Eva et al., 2012; Vågen et al., 2013).

2.2 Indicator 1: Land cover

According to the UN Land Cover Classification System (LCCS), land cover refers to the observed (bio)physical cover on the earth's surface. It is one of the most commonly used indicators for human-induced or natural impacts on ecosystems (Herold et al. 2009), and is also used to report to the UNFCCC. This indicator can detect transitions between land cover if it is analyzed in time-steps, and may indicate degradation (UNCCD 2015c) when changes are the following:

1) natural and semi-natural land cover types (e.g., forest, shrubs, grasslands, sparsely vegetated areas) change to agricultural land and artificial surfaces (e.g., urban, infrastructure, recreation);
2) agricultural land changes to artificial surfaces;

or might indicate signs of recovery if:

3) agricultural land (and artificial surfaces) change to natural and semi-natural land cover type.

It is important to establish a solid baseline for these changes, as again, the context is central. There may be cases where highly degraded mining or agricultural lands are abandoned and the subsequent succession growth would be classified as semi-natural land cover. While these areas are still degraded when compared to the original land use, they may be classified as non-degraded when compared to the previous land use. This can be found in e.g. tropical rain forests, where cleared areas show quick succession after they are abandoned.

A combination of approaches might be needed for detailed assessments of land cover baselines at a fine scale, as discussed above. It is advised (UNCCD 2015c, 2016a) that data used to establish a baseline should preferably be an average of a period of 10-15 years, and therefore, should be available from at least the year 2000 and onwards. The measurement unit should be in hectares, and the classification be based on Food and Agriculture Organization's (FAO) Land Cover Meta Language (LCML) is recommended to ensure global comparison is possible (UNCCD 2016a).

2.2.1 ESA CCI-LC

The European Space Agency's (ESA) Climate Change Initiative Land Cover dataset (CCI-LC) (*www.esa-landcover-cci.org*) is the default tier 1 option for land cover set by UNCCD (UNCCD

2016a). This dataset is based on modeling of multiple remote sensing products (SAR, Landsat, MERIS, MODIS), has a 300m resolution, is publicly available, and is produced every five years since 1998, with the last updates in January of 2016. It classifies 22 different land cover categories. The spatial resolution can miss some of the detail important for sub-national assessments of land use changes (Ban et al., 2015), as for instance in small scale heterogeneous landscape, as shown in Figure 2.1. However, ESA's CCI-LC datasets were shown to be quite accurate at a global scale (74% accuracy) (Bontemps et al., 2015). Furthermore, it is still in production so will be available for future monitoring and evaluation (M&E) procedures, as well as be comparable between regions.

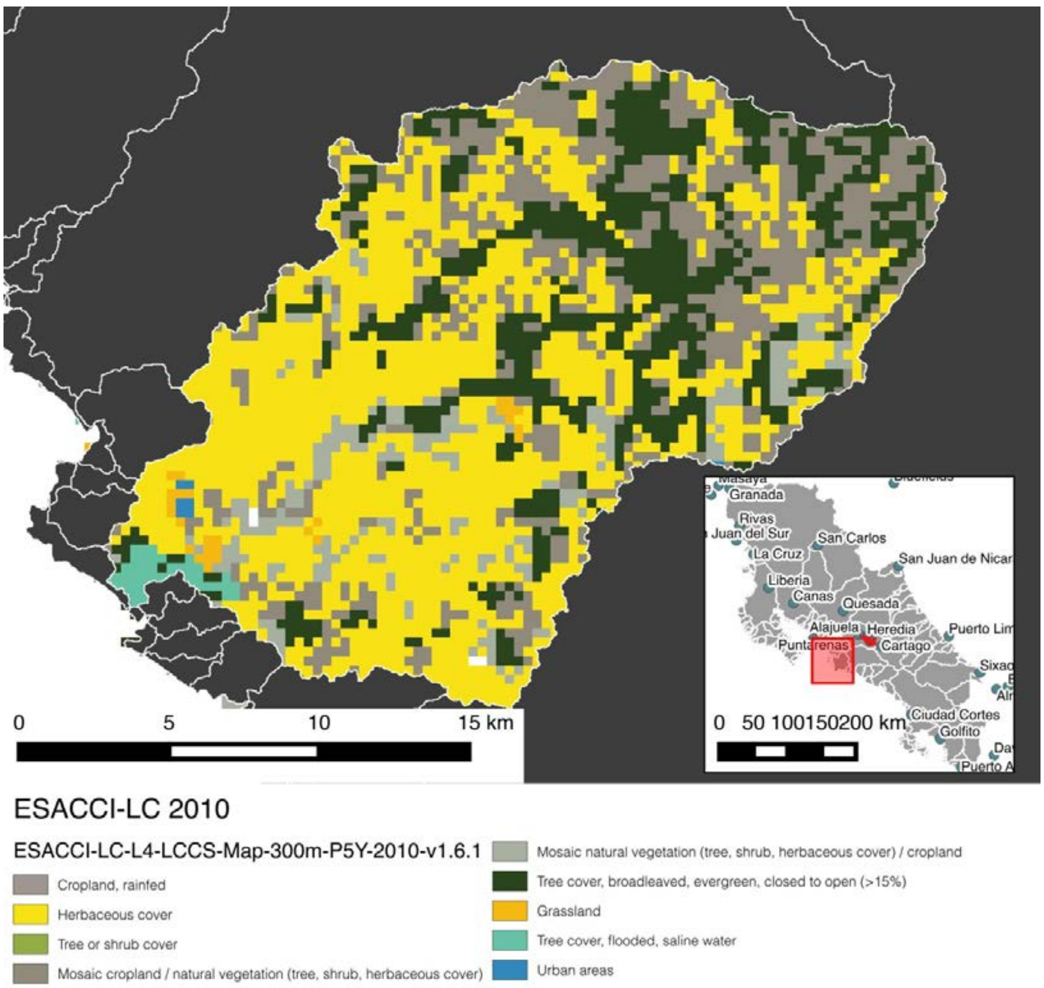


Figure 2.1. ESA CCI-LC map for the Jesus Maria watershed in Costa Rica, 2010. Spatial resolution for this product is 300m.

2.2.2 Globeland30 (GL30)

This initiative was launched by China in 2010 with the aim to develop a set of land cover mapping products globally. The approach is a model that combines imagery from the 30m resolution Landsat, MODIS imagery, and SRTM digital elevation data (www.globeland30.org). Maps were produced for 2000 and 2010 (**Error! Reference source not found.**2.2) and thus have the recommended 10 year coverage for land cover baseline assessments. It is however, no longer updated and therefore will not be sufficient for future change detection. There are 10 land cover classes, comparable to the proposed UN Land Cover Classification System (LCCS): (1) cultivated land; (2) forest; (3) grassland; (4) shrubland; (5) water bodies; (6) wetland; (7) tundra; (8) artificial surfaces; (9) bare land and (10) permanent snow or ice. The GL30 is a publicly available at globallandcover.com.

The land cover classes can be quite coarse for baseline studies at sub-national levels. GL30 is included in this review because it has a finer spatial resolution and better accuracy than ESA CCI-LC (300 m), and might be able to better capture the changes in small scale landscape mosaics. Figure 2.2 shows a 30m resolution land cover map for Namibia. Furthermore, GL30 is produced from a combination of multiple imagery and is an example of how additional spatial data can improve the final product, if spatial resolution is too coarse (Congalton et al. 2014), as discussed above[4].

[4] See *http://ngcc.sbsm.gov.cn/article/en/ps/mp/201302/20130200001694.shtml* for a breakdown of the modelling procedure behind of GLC30

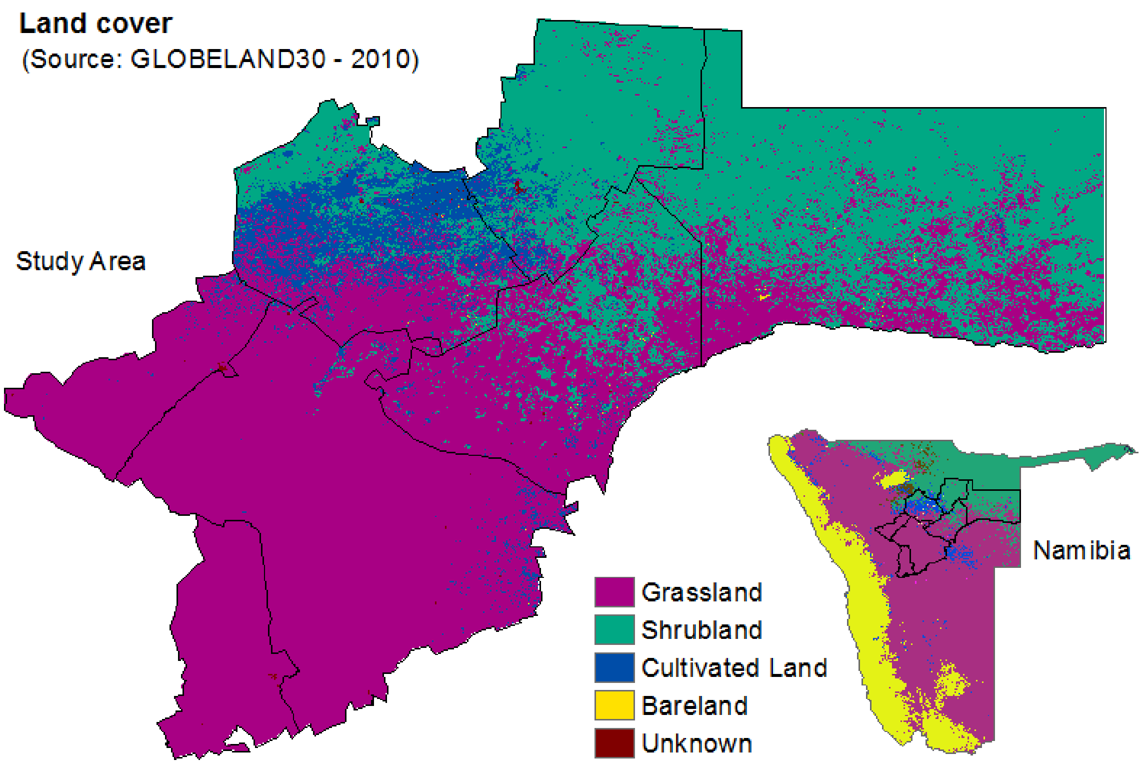


Figure 2.2. Land cover classes for Otjozondjupa, Namibia based on GLOBELAND30, representing the year 2010.

2.2.3 JRC TREES-3

The Joint Research Centre (JRC) Trees-3 project was designed to produce estimates of tree (forest) cover change in tropical regions and biomes globally, as a contribution to UN's Reducing Emissions from Deforestation and Forest Degradation (REDD), and to provide information to the European Commission (http://forobs.jrc.ec.europa.eu/trees3/). The time-step coverages are 1990-2000 and 2000-(2005)-2010, and it is based on Landsat TM and ETM+ data. It uses a multi-temporal segmentation to classify imagery based on a 1×1degree geographical grid (~20×20km). Each of these $20km^2$ sample units is divided into 5ha minimal mapping units, based on a more detailed resolution (30m) picture of the watersheds within the sample unit.

