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Chapter 5 Analysis of the impact of land management options in tackling land degradation in sub-Saharan Africa: example study based on long-term remote sensing and climate data

Lulseged Tamene[1*], Quang Bao Le[2], Sileshi Gudeta[3], Ermias Aynekulu[4]; Fred Kizito[5], Deborah Bossio[6], Paul Vlek[6]

[1]International Centre for Tropical Agriculture (CIAT), Chitedze Agricultural Research Station, P.O. Box 158, Lilongwe, Malawi

[2]Natural and Social Science Interface (NSSI), Institute for Environmental Decisions (IED), ETH Zurich, Universitaestrasse 22, CH-8092, Switzerland

[3]World Agroforestry Center(ICRAF), Chitedze Agricultural Research Station, P.O. Box 30798, Lilongwe, Malawi

[4]World Agroforestry Center(ICRAF), Nairobi, Kenya

[5]International Center for Tropical Agriculture (CIAT) c/o ICIPE Duduville Complex, Off Kasarani Road POBox 823-00621, Nairobi, Kenya

[6]University of Bonn, Center for Development Research (ZEF), Walter-Flex-Str. 3, 53113 Bonn, Germany

Correspondence: Lulseged Tamene (e-mail: lt.desta@cgiar.org*)*

Summary

Tackling land degradation and restoring degraded landscapes requires information on areas of priority intervention, since it is not economically and technically possible to manage all areas affected. Recent developments in data availability and improved computation power have enhanced our understanding of the major regional drivers of land degradation and possible remedial measures at different scales. In this study, we used the land degradation hotspots identified using satellite and climate data covering the period 1982-2003 (Vlek et al. 2010) and simulated the potentials of different management measures in tackling land degradation in sub-Saharan Africa (SSA). Scenario analysis results show that about 14 million people can benefit from the application of sustainable land management (e.g., integrated soil fertility management, conservation agriculture, and soil and water conservation) techniques targeted to improve the productivity of croplands. Setting aside degraded areas and allowing them to recover (e.g., through exclosures) could improve their productivity. However, this intervention requires designing ways of accommodating the needs of about 8.7 million people, who utilize those “marginal” areas for cultivation or livestock grazing. This study illustrates the benefits of utilizing long-term satellite data to analyze the potentials of targeted land management and restoration measures to improve land productivity in SSA. This approach and framework can be used to design suitable land use planning targeted to the restoration of degraded areas and to perform detailed cost-benefit and trade-off analysis of various interventions.

Keywords: Land degradation, NDVI, rainfall, restoration, sustainable land management options, sub-Saharan Africa (SSA)

5.1. Introduction

Recent trends show that pressure on land resources due to natural and human-related processes have increased, leading to high land degradation and productivity decline (Eswaran et al. 2001, Lal 2010, Lal and Stewart 2011). Land degradation is more challenging, as it generally leads to an interlinked, downhill spiral of increasing poverty and diminishing potential productivity (Greenland et al. 1994). This cyclic process—the vicious feedback loop of land degradation-productivity decline-land degradation is experienced mainly in poor societies that have much more limited options of coping, once degradation and productivity decline set in.

Sub-Saharan Africa (SSA) is often cited as most seriously affected by soil degradation, with huge implications on food security, economic development, and ecological integrity (Dregne and Chou 1994, Lal 1995, Scherr and Yadav 1996, Hountondji et al. 2006). Batjes (2001) reports that degraded soils amount to about 494 millionhectares in Africa. Estimates also show that 65% of SSA's agricultural land is degraded because of erosion and chemical and physical degradation (Oldemanet al.1991, Scherr 1999). According to Sanchez et al. (2009), many landscapes in the region are characterized by a combination of poor soils, low crop yields, water scarcity, and poor livestock health, which contributes to poor human health and low levels of economic development. Considering the increasing population pressure, accompanied with low investments in land conservation, the future health of the land in SSA is in question (Vlek 2005). The poverty traps that African smallholder farmers and pastoralists are locked into are also preventing urgently needed investments to maintain soil resources, and are thus likely to result in further losses in agricultural productivity and a decline in the provision of ecosystem services (Sanchez et al. 2009).