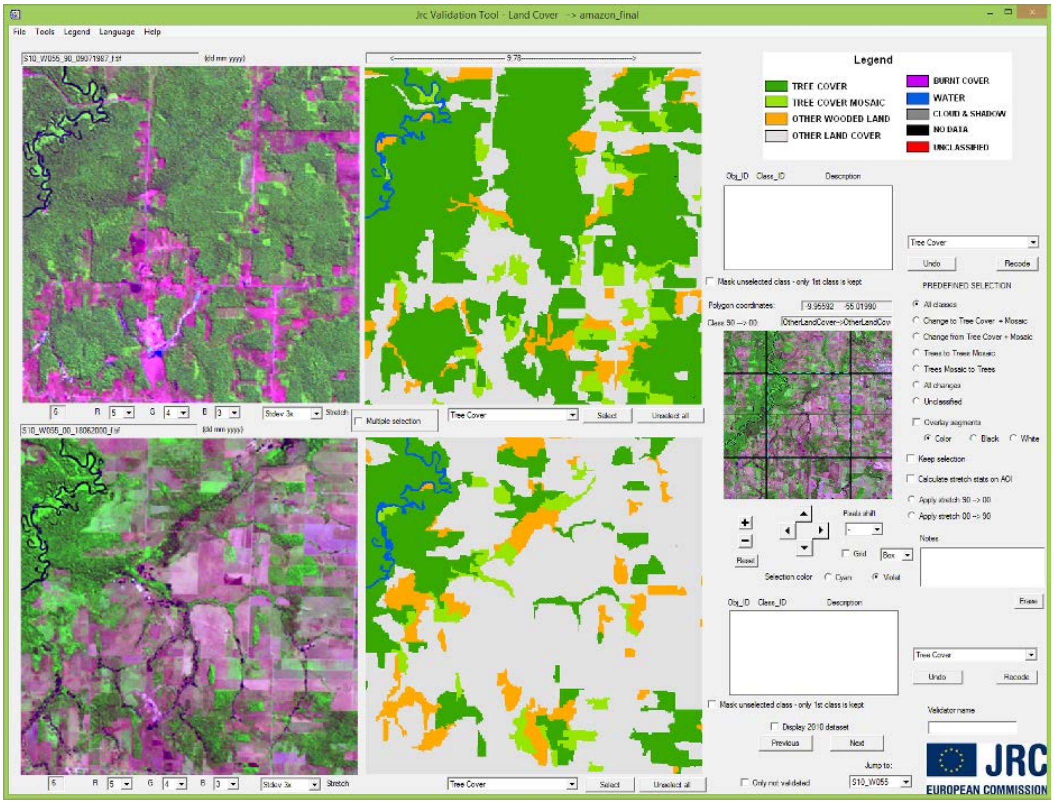


Figure 2.3 Visual validation tool for JRC TREES-3 from http://forobs.jrc.ec.europa.eu/products/software/validation/JRC_validation_tool_60.png

This spatial segmentation is then used to calculate on what type of land cover change has occurred. The final step in the JRC Trees-3 framework includes a visual validation process by experts, and therefore has an integrated validation program for processing. This is shown to be up to 90% accurate. The Trees-3 is also equipped to scale up the sub-national baselines in a consistent manner, and thus would contribute towards a transparent and internationally comparable baseline methodology. It does however, only cover tropical (humid) areas and within these, only forest land cover. Thus, it lacks a continuous cover for overall terrestrial land degradation.

2.2.4 JRC Phenology based land cover classification

Another promising JRC land cover dataset is a phenology[5]-based land cover classification that can use multiple remote sensing products, including Landsat 8 (30m), MODIS (250m) and

[5] Phenology is the study of periodic changes, in this case in vegetation, influenced by e.g. climatic cycles and interannual changes of for instance leaves on trees. This can differ much between seasons and in some cases cause wrongful classification of the land cover (http://forobs.jrc.ec.europa.eu/products/software/).

now also Sentinel 2 imagery (10m resolution) (http://forobs.jrc.ec.europa.eu/trees3/). This method has the same geographical structure and validation process as TREES-3 and exhibits equally high accuracy in tested areas (between 82% and 90%). It offers a few more land categories than TREES-3, shrub, grassland and sparse vegetation, but no land uses (e.g. cropland). The idea behind the phenology based land cover mapping is to capture differences in vegetation over the seasonal changes that might occur, and thus give a more accurate picture of the vegetation, than one time imagery. This method has been applied to Landsat 8 imagery and thus, only provides data going back to 2013, but is compatible with older products from Landsat imagery for backdating (Simonetti et al. 2013). The product is still being developed and tested and only a few areas have been mapped to date. Furthermore, the script is available for Google Earth Engine (a data archive and cloud computing platform), which is free but has a selective membership process through application.

2.2.5 Terra-I

Terra-I is a fully automated near-real time observation system for monitoring deforestation activities, developed primarily for the humid tropics (www.terra-i.org/). Terra-I has finer spatial resolution than ESA CCI-LC, at 250 m at 16 day intervals, as well as the ability to discern between natural and human induced land degradation, which could prove important in determining land degradation drivers[6]. The model consists of a forecasting model that predicts future normalized difference vegetation index (NDVI) values[7], based on historic greenness (MODIS NDVI time-series), and observed or estimated meteorological and climate fluctuations and thus estimates the probability of change attributed to human disturbances (Reymondin et al. 2013). This method has not been applied for assessment of land degradation as such, other than deforestation, and is as such not equipped to detect degradation in non-forested systems such as grassland or agricultural fields.

2.2.6 The Land Potential Knowledge System (LandPKS)

The LandPKS currently consists of two smartphone apps – LandInfo and LandCover – for data collection (http://landpotential.org/index.html). The main aim of LandPKS is to use mobile technologies and cloud computing to crowd-source knowledge and information, expanding the concept of Ecological Knowledge (Herrick et al., 2013). The LandPKS has been applied for assessing soil texture and land cover, with case studies in Namibia (not in Otjozondjupa), Kenya, and Ethiopia. The method has not yet been applied to assess land degradation and is still under development. Thus, this system would have to be developed further, and may in the future offer a low-cost rapid assessment of LUC in LDN assessments.

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[6] http://www.terra-i.org/dam/jcr:508a0e27-3c91-4022-93dd-81cf3fe31f42/Terra-i%20Method.pdf

[7] a proxy for net primary production (NPP), which will be discussed in further detail in section 2.3

2.2.7 The Land Degradation Surveillance Framework (LDSF)

The LDSF (Vågen et al., 2013a) was designed for landscape-level assessments of land degradation (*http://landscapeportal.org*). It includes soil carbon dynamics and stocks, land cover change (vegetation cover and floristic composition), land use, soil health, hydrological properties, biodiversity, soil erosion and compaction. It uses "sentinel sites" designed to provide accurate baseline data and monitoring of land health. By combining field measurement protocols that are systematic with remote sensing data from a range of different platforms (e.g. MODIS, Landsat, RapidEye and Sentinel-2), the LDSF is being used for identification of land degradation hotspots and soil mapping at both regional and local scales.

The LDSF has been applied in more than 35 countries in the tropics for baseline assessments of land degradation at multiple spatial scales, as well as for local assessments of soil health and land degradation with spatial resolutions ranging from 5 m to 30 m (Vågen et al., 2013b; Winowiecki et al., 2015) and at continental scale with a spatial resolution of 500 m (Vågen et al. 2016). The methodology has four main components:

1) A spatially stratified, hierarchical, field sampling design using 10x10 km sentinel sites;
2) Use of soil infrared (IR) spectroscopy for prediction of soil properties (for Indicator 3)
3) Use of remote sensing and ensemble learning methods for mapping of land degradation and land health;
4) Remote sensing for mapping of land cover and land use change.

LDSF uses a combination of Landsat and MODIS derived data to determine the land cover, and thus has the same time series as these products.

2.2.8 Indicator 1 overview

The following table includes a brief overview of the advantages and disadvantages of each method as mentioned in section 2,2

Table 2.2. Overview of data sources for Indicator 1: Land Cover

Method/ framework	Implementer	Main indicators	Spatial scale/resolution	Primary data collection	M&E potential	Accuracy	Pro	Con
ESA CCI	ESA	6 Land cover types	300 m	No	+	74 %	LDN default, available in the future comparable to other LDN countries, open source, used in other reporting obligations	Low spatial resolution
GL30	NASG/ UN	10 land cover types	30m, but effective scale can vary	No	-	80 %	High resolution Land cover, 10 land cover classes, open source, inter/nationally comparable	Accuracy varies, no longer updated, 2 time-steps
JRC: TREES-3	EC/ JRC	NDVI Tree (forest) cover	20km grids, underlying 5ha units based on	No	+	Up to 90 % accuracy, dependent on LUC-type	High accuracy for the proposed LU/C trend, 11 sites for Otjozondjupa region,	No continuous cover, no land use categories, low thematic detail

			30m resolution					
JRC Phenology	JRC	NDVI based phenology observations	10-30m	No	+	82-90%	Fine spatial resolution, high accuracy, can possibly detect changes in bush encroached areas	No continuous cover, no land use categories, low thematic detail, only time-steps since 2013
Terra-I	CIAT	Forest cover change	250m	No	++	73 %	Human-induced degradation, near real time updates (16 days)	Low thematic detail, only forest cover changes
LandPKS	USDA	Soil texture, vegetation cover	Point data	Yes	++	n/a	Rapid assessment tools, relies on crowd sourcing, potentially usable for M&E field validation	No validation available, no time series, secondary processing necessary
LDSF	ICRAF/ CIAT	Soil health, land use, land cover and phenology, biodiversity, erosion	5 m to 500 m	Yes	+	n/a	Different resolution options, wide variety of degradation indicators	Depending on resolution: relatively high labor and data input required, high cost

2.3 Indicator 2: Land Productivity

Land productivity is a measure of above ground net primary productivity (NPP), and is defined as the difference between the total photosynthesis and the total plant respiration in an ecosystem, or as the total new organic matter produced during a specified interval (Clark et al. 2001). It is reported in tons of dry matter per hectare per year (tDM/ha/year).

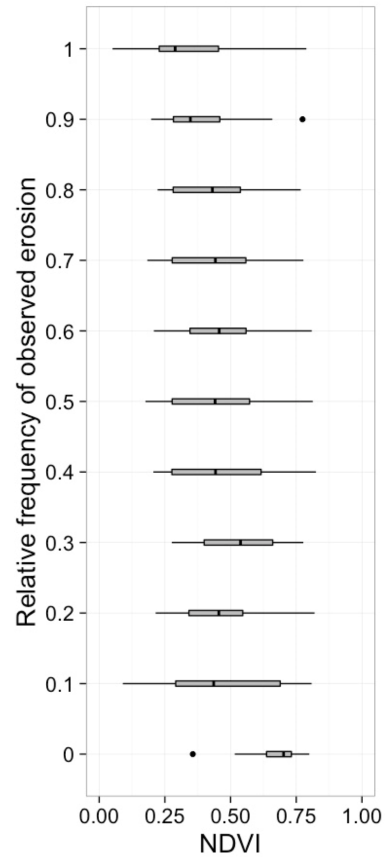

Figure 2.3. The relationship between erosion observed in the field and NDVI calculated based on Landsat 8 for 81 LDSF sites.

Primary productivity of plants shows distinct dynamics over different temporal scales; daily variability due to the position of the sun, intra-annual variability due to seasonal effects and inter-annual variability due to changes in climate, or changes in management and land use. In order to detect degradation from temporal series of NPP, it is therefore important to filter out the effects of the vegetation's natural dynamics, that is specific for the type of ecosystem in question (Dutrieux et al., 2016; Jacquin et al., 2010).

The LDN TSP (UNCCD 2016a) guides land productivity to be disaggregated by type of land cover it occurs in and productivity is therefore a proxy for management, land use intensity, and potentially degradation. If organic matter is extracted faster than it is produced NPP will decrease and is an indication that the ecosystem is being degraded (Haberl et al. 2001).