In light of the severity of resources degradation in SSA, and to fulfil some of the targets of the upcoming sustainable development goals, investments in preventing further degradation and restoring degraded landscapes should be given priority. The availability of information on land degradation hotspots and major drivers of degradation can help guide management and investment plans (Vlek et al. 2008, Sanchez et al. 2009). With improved data availability at global or regional scales and improved computation power, such as remote sensing and geographical information systems, information on the extent, trend, and severity of land degradation is becoming available at different scales (Bai et al. 2008, Hellden &Tottrup 2008, Vlek et al. 2008). This study targets land management options on hotspots areas of land degradation mapped by Vlek et al. (2008, 2010). The hotspots were derived based on long-term satellite Normalized Difference Vegetation Index (NDVI) of the Advanced Very High Resolution Radiometer (AVHRR) and climate data (Tucker et al. 1991, Prince et al. 1998, Milich and Weiss 2000, Weiss et al. 2001, Groten and Ocatre 2002, Thiam 2003, Evans and Geerken 2004, Herrmann et al. 2005, Vlek et al. 2008; Le et al., 2012). The potential impacts of different land management options on improving the productivity of the concerned hotspots was then simulated. The results demonstrate the need for and possibility of identifying priority areas of concern and subscribing specific management options to address land degradation problems at the sub-continental/regional scale.

5.2. Methodological approach

5.2.1. Identify land degradation hotspots in SSA

In this study we followed the approach used by Vlek et al. (2008, 2010) to map hotspot areas of land degradation in SSA. The AVHRRNDVI, with a resolution of 64 km^2, has been analysed for the period 1982–2003 on a pixel-by-pixel basis to evaluate the temporal trend of vegetation productivity (Vlek et al. 2008, 2010). This is based on the assumption that if the NDVI slope exhibits a statistically significant decrease over time, then the temporal trend in vegetation productivity is declining and the area imaged in that pixel is undergoing land degradation, and vice versa (Weiss et al. 2001). The hotspot areas were then categorized into different climate zones of *arid* (MAR <500 mm yr^{-1}), *semiarid* (500 mm yr^{-1} ≤ MAR ≤ 800 mm yr^{-1}), *subhumid* (800 mm yr^{-1} ≤ MAR ≤ 1300 mm yr^{-1}), and *humid* (MAR > 1300 mm yr^{-1})

as shown in Fig. 5.1 (Vlek et al. 2010). The climate zones were designated using mean annual rainfall (MAR) for the period 1981–2002 (Mitchel and Jones 2005).

Figure 5.1 Precipitation zones classified using MAP for the period 1981–2002. MAP calculated based on monthly rainfall from the CRU TS 2.1 data (Source: Vlek et al. 2010)

In order to discriminate whether the observed land degradation is driven by climate- or human-related factors, the response of green biomass (NDVI) to inter-annual rainfall variability was analysed using correlation analysis (Vlek et al. 2008, 2010). The hypothesis is that a decline in vegetation greenness without a decline in precipitation can be interpreted as a decrease in the ability of the land to produce biomass, due to factors other than rainfall (Fig. 5.2). It is anticipated that if the upward/downward trends in NDVI and precipitation are synchronous (Fig. 5.2a and b), an improving/declining vegetation cover would be observed due to increasing/declining precipitation amounts, and vice-versa. If the trends are asynchronous, meaning an increased NDVI for an observed decline in precipitation (Fig. 5.2c), we conclude that vegetation cover is recovering, despite declining rainfall. This could be attributed to improving land management or diminishing human impact. In situations where the trends are more asynchronous, such that there is a decline in NDVI, despite an observed improvement in precipitation (Fig. 5.2d), we anticipate that the observed increase in precipitation did not cause improvement in vegetation productivity. Such an observed negative trend in vegetation productivity, despite an increase in precipitation, would be due to human-induced decline in productivity.