Proxies for NPP, such as the much used Normalized Difference Vegetation Index (NDVI) (Rouse et al., 1974) from MODIS, basically account for the quantity of the standing biomass at a given time. Although biomass and productivity are closely related in some systems (Lohbeck et al., 2015), they can differ widely when looking across land uses and ecosystem types. For instance, a challenge with NDVI, specific to rangelands with bush encroachment, is that productivity will likely increase.

In such a scenario, an increase in NDVI means that land degradation is occurring, where normally an increase of productivity would indicate the opposite. Similarly, intensive mono-cropping systems with fertilizer application could also produce a false positive, i.e. an increase in productivity that is not associated with a decrease of land degradation. In this case, fertilizer-use can mask the real state of the land under production (UNCCD 2015c). These scenarios need to be evaluated in the context of the region of the LDN baseline assessment (UNCCD 2016a).

Also, there are discussions about whether NDVI tends to saturate when applied over densely vegetated areas (Huete et al., 1999), which is a concern when using NDVI to estimate NPP in forested regions, or when applying it to forest degradation (Kennedy et al. 2010).

NDVI has also been suggested as a simple proxy for overall land degradation in areas where precipitation is not the main driver of vegetation dynamics, e.g. in humid tropics (Yengoh et al., 2014). However, the relationship of NDVI and – for example – soil erosion, which is a major land degradation process, is very weak (figure 2.3).

Given some of the challenges with NDVI-derived products mentioned above, there are some commonly used vegetation indices that can be used as an alternative or an addition to traditional NDVI products. In the following section, firstly the JRC Land Productivity Dynamics (LPD) – default Tier 1 option for Land productivity as defined by UNCCD – is presented, and then three commonly used derivative products are discussed for their added value at national and/or subregional level: Enhanced Vegetation Index (EVI), Soil-Adjusted Total Vegetation Index (SATVI), and The Normalized Cumulative RUE Differences (CRD) index. These could potentially improve the existing NDVI based productivity estimates in certain contexts, either by themselves or as in complementation to NDVI.

2.3.1 JRC Land Productivity Dynamics

The JRC Land Productivity Dynamics (LPD) data has been proposed as a default dataset by UNCCD (2016a) when countries do not have better alternatives available. This dataset is based on a 15-year time-series of NDVI observations, and as such already includes the trends. It is produced at a spatial resolution of 1 km and data are classified into five productivity classes depending on the state of the system (see Table 2.3). The NDVI is adjusted for seasonality and phenology, as mentioned above, in an analysis of long-term changes (29 years, using NOAA GIMMS 3G) and current (5 year SPOT VEGETATION) efficiency levels of vegetative above ground biomass was combined into land productivity dynamics (Cherlet et al. 2013). A global map of LPD was furthermore derived by using 15 year SPOT VEGETATION 1999-2013.

Table 2.3: Classes of productivity in the JRC LPD data.

Class	Description	Criteria[8]
1	Declining productivity	3% decrease over 10 years
2	Early signs of decline	2% decrease over 10 years
3	Stable, but stressed	1% decrease over 10 years
4	Stable, not stressed	no change
5	Increasing productivity	Increase

[8] See LDN-MN (2015) for explanation of these criteria.

The JRC dataset's 1 km resolution is unlikely to be of appropriate scale to reflect human activities at a sub-national scale (Ban et al., 2015), especially in small scale landscape mosaics. UNCCD (2016a) suggests using the above classification to determine the degree of degradation. The method relies on remote sensing measures of productivity trends of above ground biomass, such as NDVI, for different land uses, e.g. forest or agriculture.

2.3.2 EVI

The Enhanced Vegetation Index (EVI) was proposed by the MODIS Land Discipline Group (Huete et al., 1999) as an improvement over NDVI, as it takes more information into account about vegetation and canopy structure, and is more reliable in areas that has a high biomass, where NDVI has been shown to saturate. EVI uses the same satellite imagery as MODIS NDVI and is thus also available at 250m resolution. It includes coefficients to reduce the influences of soil (i.e. light reflectance under the plants) and atmospheric conditions (i.e. light reflectance above the plants, e.g. cloud cover) on the VI[9]:

$$EVI = \frac{NIR - Red}{NIR + C_1 \cdot Red - C_2 \cdot Blue + L}(1 + L)$$

Figure 2.4 shows an example of the application of the EVI to detect trends in land productivity in Otjozondjupa, Namibia, at a 250m resolution. EVI is shown to have an accuracy of 85% (Huete et al., 1999)

[9] The soil adjustment factor L corrects for soil background effects, while the coefficients C_1 and C_2 correct for aerosol scattering in the atmosphere.

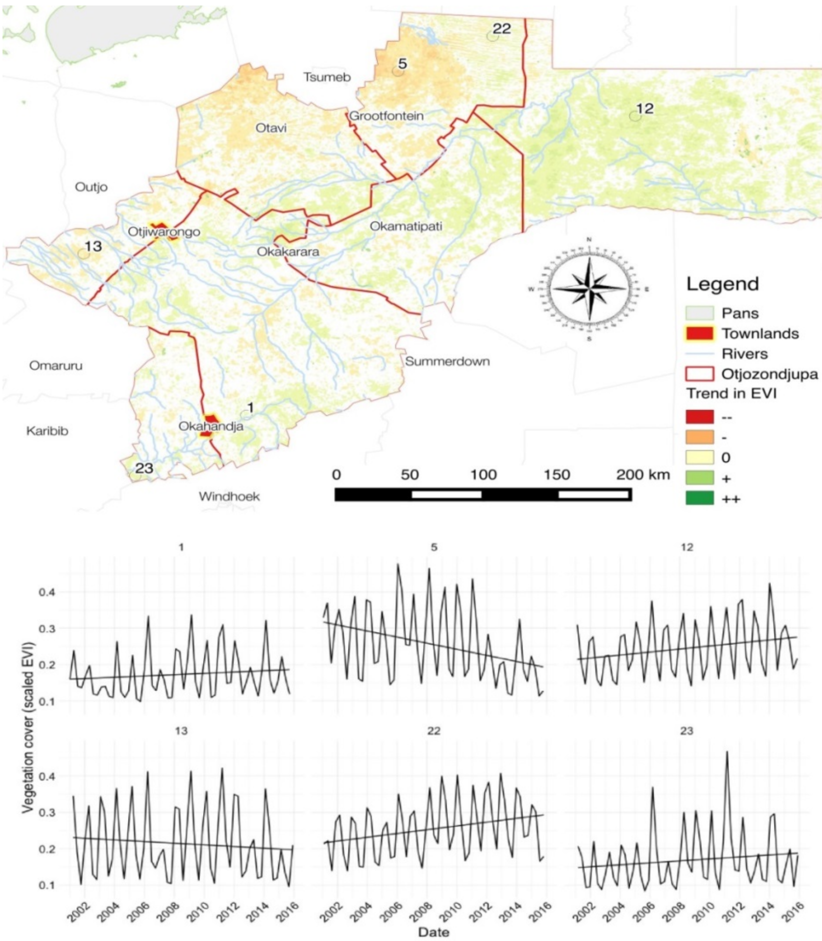

Figure 2.4. Vegetation cover trends in Otjozondjupa, Namibia, during the period 2001 through 2015 (map on top), based on MODIS EVI (250 m spatial resolution). The trends were computed after first removing the seasonal cycles from the time-series. The graphs on the bottom show time-series for selected areas (see points on map, labeled as per the plots), with simple linear trend estimates.

2.3.3 SATVI

The Soil-Adjusted Total Vegetation Index (SATVI) from Landsat 5 TM[10] was developed to specifically measure above ground biomass in arid vegetation, by including both green and senescent – dry — vegetation for rangeland monitoring (Marsett et al. 2006). Thus, the SATVI is more sensitive to dryland vegetation that has a weak signal of chlorophyll compared to other VI indices, as e.g. NDVI (Qi et al. 2002, Marsett et al. 2006)[11]:

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[10] *Bands 3, 5, and 7*

[11] *Where ρ is the reflectance values of the different bands of the sensor: band 5 (short-wave infrared), 3 (red) and 7 (mid-infrared band).*

$$SATVI = \frac{\rho(SWIR) - \rho(red)}{\rho(SWIR) + \rho(red) + L}(1 + L) - \frac{\rho(MIR)}{2}$$

However, SATVI has been shown to falsely suggest vegetation in barren and rocky areas and such areas should be masked out before processing. Furthermore, it is limited to satellites using short-wave sensors, such as Landsat, which gives a minimum resolution of 30m (Marsett et al. 2006).

2.3.4 CRD

The Normalized Cumulative RUE Differences (CRD) index uses Rain-Use Efficiency (RUE; Le Houerou 1984) to normalize MODIS NDVI and decouple the rainfall variability from productivity (Landmann and Dubovyk 2014). This separates human-induced productivity changes from climatic variations. CRD is thought to be an indicator for productivity decline in dryland areas, where vegetation dynamics are strongly linked to precipitation (Yengoh et al. 2014). However, there have been quite a few reported inaccuracies with this method, especially when modelling over short time series in high intensity agriculture systems, which challenge the use of CRD as a stand-alone indicator (ibid). Nevertheless, CRD has been shown to have an accuracy of 68% or higher in detecting changes in vegetation productivity depending on land cover type in drylands (Landmann and Dubovyk 2014).

2.3.5 Indicator 2 overview

The following table includes a brief overview of the advantages and disadvantages of each method or datasets as mentioned in section 2.3.

Table 2.4. Overview of data sources for Indicator 2: Net Primary Productivity

Method /frame work	Implem enter	Main indica tors	Spatial scale/res olution	Primary data collection	M&E potenti al	Accuracy	Pro	Con
JRC LPD	JRC/EC	NDVI	1km	No	+	n/a	LDN Default. internationally comparable	Low resolution, NDVI based
MODIS-EVI	NASA	Enhanced VI	250m	No	+	85%	Enhances accuracy of MODIS NDVI, internationally comparable	Low resolution, can have problems with agricultural land productivity
SATVI	Marsett et al. 2006	Soil adjusted VI	30m	No	+	n/a	Takes both photosynthetically active and inactive vegetation into account, internationally comparable	Problems with detecting barren land
CRD	Land-mann and Dubovyk 2014	Rainfall adjusted VI	250m	No	+	68%	Decouples human and climatic variations, internationally comparable	Shown to be inconsistent in short timescales and outside semi- and arid ecosystems,

2.4 Indicator 3: Soil Organic Carbon (SOC)

Soils that are losing organic carbon are experiencing degradation and SOC is thereby a key indicator of soil health. The organic carbon also plays an important role in the biogeochemical cycles that can restore soil health. Soil carbon sequestration is therefore recognized as an important strategy for both, climate change mitigation as well as adaptation.

Indicator 3 reports on organic carbon stock above (biomass and leaf litter) and below ground (soil), however since above ground organic carbon is already to some extent reported through the UNFCCC, and there is no operational total terrestrial carbon estimation methodology to date, this baseline assessment will concentrate on Soil Organic Carbon (SOC). Furthermore, SOC has so far mostly relied on modeled trends based on LUCs (LDN-MN 2015, IPCC 2006). SOC is to be reported as tons of carbon per hectare (t/ha C). In the following sections, we review some of the existing methods that are available for a specific country or context to report and monitor SOC stocks, and we outline important considerations when assessing SOC.