Figure 5.2 Scenarios of a possible long-term relationship between NDVI and precipitation (a) improving NDVI due to increasing precipitation (b) declining NDVI due to declining precipitation (c) improving NDVI despite declining precipitation (d) declining NDVI despite improving precipitation

Based on the correlation between NDVI and rainfall, and its significance levels (Vlek et al. 2008, 2010, Le et al. 2012), the SSA was classified into three categories: *positive, neutral, and negative* (Fig. 5.3). According to Vlek et al. (2008, 2010), around 2.13 million km^2 (10% of SSA) inhabited by over 60 million people is affected by land degradation over the observation period of 23 years. Of the 2.13 million km^2 degraded area, the majority (ca. 44%) is covered by woodland/shrubland, followed by cropland (13%) and grassland (12%). On the other hand, unsuitable areas, such as rock outcrops and barren land, are the least degraded (5%). Of the hotspot areas, around 0.19 million km^2 is grassland, largely in the dry areas, which could be under the influence of over-grazing. Woodland/shrublands are most in decline in the sub-humid tropics, where they are predominant, whereas forest/savannah and dense forests are threatened in the humid areas. As much as 38% of the woodland/shrubland in the sub-humid and humid areas is in decline. For the more densely forested regions, the degrading area (of forest) amounts to11% of the degraded areas, most of which is in the humid zone.

Figure 5.3 Hotspot areas of human-induced land productivity decline in SSA for different climate zones based on satellite and climate data for the period 1982 – 2003 (Reproduced based on Vlek et al. 2010). Note that the “contours” inside represent climate zones. No data category represents areas that do not suffer from “human inducted land degradation”

5.2.2. Characterize the identified land degradation hotspots

In order to assess possible management options to tackle land degradation, the hotspots (Fig. 5.3) were characterized in terms of climate zone, population density, soil and terrain conditions, and land use/cover types. Average mean population densities for the years 1980, 1990, and 2000 were obtained from the Grid Population of the World Version 3 (GPWv3) dataset of the Center for International Earth Science Information Network at Columbia University and Centro Internacional de Agricultura Tropical (CIAT) (Balk and Yetman 2004). Each of the degrading pixels of the respective rainfall zones was differentiated according to three classes of population density (smaller than the mean, more than twice the mean, and between these two) to assess how population is distributed within the degrading zones (Vlek et al. 2008). Soil condition classes were derived from the FAO classification of soil constraints (Fischer et al. 2002), by aggregation, as follows: *Good* (FAO class 1, 2, 3 or 4), *Poor* (FAO class 5 or 6), and *Unsuitable* (FAO class 7 or 8). Topographic Shuttle Radar Topography Mission (SRTM) elevation data obtained from the United States Geological Survey (USGS 2004), with a resolution of 1 km, was used to derive terrain constraint with respect to agricultural productivity. The slope and elevation data was delimited into the following categories: *Good* (0° ≤ slope ≤ 15° and >0 elevation and ≤ 3500 m.a.s.l.), *Bad* (15° < slope ≤ 25° and 0 > elevation ≤ 3500 m.a.s.l.). Pixels with elevation > 3500 m above sea level or surface slope >25° were considered not suitable for agriculture (Sheng 1990). The GLC2000 (Mayaux et al. 2004) map derived from Satellite Pour l’Observation de la Terre vegetation was used to differentiate the areas subject to land-degrading processes according to land-use/cover types (Vlek et al. 2008).

Each map was pre-processed and the spatial resolution adjusted to be congruent to that of the NDVI (64 km^2). The land productivity decline map was then cross-referenced with the respective maps to understand the major attributes of the identified hotspots in terms of major biophysical and population attributes (Flugel 1997, Bull et al. 2003). This information can serve as a basis to understand the major constraints of the degraded areas and design suitable management options.

5.2.3. Identify suitable land management/restoration options

Ecological restoration of degraded landscapes is now regarded as an effective response to reducing the negative effects of habitat loss, degradation, and fragmentation on native biological diversity and ecological processes (Aerts et al. 2007). Optimal restoration of degraded lands, both in terms of resource endowment and recovery time, requires management options that are suited to the biophysical, socioeconomic, and political conditions of the targeted hotspots (Woodwell 1994, Parker 1997).