There are a number of existing methodologies and datasets available to measure soil organic carbon (Aynekulu et al., 2011; Ellis and Larsen, 2008; McBratney et al., 2006; Stockmann et al., 2013 among others). They differ in the sampling framework used, field sampling methods and observations, laboratory analytical methods, uncertainty and change detection, and costs. Most important, however, is making sure the sampling framework and associated measurements comply with the objectives of the study at the appropriate scale. Furthermore, one should carefully match the type of analysis with the appropriate sampling strategy. In fact this is a continually debated subject in the soil science community (Brus and de Gruijter, 1997; Heuvelink and Webster, 2001).

Laboratory measurements

Two widely used analytical methods to measure soil carbon concentration are the Walkley-Black (wet chemical oxidation) procedure (Walkley and Black, 1934) and dry combustion. Dry combustion is generally the recommended reference test for soil carbon as the Walkley-Black procedure only recovers about 75% of the SOC in the soil sample (Bhattacharyya et al., 2015). The latter method is, however, recommended when working in low SOC soils (less than 2%) (Rowell and Coetzee 2003).

Soil infrared spectroscopy (IR) is another (emerging) technology that makes large area sampling and analysis of SOC feasible (Brown, 2007; Brown et al., 2006; Shepherd and Walsh, 2002; Vågen et al., 2006). The use of IR, and in particular mid-infrared (MIR) spectroscopy, produces consistent (and reproducible) predictions of SOC and allows for increased sample densities in order to capture the high spatial variability of SOC across landscapes (Terhoeven-Urselmans et al., 2010; Vågen et al., 2016). Recent reviews show a strong increase in the use of both NIR and MIR spectroscopy for soil analysis (Bellon-Maurel and McBratney, 2011; Stenberg et al., 2010; Viscarra Rossel et al., 2011). The use of IR data can be integrated with geospatial statistics and remote sensing for estimation of SOC concentrations and stocks at scales that range from local (within farm) predictions to continental assessments (Vågen et al., 2012, 2013b, 2016, Winowiecki et al., 2015, 2016). Another major advantage of IR for soil analysis is the capacity to predict many soil properties simultaneously from a single spectrum (Stenberg et al., 2010), which further reduces the total analytical costs of soil analyses. When combined with the high throughput achievable when using IR for soil analysis, inventories of SOC stocks at project level or larger geographical extents become feasible.

Assessing the spatial distribution SOC, including changes over time

Methods for mapping of SOC concentrations and stocks at different spatial scales are under rapid development, with significant progress being made based on the systematic collection of data on SOC stocks, combined with remote sensing and novel approaches for statistical modeling, such as machine learning algorithms. Previous estimates of the spatial distribution of SOC were generally based on available soil maps, such as the Digital Soil Map of the World (DSMW) and later the HWSD (Batjes, 1996, 2004; Henry et al., 2009). These maps were produced at a very coarse spatial resolution, with large uncertainties, and were at best able to give rough estimates SOC stocks at continental scales. More recently, SOC has been mapped based on remote sensing, including air-borne light detection and ranging (LiDAR) (Asner et al., 2012), and space-borne Landsat (Vågen et al., 2013b), Quickbird (Vågen et al., 2012) and MODIS (Hengl et al., 2014; Vågen et al., 2016). Combining the use of cumulative soil mass to calculate SOC stocks with IR and remote sensing has been shown to have potential for assessing the spatial distribution of SOC stocks in landscapes (Winowiecki et al., 2016) by being both cost-effective, logistically efficient, and yielding high levels of accuracy.

2.4.1 The International Soil Reference and Information Centre (ISRIC) SoilGrids

The default option set by UNCCD (2016a) to measure soil organic carbon is the SoilGrids database from the International Soil Reference and Information Centre (ISRIC) (*http://soilgrids.org*). In terms of the indicators relevant to LDN processes, the SoilGrids database provides predictions on soil properties and classes at a resolution of 250m (see figure 2.5). The SoilGrids system is freely available and can be used by countries that don't have more accurate national or sub-national data available. ISRICs main objective is to provide the international community with information on global soil resources, focusing on soil data and soil mapping, as well as the application of soil data.

This means that the soil maps are based on the best global fit and might need field verification on a national or subnational scale to increase accuracy. However, SoilGrids is based on a continuously increasing number of soil profile descriptions (currently around 150.000) and covariates so that accuracy is increasing rapidly. Besides providing baseline maps of soil organic carbon, the mapping framework is built to accommodate shared soil data from different sources. Existing and newly gathered soil data (including soil spectroscopy data) for an area of interest can be uploaded – e.g. through the SoilInfo App (*http://soilinfo.isric.org*) – to improve the accuracy of predictions.

Soil organic carbon is predicted for six different depths, allowing for the calculation of carbon stocks, which can be used as approximations for baseline values for carbon monitoring. These baseline maps can also be used for optimization of sampling strategies for future carbon monitoring.

For Africa, the 250 m soil property maps used a combination of legacy soil data from the Africa Soil Profiles databases and soil data collected as part of the Africa Soil Information Service (AfSIS) project. The SoilGrids framework can also be used as a tool for monitoring and evaluation.

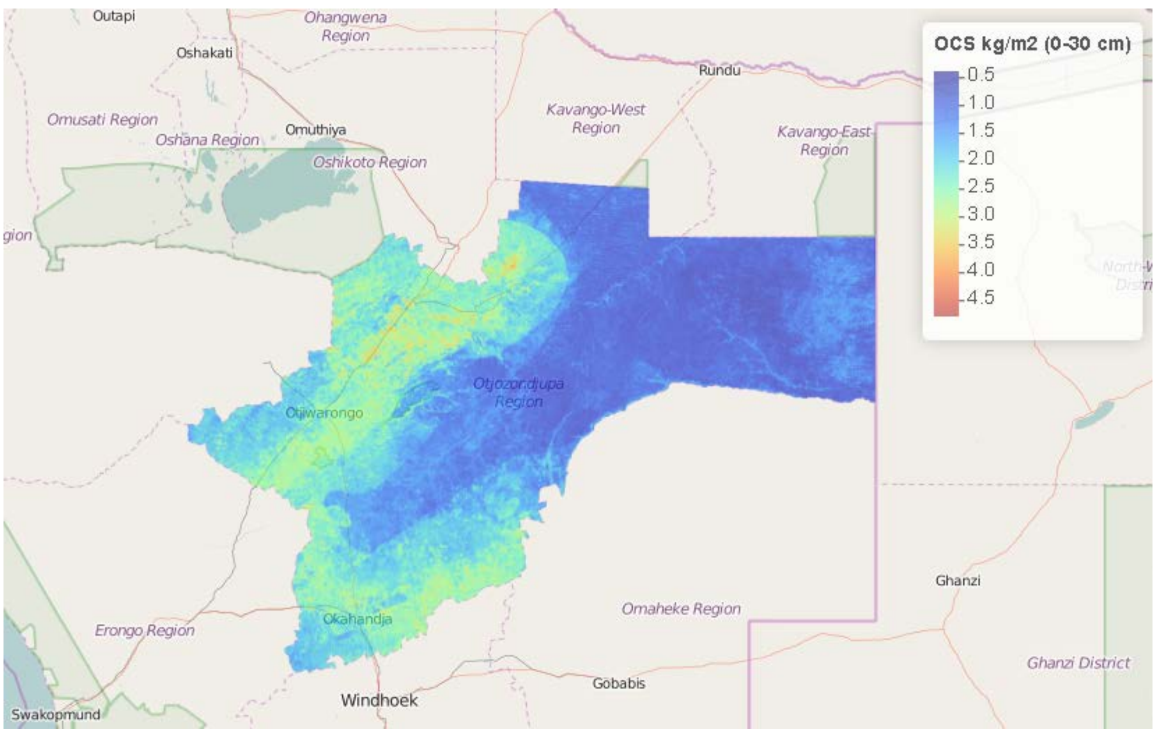

Figure 2.5. Predictions of soil organic carbon stock (0 to 30 cm, in kg/m2) for Namibia Otjozondjupa region, based on ISRIC SoilGrids.

The combination of a) an automated mapping system and b) a mechanism for crowdsourcing makes SoilGrids a tool for monitoring changes in soil organic carbon. Regular model runs will use the new sets of observations or measurements contributed, and automatically produce new maps for the area of interest.

2.4.2 LDSF

The main components of the LDSF are mentioned under Indicator 1, section 2.2. LDSF relies both on field sampling, soil infrared spectroscopy, remote sensing, and geospatial statistics for continuous soil organic carbon cover based on sentinel sites field sampling. Moreover, LDSF provides a detailed characterization of soil physical and chemical properties as well as effective rooting depth, and soil erosion status (Vågen et al., 2013b; Winowiecki et al., 2015), and at continental scale with a spatial resolution of 500 m (Vågen et al., 2016).

2.4.3 JRC Threats to Soil

The JRC publishes several datasets and maps under its Hub *Threats to Soil thematic area* – including soil erosion. The base maps available cover Europe and consist of maps based on the Revised Universal Soil Loss Equation (RUSLE), Soil Organic Carbon content (global at 30 arc-sec resolution, ~ 5 km) and a number of other layers for Europe or globally, such as salinization, pH and compaction. It also gives access to the DESIRE and GIS4ME portal maps generated under the land degradation projects GLASOD, LADA/GLADIS, and other large scale land degradation assessments. The Threats to Soil is primarily a repository for maps and methods, and does not have a framework or protocols for assessments of land degradation *per se*.

2.4.4 Harmonized World Soils Database

The Harmonized World Soils Database (HWSD) http://eusoils.jrc.ec.europa.eu/ESDB_Archive/octop/Global.html) was created by UNEP-WCMC and JRC. The dataset has a spatial resolution of 1km and estimates SOC content (tC/ha) for a depth of 1m, divided into 0-30cm topsoil layer and a 30-1m subsoil layer. The SOC is modelled using existing/legacy maps from FAO, IIASA, ISRIC, and ISSCAS for best global fit. The HWSD is no longer updated, nor does it have time-steps for trend assessment.

2.4.5 Indicator 3 overview

The following table includes a brief overview of the advantages and disadvantages of each method or datasets as mentioned in section 2,4.

Table 2.5. Overview of data sources for Indicator 3: Soil Organic Carbon

Method/framework	Implementer	Main indicators	Spatial scale/resolution	Primary data collection	M&E potential	Accuracy	Pro	Con
SoilGrids	ISRIC	Soil functional properties	250m to 1 km	Yes/No[12]	+	Validation tool available	High temporal and spatial resolution, provides an objective estimate of the uncertainty of mapping (per pixel), new global dataset available medio 2016, internationally comparable	Based on a global best fit, still under development
LDSF	ICRAF, CIAT	Soil health, land use, land cover pheno-logy, biodiversity, erosion.	5 m to 500 m	Yes[d]	+	n/a	Covers 3 indicators, high accuracy, different resolutions	Relatively high labor and data input required, depending on resolution, site specific, not internationally comparable
Threats to Soil	JRC	SOC, erosion, WRB Soil groups, etc.	30 arc-sec (~1 km)	Yes	-	n/a	Portal for soil assessments, e.g. LADA/GLADIS, DESIRE	No readily available data, only for Europe and global, not internationally comparable
HWSD	UNEP-WCMC, JRC	SOC tC/ha	1km, 9km	No	-	n/a	Globally available, internationally comparable	Coarse resolution, not updated

[12] Depending on resolution chosen

3 Selection of data and methods for development of sub-national LDN baselines in Costa Rica and Namibia

This chapter focuses on the process of evaluating the methods that have been presented in chapter 2, plus any additional methods as well as tier 2 and 3 data available or being developed in Namibia and Costa Rica and identified during local workshops. Furthermore it describes the evaluation of additional indicators beyond the UNCCD indicators Land cover, NPP, and SOC. The overall evaluation process consisted in selecting and weighting different criteria, ranking the available methods, and developing a plan for the implementation of baseline production.