For a heavily degraded ecosystem to recover from a disturbance, the disturbing agent(s) must be removed, and/or inputs (conservation measures) that can enhance recovery or prevent further decline should be provided (Lamb 2000, Bussmann 2001, Suding et al. 2004). According to studies in different regions (Lamb and Gilmour 2003, WOCAT 2007, Twomlow et al. 2008, Gabathuler et al. 2009, Schwilch et al. 2012), some key land use and management options (alone or in combination) can be applied to reverse degradation and restore degraded areas, as well as improve productivity at the regional/continental scale. In this study, information from the literature, especially that compiled by World Overview of Conservation Approaches and Technologies (WOCAT) and Desertification Mitigation and Remediation of Land (DESIRE), have been used to define suitable management/restoration measures that can help alleviate land degradation in the hotspot areas identified at the sub-continental scale (WOCAT, 2007, Schwilch et al. 2012). Among the commonly recommended interventions, the potentials of exclosures, afforestation, agroforestry, biofuel plants, and integrated soil fertility management (ISFM) in tackling land degradation were assessed. The importance and contributions of these technologies in retarding land degradation and improving productivity were discussed in various publications (e.g., Fimbel et al. 1996, Nedessa et al. 2005, Vanlauwe et al. 2005, FAO 2008, Zomer et al. 2008, Mekuria et al. 2011, Schwilch et al. 2007, Yayneshet et al. 2009, Schwilch et al. 2012, Dosskey et al. 2012).

5.2.4. Assess the "environmental" requirements of the restoration options

The efficiency of interventions can be improved, not only if they are targeted to a problem they can cure, but also if they are dedicated to locations where their requirements can be met. For instance, it will not be wise to introduce ISFM in locations where soil, terrain, climate conditions, and socioeconomic realities do not support the system. It also may not be efficient to introduce a “system” that cannot be adopted by locals, either because it is too expensive or because it is not culturally acceptable. The type of prescription for different climate zones and land conditions also varies: for instance, it may not be feasible to prescribe ISFM in arid areas where water limitation could prohibit meaningful agricultural practices, nor may it always be acceptable to prescribe exclosures for a sub-humid environment characterized by high population density, good soils, and terrain. Though the latter option might be economically feasible, it may not be socially acceptable, if it directly competes with agricultural land. Adequate knowledge of the land requirements, sensitivities and potentials of the identified management interventions is therefore necessary before they are introduced.

Once “candidate” restoration options are identified, the next steps are assessing the limitations of each option (conditions where they cannot perform well, i.e.,their requirements will not be met), evaluating their tolerances (relative ability of each option to tolerate stress), and analyzing their susceptibilities (events or conditions to which they are vulnerable and under which they will not function properly). The main aim here is to understand the specific requirements that must be satisfied in order for a given landscape restoration measure to be effective and perform well. This knowledge will help fit restoration measures (with different sets of requirements) to landscapes and their positions (with different potentials, constraints, and capabilities). Since this study is focused at a sub-continental scale, the choice of candidate restoration options mainly considers general requirements based on soils, terrain, climate, and existing land use/cover types.

5.2.5. Matching the problem to its potential solution

Once the conditions of the hotspots and the requirements of selected management options are determined, the next step will be matching an appropriate restoration option to a given hotspot. In this case, the use of geographical information systems (GIS) can be helpful in order to easily manage geo-referenced data. GIS, coupled with multi-criteria evaluation (MCE), has been applied in a number of applications related to nature conservation, environmental planning, forest management, and the identification of rehabilitation and conservation priorities (Pereira and Duckstein 1993, Store and Kangas 2001, Ceballos-Silva and Lopez-Blanco 2003, Marjokorpi and Otsamo 2006, Zhang et al. 2010). In this paper, a simple, rule-based, multi-criteria approach is employed in a GIS environment to identify hotspots and assign them suitable management options. The approach follows an iterative sequential process (Table 5.1) with a general form: *"If an area experiences significant productivity decline and shows no or negative correlation with rainfall (qualifies as an area of concern) AND if the area is cropland AND if the area has suitable soil and terrain, AND if the area is located in humid-sub-humid zone, then assign ISFM, ELSE proceed to the next step"*.

This example typically seeks to match a management measure to a specified problem, considering the potentials and constraints of hotspots and the requirements of management options concerning a given land use. In areas where water limitation is expected (for instance, in arid areas), water harvesting is suggested as a "supplement" in order for a given management option to be successful. Most of the management measures can also be implemented along with soil and water conservation (SWC) practices.