3.1 Criteria for method selection

Multiple sources of combined data are likely to be most precise, as was the conclusion from earlier land degradation assessments (LADA/GLADIS 2009, Sommer et al. 2010, Reed et al. 2011). This is especially relevant if assessments must capture changes over time in at fine scale with heterogeneous land uses, compared to changes at large spatial scales.

While general criteria for LDN methods are presented in Box 1 above, national partners in Namibia and Costa Rica stressed that the following three criteria, in particular, were crucial for a baseline assessment. The selected method(s) must be:

1. cost-effective,
2. appropriate for the available national capacity and be repeatable independently by local partners, and
3. have value for other regional and national projects.

This specific emphasis does not necessarily imply that partners are less interested in methods that offer the highest resolution or accuracy. However, final decisions on the methodologies selected depend to a great extent on data requirements for local initiatives and capacities to implement the methods independently.

For instance, in Namibia, the pilot area is much larger and local capacities are being developed, partners are less interested in the latest techniques, if this means that the method is not cost-effective or that the methods have to be implemented by non-Namibian organizations. Contrarily, in Costa Rica the area is much smaller and there is a need for high resolution data. Here national institutions and universities have varying capacities, and thus partners were more interested in robust methodologies, that generate highly detailed information needed for local planning and local/national implementation.

Many countries have other commitments to the different UN conventions. It is therefore not desirable to increase the burden on national governments for reporting. One way to lessen the burden and be more cost-effective is to share datasets and monitoring tasks, for example on land cover and land use change. It is also increasingly more important that methods meet the available capacity and can be built to implement the methods and monitoring system independently.

Partners in Namibia and Costa Rica also emphasized that the LDN baselines needed to support ongoing development and sustainable land management plans. Where methods can support such plans, they will find greater buy-in and political support. This is especially important when the baseline is complete and targets are set for reaching land degradation neutrality. For example, degraded agricultural lands may already have targets related to NPP and SOC and the LDN targets should not conflict existing targets. Similarly, areas may already have land cover and land use change targets such as reforestation of areas that were previously deforested. Therefore, selecting a baseline method needs to be informed by ongoing national and regional (planning) processes and sustainable development plans.

3.2. Process for method selection

One of the difficult tasks with multi-criteria tradeoff analyses is setting weights for different criteria. For example, it is not a trivial task to compare cost-effectiveness and national capacity. Perhaps one method provides an opportunity to train national staff in a desired methodology but it does not provide the proper time-frame (10 years) to establish a trend for LDN. Weighing or ranking different criteria with a large group of workshop participants who have different perspectives can become problematic. Even the process of who is invited to the workshop and gets to decide, influences the process. Another challenge is that facilitators and decision makers often have to work with incomplete information. For example, not all the cost of implementing different methods were available at the time of the workshops, which was a challenge given that cost-effectiveness was one of the most important criteria.

During the workshops, it was therefore important to have a transparent process and recognize the limitations of selecting methods with incomplete information. There was deliberately extra time built-in for debate and discussion, and time was taken during each step of the process to make sure issues were clearly disseminated and understood, and thus that there was consensus to move forward. Overall, the selection process followed a three-step approach:

1. Overview of available information on methods, including national approaches, and reaching agreement on additional indicators where necessary
2. Weighting of selection criteria by LDN indicator
3. Completion of selection matrix to select one method for each indicator

During each workshop, presentations were given by experts on the different methods for each indicator (see chapter 2). Workshop participants were given ample time to ask detailed questions to make sure there is clear understanding of the pros and cons of the different methods. Local experts were also invited to give presentations on approaches used at the national level. The tables presented in chapter 2 at the end of each section were very useful to stimulate discussion.

Two approaches were used for weighting and scoring (1 to 5, with 1 being unsuitable and 5 being highly suitable) the different options. In Namibia, participants were divided in groups and each group discussed how the criteria should be weighted, and what score should be given for all three LDN indicators. The scores were then combined to determine the approach for each indicator. In Costa Rica, the workshop participant group was larger and there was more expertise in specific topics so that the groups were divided according to the LDN indicators. In each sub group, participants were asked to weigh the criteria and then assign scores to the different methods. In both cases, the groups had to agree to give one score collectively. This requires that everyone is engaged and this approach promotes discussion. Having a facilitator in each group helped to guide the discussion and allow all members of the group to be heard. Alternatively, we could have asked each participant to give a score which allows all participants to participate fully and does not allow a single person to dominate the discussion.

The final step could not always be completed given the lack of critical information as described above. In both Costa Rica and Namibia, additional information was collected after the workshops ended. In Costa Rica, participants selected four methods for the three LDN indicators plus erosion risk. They also expressed a desire for more training to understand some of the methods better and be able to make more informed decisions at a later stage. In Namibia, participants narrowed it down to two approaches and requested that the budgets were worked out first so that the final decision could be taken by the Ministry of Environment and Tourism, which is responsible for executing the LDN agenda in Namibia. Before we present the final selections, an overview of each region is given below.

3.3 Selection of baseline methods in Otjozondjupa Region

3.3.1 Overview of Otjozondjupa Region

The Otjozondjupa Region (figure 3.1) is situated northeast of the capital of Windhoek and spans 105,460 km^2 and a low population of approximately 144.000 people (0.73 persons/km^2) (Namibia Statistics Agency 2011). The region is predominately characterized by grassland and sparsely vegetated shrubland, and scattered small areas of closed canopy forest. The land tenure is predominantly privatized, except for the community lands in northeast districts. Land use is mostly rangeland cattle farming, much of it being intensive commercial cattle farming, grain production, and a large proportion of smallholder subsistence agriculture mainly in the communal lands (King et al. 2011, Gilolmo and Lobo 2016). Namibia is naturally the most arid country in sub-Saharan Africa, and prolonged droughts are well-known occurrences, which is projected to increase and become more unpredictable in the future (Ziedler 2010).

Figure 3.1 Otjozondjupa region Namibia

Bush encroachment represents a great threat to the livelihoods of the (e.g. pastoralist) communities living in dryland ecosystems (e.g. Angassa and Oba, 2008). It is described as the increase in biomass and abundance of woody species and the suppression of perennial grasses and herbs (Ward, 2005) leading to dense thickets often composed of thorny and/or unpalatable bushes. It often occurs as a result of land degradation in African drylands, for example due to overgrazing or changes in fire regimes (Zimmermann et al., 2008). Once established, invasive woody species can also be a major driver of land degradation due to the suppression of perennial grasses and reduced ground cover as a result (Joubert et al., 2008) and soil nutrient depletion (Klintenberg and Seely, 2004; Moleele and Perkins, 1998; Oldeland et al., 2010; Rocha et al., 2015).

In Africa, certain species of the genus *Acacia* are known encroachers. In Namibia, grasslands are often encroached by *Acacia mellifera* and *Acacia reficiens*, often occurring together

(Joubert et al., 2008; Zimmermann et al., 2008). While these are native, encroaching species invade land by being very efficient in utilizing available resources (nutrients, water, light, energy), and have traits that allow them to quickly take up these resources making them unavailable for other plants (Funk and Vitousek, 2007).

The negative consequences of bush encroachment are widespread and include: adverse effects on native species (Meik et al., 2002; Spottiswoode, 2009), diminishing agricultural production, rangeland degradation (Angassa, 2005), watershed quality (Huxman et al., 2005), increasing erosion (Grover and Musick, 1990; Vågen and Winowiecki, 2014) and loss of ecosystem carbon (Jackson et al., 2002) and loss of aboveground biodiversity. (Jackson et al., 2002) reported higher SOC in encroached areas in dry areas and a decrease in SOC in wetter regions.

The deeper and more expansive root systems of many woody vegetation types, compared to herbaceous plants, means that they have access to soil water from deeper soil layers, which in turn means that they tend to have longer seasonal periods of water extraction and can thereby reduce soil water content consistently throughout the year (Kemp, 1983). In addition, their greater leaf area will increase water loss by transpiration and increase soil evaporation through the exposure of the soil (Huxman et al., 2005). As a consequence, encroachment has been shown to directly decrease streamflow in some cases (Cleverly et al., 1997).

While there are limited data available on degradation currently, Namibia is concluding a number of action-plans to combat environmental degradation and integrate management of all the regions as well as land tenure reforms, and thus centralizing national data might become a priority in the near future (King et al. 2011). Globally available datasets show an increase of NDVI in grassland regions which is most likely due to bush encroachment (LDN Country Report 2015, Gilolmo and Lobo 2016). Bush encroachment is not always a direct consequence of land use change however. Drivers of bush encroachment are much debated (Ward, 2005) and likely include a combination of different factors including grazing intensity, fire management, and climate change. Unless extremely severe, it is unlikely that the three standard LDN indicators recommended by UNCCD can detect bush encroachment.

3.3.2 Indicator 1: Baseline of land cover in Otjozondjupa

To our best knowledge there are no existing tier 2 or 3 land cover maps for Otjozondjupa Region that could improve on the default ESA CCI land cover maps. However, Namibia is currently developing the Integrated Regional Land Use Plan (IRLUP) based on participatory land use planning which is scheduled to be completed in 2016. The plan will include georeferenced land use maps for each region for both present and future land uses.

3.3.3Indicator 2: Baseline for land productivity in Otjozondjupa

Changes in productivity presume that healthy land exhibits a high productivity while degradation reduces the net primary productivity, but that is a matter of context as outlined above. For Namibia, bush encroaching vegetation increases (aboveground) biomass and productivity compared to the grassland it encroaches. Therefore, applying straight forward Tier 1 productivity maps as an indicator, may erroneously classify degrading encroached areas as areas under recovery. Bush encroachment in drylands can be difficult to detect with some of the most commonly used VIs, such as NDVI and CRD, since many of the new species found in these areas have a relatively weak signal in terms of chlorophyll. Other types of VIs have been explored as alternatives, including the EVI and SATVI (Marsett et al., 2006; Qi et al., 2002) as they tend to be more sensitive to canopy structure and dryland vegetation cover (i.e. senescent vegetation).

There is an existing program in Namibia that monitors land productivity trends based on MODIS data. The Rangeland Monitoring Project (*http://www.namibiarangelands.com/*) publishes mean monthly NDVI, precipitation, and vegetation condition maps on their website. The project is also developing new methods to map bush encroachment that will become available in 2017.

3.3.4 Indicator 3: Baseline for soil organic carbon in Otjozondjupa Region

In addition to Figure 2.5 above (SoilGrids250), Figure3.2 shows a soil carbon stock map based on the LDSF framework. Existing studies of SOC for Otjozondjupa and surrounding areas have reported values ranging from about 6.2 g C kg^{-1} to 11.5 g kg^{-1} in the topsoil (0-20 cm depth) in rangeland soils. Somewhat higher SOC concentrations can be expected in dense bushlands or dry forests.

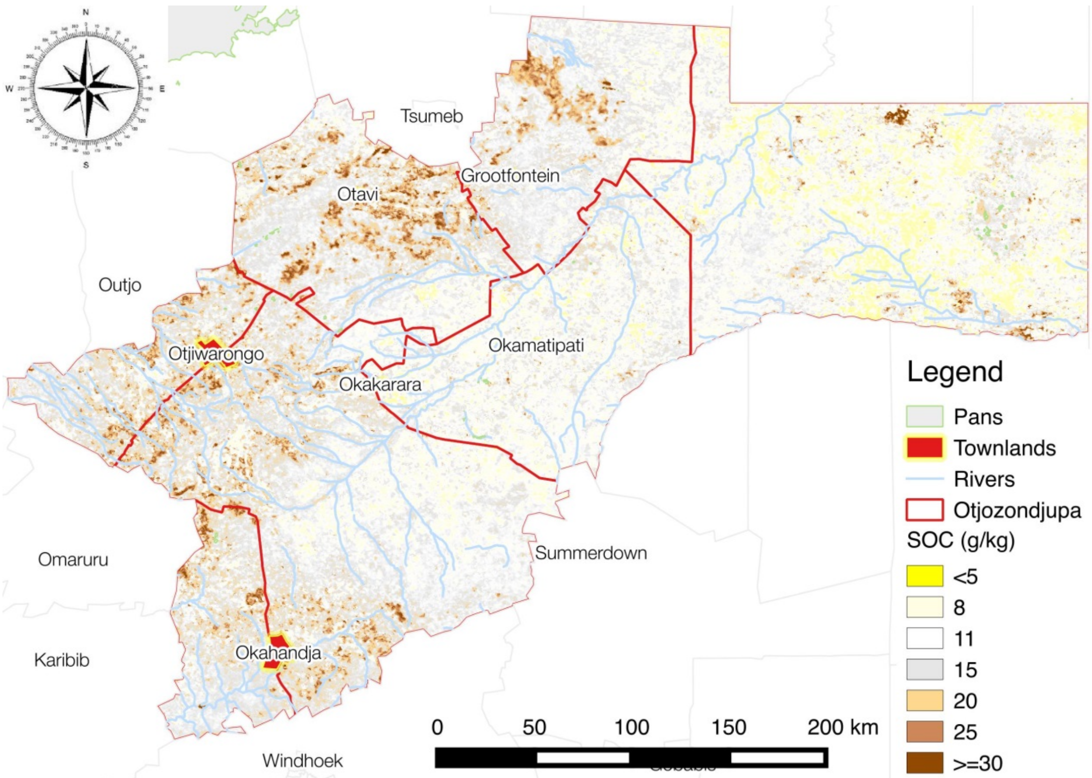

Figure 3.2. Soil organic carbon (SOC) map of Otjozondjupa, Namibia for the upper 20 cm of the soil profile, based on the LDSF (see Vågen et al., 2016)

As described in chapter 2, the methodologies that were used to make these maps are based on soil profile data collected in sites across the world (so called sentinel sites), and thus have a global best fit, not a national or regional best fit. There are no tier 2 or 3 data available in Namibia to test the *in situ* accuracy of either map, although these methodologies have a published accuracy based on studies done elsewhere. One way forward would be to improve on these two methods by collecting local data to validate the models.

3.3.5 Additional Indicator: Bush Encroachment in Otjozondjupa

Biodiversity and functional properties (e.g. time of leaf emergence) of the vegetation are important indicators of land degradation, and using these as additional indicators will be helpful especially for detecting bush encroachment as this may prove to be challenging using the current tier 1 indicator. Remote sensing has been used for mapping of woody species diversity (Innes and Koch, 1998; Rocchini et al., 2015) and can be applied in the assessment of land degradation. Such additional indicator may help in the detection of bush encroachment as species composition and biodiversity change in bush encroached areas. Some remote sensing techniques can also distinguish between the leaf phenology of the two types of Acacia prevalent in bush encroachment areas in Namibia (Oldeland et al., 2010): *A. mellifera*, which has leaf flushing in September and *A. reficiens,* which has leaf flushing in December. The JRC Phenology land cover data could potentially detect the differences in phenology and thus bush encroachment at 30 m resolution. Furthermore, dryland grasses have different metabolic pathways in the photosynthesis than bushes and trees, called the C_4-pathway. Recent techniques can detect this and use C_3/C_4 carbon isotope ratio in soil carbon and map this using remote sensing. This can be used to assess bush encroachment, because the relative abundance of C_3 carbon will be higher in soils under woody vegetation, as compared to soils under tropical grasses that have a C_4 photosynthetic pathway.

3.4 Selection of baseline methods in Rio Jesus Maria Watershed

3.4.1 Overview of Rio Jesus Maria Watershed

The Rio Jesus Maria watershed (352 km^2) in Costa Rica is very different from the Otjozondjupa region in Namibia and thus other issues arise when developing a baseline. Rio Jesus Maria watershed is situated along Costa Rica's Pacific coast (Figure 3.3) and has lost most of its natural vegetation cover due to deforestation and agricultural expansion. Currently the majority of the watershed consists of grasslands for extensive cattle ranching and secondary forests (Centro Agronómico Tropical de Investigación y Enseñanza (CATIE), 2011). Reduced vegetation cover, poor infrastructure, and extensive cattle ranching have led to wide scale soil degradation and erosion and the concomitant widespread loss and redistribution of soil and nutrients in the watershed, degradation of soil structure, water pollution and downstream floods.

Studies show that local communities, especially the ones living downstream, are affected by lack of fresh water supply, failing crop yields during floods, ultimately increasing food insecurity and poverty in the region (Centro Agronómico Tropical de Investigación y Enseñanza (CATIE), 2011). Floods sometimes also inundate populated areas resulting in

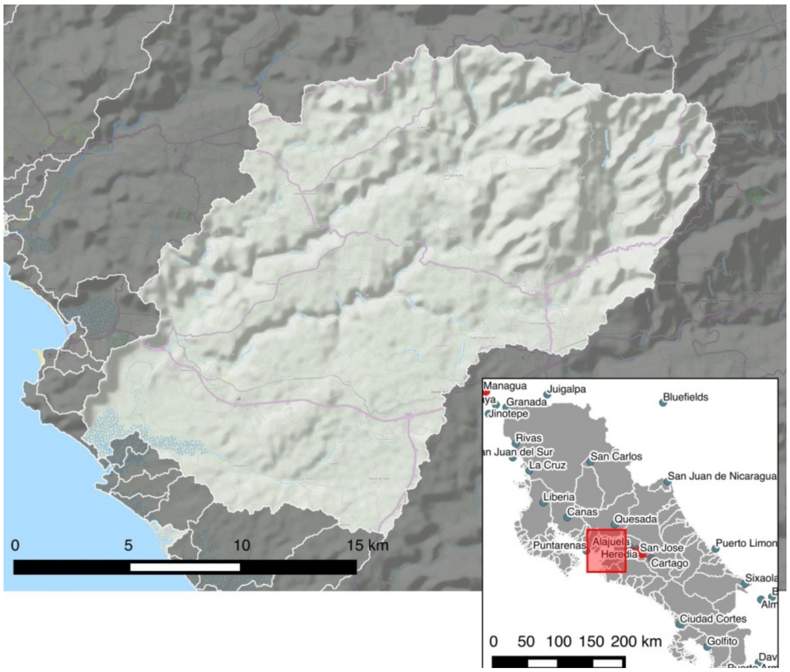

Figure 3.3. The Rio Jesus Maria watershed in Costa Rica. Watershed delineation was done using SRTM elevation data. The inset map shows the location of the watershed (red box) relative to a map of Costa Rica. Background map: Open Street Maps (OSM).

damage to infrastructure and properties.

The complex topography of the Rio Jesus Maria watershed, and its relatively small size, means that assessments of land degradation need to be made at fine spatial resolution to capture the level of degradation properly. This will present a challenge for most tier 1 remote sensing products publicly available, as their spatial resolution is most often too coarse to capture small-scale dynamics. Furthermore, the use of remote sensing products can be challenging as there is often extensive cloud cover in the area. However, Costa Rica has a suite of tier 2 data developed and available.

3.4.2 Indicator 1: Baseline for land cover in Rio Jesús Maria Watershed

Land cover is important for detecting deforestation which is the primary cause of land degradation in Rio Jesús Maria watershed. However, the resolution of land cover change detection plays an extremely important role in being able to detect land degradation. In addition to changes in land cover from forest to non-forest, combinations of land use with soil type, topography, and management (practices / intensity) also drive land degradation in this geographical context (Hoyos, 2005). As a result, the direct relationship between land cover change and watershed degradation may not always be accurate (Ponette-González et al., 2015). The coarse resolution of a tier 1 dataset describing forest loss/gain, does not match the trends estimated by national institutions as part of the national programs for monitoring forest cover (MINAE 2015). As the national initiatives' tier 2 datasets use finer resolution and are linked to the national programs for payment for ecosystem services and REDD, existing data such as those produced as part of various initiatives to map forest cover in Costa Rica may be very useful for assessing land cover.

Costa Rica developed various policy reforms and incentives in the 1990s to stop deforestation and forest degradation, and favor reforestation in areas where forest cover was lost. The main national mechanisms for support of reforestation are the national forestry development plan and the national program for payment of ecosystem services managed by the National Fund for Forest Financing (FONAFIFO) of Costa Rica. In order to track progress linked to these national policies and incentives, FONAFIFO and the National System of Conservation Areas (SINAC) have worked to develop forest cover maps for 2000, 2005, 2010 with a resolution of 30 x 30 m. These maps were derived from Landsat and SPOT images and focus only on two types of land cover: forest and non-forest.

In 2013 SINAC updated the national forest cover map using RapidEye Images (from December 2011 until July 2012) to generate the first forest cover map at resolution of 5m. This map identifies eight categories of forest, from pristine mature forest, secondary forest, deciduous forest, palm forest, silvopastures, forestry plantations, mangroves and paramo. Other lands uses such as annual and perennial crops, wetlands, water bodies, bare soil, sand and urban infrastructure are grouped in one category of "non-forest". This detailed forest map was the basis for the stratification and location of sample plots for the 2013 National Forest Inventory (SINAC 2015) (see Figure 3.4).

In order to cover a multitude of reporting methodologies, Costa Rica is developing a national system for monitoring land use change dynamics. This system should provide information on land cover, land use change for forest and other important ecosystems, and will be the cornerstone for reporting on national targets to reduce greenhouse gas emissions (linked to REDD and Nationally Appropriate Mitigation Actions [NAMA]). A group of experts is currently working on the development of this system, particularly in the development of a unique land classification system for the country. The monitoring methodologies have not been defined yet and could therefore be streamlined with LDN reporting needs.