In this example application, we restrict ourselves to demonstrating the procedure in crop and grasslands, considering that human influences are more pronounced on cultivated and grazing lands, compared to others—although woodland and forest areas can also be affected, due to deforestation or selective logging. Though the procedure shown in Table 1 is simple and utilizes easily available data, it can be expanded to incorporate wider co-variants, including socioeconomic conditions, when identifying candidate management/restoration options to rehabilitate degraded areas.

Table 5.1 Framework employed to assigning management options to restore land degradation hotspot. Note that different combinations are possible and only example are shown in this Table

If …					Do this
Land use	Climate zone	Soil	Terrain	Population density	Option
Cropland	Semiarid-humid	Unsuitable	Unsuitable	Any	Set-aside/exclosure
Cropland	Semiarid-subhumid	Poor+	Altitude <2500m	Low-medium	Agroforestry/parkland
Cropland	Subhumid-humid	Poor+	Good	Low	Improved fallow
Cultivated	Semiarid-humid	Poor-	Good	Medium-high	ISFM
Pasture/cultivated	Semiarid-subhumid	Poor-	Good	Low-medium	Agroforestry/silvopastoral
Non-cultivated	Semiarid-humid	Any	Any	Low	Reforestation/exclosure
Non-cultivated	Arid-subhumid	Poor-	Any	Low	Biofuel plants-Jatropha

Note: $Poor^{+}$ = very poor soil; $Poor^{-}$ = poor soil that requires input

5.3. Results and discussion

5.3.1 Identified restoration options and their requirements

Table 5.2 highlights the main requirements of the restoration options identified and defines the corresponding hotspot for which those measures could be effective, provided that some conditions are met. This documentation is based on experiences gained in different regions, related to the site-specific effectiveness of the respective restoration measures (e.g., WOCAT 2007, Schwilch et al. 2007, Schwilch et al. 2012, Dosskey et al. 2012). The table also illustrates cases where some policy and institutional arrangements should be in place for the successful implementation of some of the interventions, such as exclosures. Because exclosure requires restriction of human and livestock interference, its applicability at high population/livestock density areas can be questionable or appropriate alternatives should be designed before implementing the option. In addition, suggesting exclosure of areas that are currently under cultivation or grazing needs 'compensation' or provision of options to change the current use because the benefits from exclosures may not necessarily substitute that was derived from using for cultivation or grazing, at least in the short term.

Table 5.2 Restoration options and their potential 'applicability' to tackle land degradation in SSA

Management option	**Basic environmental requirements and conditions for the interventions to be efficient and effective**
Exclosures	A range of environments and hillsides, but if gullied, may need physical soil and water conservation measures. Suitable for degraded areas with no or very low population density. Not attractive if area is already under cultivation or private grazing. Clear land tenure and public land use policy required to succeed
Reforestation	Depends on which trees are identified – but generally soils and terrain should not be unsuitable; should be acceptable to farmers; should not compete with other benefits; should be in areas with very low population density; can be applied in all systems (excluding croplands) but if dry, water will be needed. High security of land tenure (e.g., clear state ownership or farmer's long-term land use right) is usually required
Agroforestry	Relatively good soils and terrain to support "agronomic" crops. Choose acceptable system to society. If in arid and semi-arid, water harvesting needed. Not in areas with no or very low population density. High security of land tenure (e.g., clear land ownership or long-term land use right) is usually required
Biofuel crops (e.g., *Jatropha curcas*)	Less suitable for cultivation, but terrain should not be unsuitable and should be no critical water limitation. Care should be given to avoid competition for land, and local community should understand its benefits. Difficult to implement if existing land use practice is cultivation or private grazing, may be as a hedge/live fence form. Species that don't necessarily exploit the soil need to be adopted
ISFM including intercropping	Soils and terrain should not be unsuitable. Could be effective in environments where farmers have the ability to adopt the technology. Not attractive to communities in arid and semi-arid unless additional water is provided. Not in areas with no or very low

and conservation agriculture	population density. High security of land tenure (e.g., clear land ownership or long-term land use right) is usually required. Incentives such as credits and subsidies may need to be in place
Physical and biological soil and water conservation measures	Terrain should not be unsuitable, or apply on proper landscape position. Effective in conditions where farmers are part of the system and show willingness to maintain. Land ownership security should be in place. Incentives are necessary to maintain interventions. Suitable biological options should be implemented.
Water harvesting	There should be adequate runoff to be harvested. Water development (e.g., shallow ground water, boreholes, river diversion) and proper management and sharing system (regulations, bylaws on water use) should be devised
Better mineral fertilizer access and use	The agricultural system in the degraded areas with good soil and suitable terrain is still the status quo, but farmers' access to fertilizer and their fertilizer use are improved to rebuild soil nutrient reserve. The measure is suitable in populated farming zones with a good physical access to market (i.e., high proximity to roads and towns)