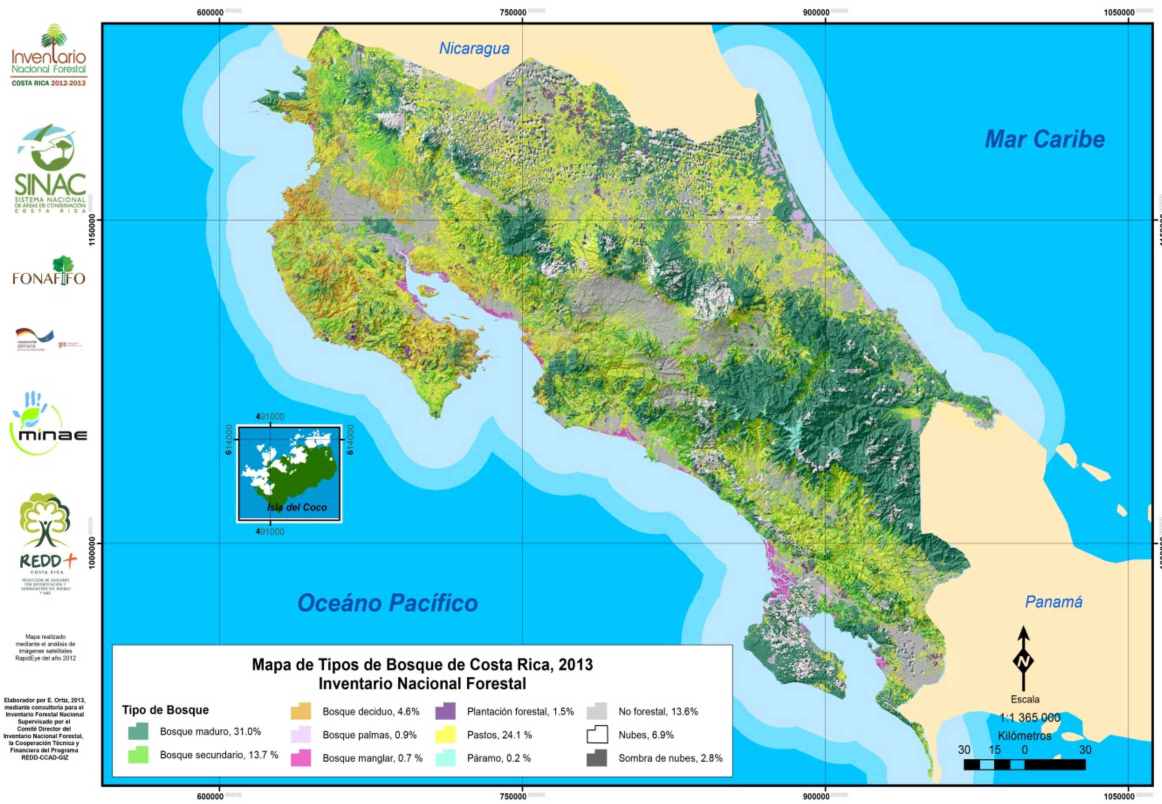

Figure 3.4. Map of forest types in Costa Rica for 2013. (SINAC 2015)

Costa Rica is also in the final period of consultation of its National REDD+ Strategy, and has submitted its proposed national Forest Reference Emission Level and Forest Reference Level (FREL/FRL) to the UNFCCC for a technical assessment. Although Costa Rica included all REDD+ activities in its national REDD+ strategy, only emission reductions from deforestation and enhancement of forest carbon stocks have been included in the FREL/FRL. FREL results are based on a temporal analysis of land use change for the period 1986-2013, using Landsat images. The classes recognized in these maps are: forest, annual crops, permanent crops, grasslands, settlements, wetlands, paramos and natural and artificial base soil (MINAE 2016).

3.4.3 Indicator 2: Baseline for land productivity in Rio Jesús Maria Watershed

The land productivity indicator involved vivid debates during the workshop. This was due to several factors. First, it was acknowledged that many different institutions had satellite data from different sources with different resolutions, and without a clear overview of the content and availability of the national repositories, it was difficult to make this decision. During the post-workshop period, it was proposed that this would be a separate consultancy, to do a complete review of data and capacities within Costa Rican institutions and to produce a land productivity baseline, which would be appropriate for both the small watershed as well as the national scales.

Since there is a strong emphasis on monitoring forest cover and deforestation, and given the relationship between forest cover and land productivity, efforts to produce these indicator baselines may be combined. For example, there is a possibility to use the newly developed FREL/FRL for reporting to the UNFCCC, to establish forest change, as an indicator for land productivity. In combination with other data, or as a stand-alone, these data might hold potential for improving spatial resolution, have long time series, and thus improve the indicator for trends in land productivity.

One other possibility that takes advantage of the relationship between land productivity and deforestation is the Terra-I framework which was reviewed in section 2.2.5. Terra-I monitors deforestation in near real-time, based on changes in productivity, and is freely available. While it has better spatial resolution (250m) than JRC LPD (1km), the workshop participants regarded this as too coarse. We mention it here to highlight potential ways to combine future efforts in Costa Rica in completing the baselines for both land cover and NPP.

3.4.4 Indicator 3: Baseline for soil organic carbon in Rio Jesús Maria Watershed

Currently there are no completed maps of soil organic carbon for Costa Rica available from national initiatives. Various institutions are working on digital soil mapping as well as on collection and systematization of nationally available soil data. For example, the University of Costa Rica and the National Institute of Agricultural Technology (INTA) have been working with the Soil Information System for Latin America (SISLAC). SISLAC is a collaboration between FAO – Global Soil Partnership, CIAT, Catholic Relief Services (CRS), EMBRAPA (Brazilian Agricultural Research Corporation), and national institutions from 19 countries in Latin America. As part of SISLAC, Costa Rica received training in digital soil mapping and has started to produce draft SOC maps. At the time of the workshop, 500 soil profiles were available which has now tripled to 1500 soil profiles, mainly available for coastal areas which had been prioritized. In addition, the National Forest Inventory collected 280 soil samples from 1,000 m^2 in 2013, covering six different forest land uses (Figure 3.5) across the whole country.

Figure 3.5. Distribution of the 280 soil sampling plots where data were collected during 2013, according to the National Forest Inventory.

Some readily available SOC maps could be used as a SOC baseline map. For example, LDSF has a 500 m resolution map of SOC for Jesus Maria watershed (Figure 3.6). However, this resolution was considered too coarse by the national stakeholders who participated in the workshop. Others are also working on making global SOC maps available at finer resolution. ISRIC, for example, has made available a 250 m resolution product recently. In order to make meaningful assessments of SOC status and trends we suggest that these will need to be made at 30 m or finer resolution for this watershed.

The currently available data may not be sufficient to produce a reliable estimate of SOC in the Rio Jesus Maria watershed because of scattered sampling plots that only cover forest land covers; with only few data points available in Jesus Maria. Therefore there is a need to increase the number of soil measurements to be able to develop digital soil maps for Jesus Maria. Also, while digital soil mapping training has started through the SISLAC collaboration, there is still an expressed need to further strengthen this through capacity building.

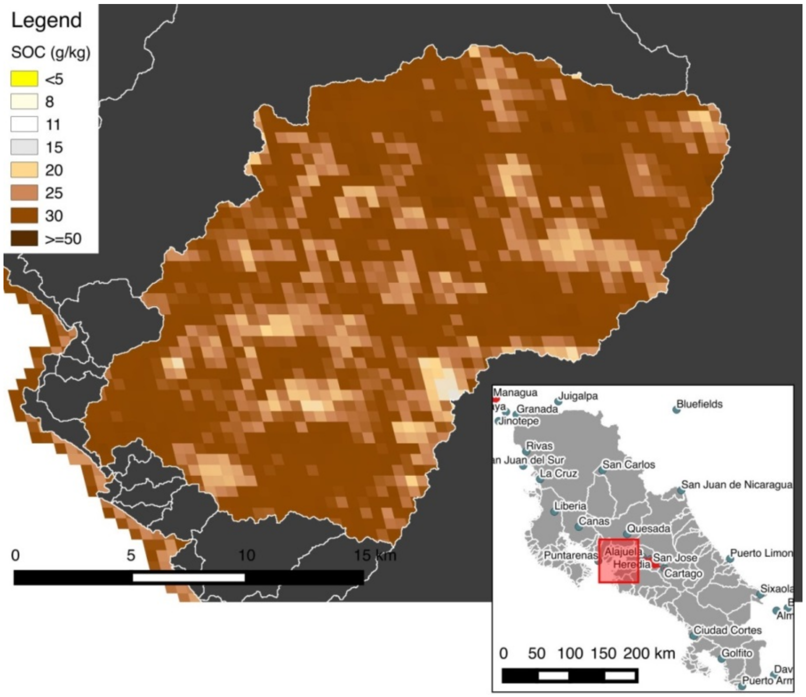

Figure 3.6. Map of SOC for the Jesus Maria watershed, based on global models using MODIS reflectance at 500m and the LDSF (Vågen et al., 2016).

3.4.5 Additional Indicator: Soil Erosion in Rio Jesús Maria watershed

A critical factor determining SOC trends in the Jesus Maria watershed is likely to be soil erosion, particularly along waterways and on steep slopes, as highlighted in the Community Development and Knowledge Management for the Satoyama Initiative[13] (COMDEKS). It is recommended as an indicator that should be considered, in addition to the three core indicators, when assessing land degradation in the watershed.

National efforts to assess soil erosion in Costa Rica, currently focus on assessing the vulnerability of soil to be eroded using the PAP/RAC methodology. During a presentation by INTA at the workshop in San José, it was explained that this method does not quantify the amount of soil lost due to water or wind erosion, but it gives an index defining the grade of erosion risk/potential (Priority Actions Programme Regional Activity Centre - Split 1997). Soil vulnerability to erosion is based mostly on soil physical properties and land cover. INTA and the University of Costa Rica are tailoring the methodology to conditions in Costa Rica and are updating the soil map of Costa Rica to have a better application of PAP/RAC methods in areas where soil information is not complete. Part of these efforts include plans to develop a detailed soil sampling to characterize soil profiles and soil properties in particular areas of the country.

[13] http://comdeksproject.com/country-programmes/costa-rica/

The soil sampling methodologies used by INTA could also complement the efforts to collect new soil samples in Jesus Maria in relation to soil organic carbon.

3.5 LDN Workshop and Outcomes in Namibia

3.5.1 Namibia – Otjozondjupa LDN Baseline

The Namibia workshop was conducted from February 9 to 11, 2016, in Windhoek. The workshop was organized in collaboration with the Ministry of Environment and Tourism (MET). One factor that was important in Namibia was the fact that very little data already existed for Otjozondjupa region. While the basic data to determine land productivity through net primary production is available at national level, there are no national baselines for bush encroachment or SOC (other than the ISRIC and LDSF datasets that are based on modeling techniques and do not yet include ground truth data). National land cover data are very coarse, and thus not of much relevance for Otjozondjupa. Furthermore, the severity of bush encroachment in Otjozondjupa and other areas of northern Namibia was critical during the methods selection process. It became obvious that extensive new field data had to be collected to map areas under bush encroachment and accurately map bush densities as well. The requirement to do extensive fieldwork influenced the selection of a methodology for the three remaining LDN indicators.

Given that extensive areas will have to be surveyed to collect data on bush encroachment, it was a logical next step that other land cover data would be collected at the same time in order to be cost-effective and complete the land cover and SOC baseline maps. During method selection, the emphasis was thus placed on optimal and efficient field sampling design for collecting data for three indicators: land cover, soil organic carbon and bush encroachment. Another factor that influenced the selection of a method for SOC measurement was the desire to execute the different components of the work locally, for as much as feasible, and therefore give preference to techniques that are locally and nationally used already. While the LDSF method was desirable because it presented a complete package for different indicators, the methodology relies on the use of soil infrared spectroscopy which is currently not available in Namibia so it was not the preferred option by the participants.

The final selected methods were thus:

- Indicator 1 – Land Cover: ground truth data collection for a supervised classification of Landsat data at 30m resolution.
- Indicator 2 – NPP: collaboration with local partners to produce a NDVI-derived baseline using the same Landsat data.
- Indicator 3 – SOC: field data collection of soil profile data, analyzed locally at the Ministry of Forestry, and baseline produced using the ISRIC methodology.

- Bush Encroachment: field data collection to produce a baseline with different gradients of bush encroachment (density) based on the methodology for Land Cover.

Appendix A provides a summary of the activities and expected cost for implementing this approach.

3.5.2 Namibia - recommendations for integrating LDN in sub-national land use planning processing

The Integrated Regional Land Use Plan (IRLUP) is an important way forward to address land degradation in Otjozondjupa. Any targets for achieving land degradation neutrality should be integrated into general land use planning. Another project of interest for the LDN study in Otjozondjupa Region is the GIZ De-Bushing Project (DBP). This project aims to quantify the extent of existing bush encroached area and determine its spatial distribution, as well as the possible economic utility of the encroaching biomass (e.g. for charcoal production). Furthermore, a proposal to establish a GIS database of the dynamics of bush encroachment (the BIS-GIS database) is pending a second round of feedback from the Namibian Statistics Agency (NSA). The outcome of this project could offer valuable information on methodology and extent of bush encroachment in the Otjozondjupa region for the LDN baseline procedures.

The review of the BIS-GIS has shed light on a few considerations expressed by National Statistics Agency (NSA), which are of relevance to the LDN methodology. Firstly, it is important that a baseline assessment relies on quantitative and ground-truthed data, and that the methodology requires validity testing to determine the level of accuracy of the products. It is also important to use existing technology and infrastructure made available by various ministries (e.g. Department of Surveys and Mapping, DSM), to reduce uncertainties and replication of already derived information and adhere to existing policies and quality standards. Secondly, spatial, temporal, and methodological consistency of available remote sensing and vector data are an expressed concern of the NSA, as not all regions of Namibia are equally well-covered. This will most likely not affect the pilot area of Otjozondjupa much as there is consistent remote sensing data coverage in this area, but might be of concern to other regions of Namibia in a national baseline assessment framework. Thirdly, of interest for the national LDN process could be the ongoing project "Biodiversity Management and Climate Change in Namibia", implemented by GIZ and Namibia's Ministry of Environment and Tourism (MET) from 2013 to 2016. This project focuses on three main areas of environmental policy development and implementation, cross-sector mainstreaming of environmental concepts, and community-based natural resource management in a changing climate. The focus areas are established to help implement new frameworks and strengthen both local and institutional readiness regarding biodiversity loss and climate change mitigation and adaptation. Possible synergies arise between the elaboration of the LDN baseline and institutional and local level capacity development in the project areas. This becomes even more relevant when considering, as mentioned in the introduction, the potential links between LDN monitoring and reporting obligations to the UN Conventions on climate change and biological diversity (UNFCCC and CBD).

3.6 LDN workshop and outcomes in Costa Rica

3.6.1 Costa Rica – Jesus Maria Watershed LDN baseline

The workshop in Costa Rica was organized in collaboration with the GIZ country office, from March 31 to April 1, 2016 in San José. Costa Rica has historically invested much in capacity building of biodiversity and environmental sciences and this became evident in the presentations on national methods by workshop participants, as it focused on more on technical aspects and in-country availability. As described in Section 3.4 above, existing data include recent land cover and land use maps, a database of soil profile information as well as a methodology for erosion risk mapping adapted to the local context.
Given the strong capacity in Costa Rica, most of the selected methods were methods that are currently used nationally and that national experts are already familiar with. The final method selections were:

- Indicator 1 – Land cover: Use the same methodology that is used to produce land cover maps for Costa Rica's REDD+ (Reduced Emissions from Deforestation and Forest Degradation) commitments to the UNFCCC.
- Indicator 2– NPP: The approach is to first investigate which data are nationally available from different government offices. Then it will be necessary to agree on which of the indexes will be used for the baseline analysis of NPP and decide whether the national organizations or an external consultant will carry out analysis to complete the baseline.
- Indicator 3 – SOC: Costa Rica has started work on SOC mapping under the SISLAC (see below) framework and decided to complete this work. In addition, workshop participants requested additional training in other Digital Soil Mapping techniques in order to do a more robust evaluation of all available techniques at a later time. Independent of the soil mapping technique used, it will be necessary to carry out field sampling in Jesus Maria watershed to be able to generate the digital soil maps.
- Additional indicator – Erosion (including existing erosion and erosion risk): Participants selected a training in the RUSLE-3D technique to produce a map of current erosion to complement their modified PAP/CAR approach. RUSLE-3D is a biophysical model that uses remote sensing data and other soil maps to estimate ongoing erosion. RUSLE-3D considers rainfall intensity, topography, soil resistance, land cover and management practices. The combination of RUSLE-3D and the modified PAP/CAR will give Costa Rican land management planners a more complete picture of erosion due to land degradation.

3.6.2 Costa Rica – recommendations for integrating LDN in sub-national plans

In Costa Rica, there are several planning processes on sub-national level that are important to address land degradation in general and for specific pilot areas, for example, municipal regulation plans, territorial rural development plans, management plan for protected areas, management or strategic plans for biological corridors, beside others.

The following considerations expressed by different stakeholders in Costa Rica are of relevance to the national LDN process:

First, a baseline assessment for LDN should rely on quantitative and ground-truthed data, be as accurate as possible using the existing data bases, technology and infrastructure available in the country to reduce uncertainties and replication of already derived information.

Secondly, a baseline assessment for the proposed, relatively small, pilot area should be applicable on national level for a national baseline assessment.

Thirdly, there are several ongoing projects of interest for the LDN process in Costa Rica.

- The Sixth Operational Phase of the GEF Small Grants Programme in Costa Rica (2016-2018) aims at enabling community organizations to enhance livelihoods by restoring degraded forest and production landscapes for socio-ecological resilience in the watersheds Jesús Maria and Barranca. It supports, among other, adaptive landscape management plans and policies, reforestation and restoration campaigns.
- The GIZ-Project "Implementation of the National Biocorridor Programme (PNCB) within the context of Costa Rica's National Biodiversity Strategy" (2014-2020) commissioned by the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB). This project supports, among other, the establishment of a baseline and monitoring system for biological corridors including in parts the same or similar indicators as proposed for LDN. Furthermore, the project facilitates planning processes for sustainable land management in biological corridors. In addition, advice for the establishment of financial mechanisms generates funding for implementing relevant SLM measures.
- The "NAMA support project: Low-carbon coffee Costa Rica" (2016-2019), commissioned by the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) and the UK Department for Business, Energy & Industrial Strategy (BEIS). This project supports the voluntary action geared to climate change mitigation, including efficient application of fertilisers, the use of shade trees and measuring, reporting and verification of CO2 reductions.

These projects can support the LDN baseline with additional information and local level capacity in the pilot project areas. Furthermore the LDN process could, as mentioned in the introduction, potentially link with reporting obligations to the UN Conventions on climate change and biological diversity (UNFCCC and CBD).

4 Conclusion and summary

The LDN Target Setting Programme of the UNCCD focuses preliminary on the national scale for land degradation assessments and LDN target setting. In order to support the implementation of a LDN approach, national assessments need to be complemented with more detailed sub-national baseline assessments. This report provides a review of the available data and methods for the three LDN indicators in the context of two pilot areas. These areas - Otjozondjupa region in Namibia and Rio Jesús Maria in Costa Rica - were identified with the respective partners participating in the national LDN processes, because both have degradation challenges that are relevant for many regions around the world. These challenges are important to address and strengthen national capacities and readiness to engage in mitigating land degradation.

There are a number of existing and free global datasets that could offer information to the land degradation assessments at sub-national scale. For Indicator 1 Land Cover Change there are multiple land cover maps available, e.g. GL30, JRC Trees-3, Terra-I, and LDSF, which are viable options to complement the default option, the ESA CCI-LC dataset. These datasets and methods can be used as stand-alone or as supplements to national data. Indicator 2 Land Productivity data are also available at the global level, which serve to derive more accurate data (e.g. using EVI, SATVI or RUE). It is suggested to use NDVI derived products that are more sensitive to senescent vegetation in dryland areas, soil conditions, and that have atmospheric adjustments in areas with extensive cloud cover. Moreover the resolution of the freely available data is not suitable for supporting local planning in countries such as Costa Rica where there is great variability in biophysical conditions over small areas.

The negative impacts of bush encroachment are widespread and include: diminishing agricultural production and rangeland degradation, decreasing watershed quality, and loss of aboveground biodiversity. While bush encroachment is considered the most severe form of land degradation in Namibia, it has confounding challenges for all three LDN indicators. This is because bush encroached lands usually show positive trends in net primary productivity and soil organic carbon, and they will reflect a land cover change from grassland and shrubland to bushland and forest, which is considered a positive change from the LDN perspective.

Workshops were held in both Namibia and Costa Rica to discuss the process with local stakeholders. For LDN methods national partners stressed that the following three criteria were important to take into account. The selected methods should be:

1. Cost-effective
2. Appropriate for the available national capacity and be repeatable independently by local partners
3. Have value for other regional and national projects

Both focus areas have a number of ongoing projects and processes that can be used to share either reporting obligations or primary data collection, and building on these commonalities can offer a reduction in costs to the LDN baseline assessment and future monitoring efforts.

In Otjozondjupa, Namibia, the main problem associated with land degradation in dry grassland is bush encroachment. There is no existing data on bush encroachment available, and therefore other options were explored further. Namibia is furthermore experiencing a lack of both existing national data, as well as a centralized data repository, and data that is available is not readily accessible. Namibia chose to opt for classification and ground-truthing of finer spatial resolution from globally available Landsat imagery and SoilGrids methodology, and extensive data collection to map distribution and densities of bush encroachment. The final selection was as follows:

- Indicator 1 – Land cover: ground truth data collection for a supervised classification of Landsat data.
- Indicator 2 – NPP: collaboration with local partners to produce a NDVI-derived baseline using the same Landsat data.
- Indicator 3 – SOC: field data collection of soil profile data, analyzed locally at the Ministry of Forestry, and baseline produced using the ISRIC SoilGrids methodology.
- Indicator 4 – Bush Encroachment: field data collection to produce a baseline with different gradients of bush encroachment (density) based on the methodology for Land Cover mapping.

In Rio Jesús Maria watershed, Costa Rica, deforestation and subsequent watershed degradation has led to severe soil erosion. Costa Rica has a large collection of national data, and local experts therefore opted to expand on existing national data for the three indicators, as well as increase national capacity on soil mapping and erosion modeling. The final selection was as follows:

- Indicator 1 – Land cover: Use the same methodology as used to produce land cover maps for Costa Rica's REDD+ commitments to the UNFCCC.
- Indicator 2 – NPP: The approach taken is to first investigate which data are nationally available from different government offices and task one with producing an NDVI change analysis to complete this baseline.
- Indicator 3 – SOC: Costa Rica has started work on SOC mapping under the SISLAC framework and decided to complete this work. In addition, workshop participants requested additional training in other Digital Soil Mapping techniques in order to do a more robust evaluation of all available techniques at a later time.
- Indicator 4 – Erosion (existing erosion and erosion risk): Participants selected training in the RUSLE-3D technique to produce a map of current erosion to complement their modified PAP/CAR approach.

Both countries have existing processes in place or starting up, which might be helpful to the LDN baseline assessments and reduce cost of primary data collection. In Namibia this is namely the IRLUP process, but also the GIZ De-Bushing Project and The Rangeland Monitoring Project, can assist in addressing the gaps in national data. For Costa Rica there are a number of ongoing national processes that will enable more extensive national data on land degradation, most importantly improvements of their reporting mechanisms to the UNFCCC and the engagement with SISLAC.

While the pilot phase provided a national baseline based on globally available datasets, this review of other datasets and methods points to a need for higher resolution (primary) data in order to develop baselines for the two sub-national regions in Namibia and Costa Rica. Moreover, subnational baseline assessments may require additional field data collection depending on the characteristics of degradation occurring locally. In certain contexts, additional indicators beyond Land Cover, Land Productivity and Soil Organic Carbon, may be required to adequately assess land degradation at a subnational level.

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