Another challenge in the implementation of biofuels as land restoration option is the assumption that the introduced plant species are not any further 'exploitative'. That it, there may be no guarantee that the biofuel plants enhance recovery without putting any stress on the land (Pimente et al. 1994). This means that the environmental benefits of biofuel plants vis-à-vis their potential sources of energy should be understood.

Generally, it is important to note that huge simplification/generalization of land use/cover is made at the original scale (64 km^2 cell size) and the corresponding land management options provided in the table 5.2 are also rough and generalized representations. However, the framework employed and results derived can be relevant for wider geographical coverage, like SSA. For catchment and plot level applications, detailed experimental studies would be needed to match a given restoration measure to a corresponding land attribute.

5.3.2 Potential impacts of the restoration options targeted to specific hotspots

After the restoration options and land conditions are matched and management measures implemented, the possible impacts of those measures need to be analysed. This requires long-term monitoring and detailed monitoring and impact assessment. In this study, we provided generalized picture of the potential impacts of the various interventions. Table 5.2 summarizes the size of the area subjected to types of intervention and its translation to restoration of or improvement in productivity, assuming that there is "direct and positive" change towards improvement by each of the interventions.

Table 5.3 Restoration measures targeting hotspots in SSA and the potential improvement in productivity

SN	***Target land use/cover***	***Climate zone***	***Land condition***	***Type of intervention***	***Extent targeted (km^2)***
1	Unsuitable land	All	Bad terrain	Set-aside/exclosure	352,000
2	All types	Arid	Poor soil	Set-aside/exclosure	117,376
3	All type	All but arid	Poor soil	Jatropha	10,394
4	Cropland	Arid and semiarid	Good terrain and good soil	SLM with water harvesting	806
5	Cropland	Sub-humid and humid	Good terrain and good soil	SLM	1,363
6	Cropland	Arid and semiarid	Good terrain with poor soil	Jatropha with water harvesting	142
7	Cropland	Semiarid	Good terrain with poor soil	ISFM with water harvesting	815
8	Cropland	Sub-humid and humid	Good terrain with poor soil	ISFM	1,569
9	Cropland	All	Bad terrain and poor soil	Improved fallow	437
10	Cropland	All	Unsuitable soil	Exclosure	1,556
12	Forest/cropland	Sub-humid and humid	Good terrain and good soil	Agroforestry or ISFM	432
13	Forest/cropland	All	Bad terrain and poor soil	Leave as forest or exclose	62
14	Grassland	All	Good terrain and soil	Controlled grazing	1,923
15	Grassland	All	Bad terrain and poor soil	Exclosure	41
Total area conserved/restored					

*Note that natural regeneration of vegetation cover and soils in arid areas may take relatively longer time compared to areas with favourable and more regular rainfall.

Figure 5.4 shows the spatial distribution of the “improved areas” in relation to the “original degraded ones” after restoration measures have been applied. Application of the restoration options identified in this study can help restore about 65% of the degraded landscapes. Targeting “unsuitable land” (based on the legend of GLC2000) will help address problems over a wide geographical extent, compared to managing other areas (cultivated or grazing) (Table 5.2). This is because larger tracts of land in SSA are categorized as unsuitable, based on GLC2000 (Mayaux et al. 2004). Targeting mosaic forest/cropland will cover smaller geographical areas, especially if restoration is aimed at the arid and semi-arid areas with good terrain and soil conditions, as there are no major “forest” covers in the arid and semi-arid environments of SSA. One of the interesting results of this analysis is that targeting croplands with unsuitable soil through the use of exclosures can restore a relatively large geographical region (1,556 km^2), and the outcome will likely be positive, because utilizing those areas with poor soil will not yield good agricultural productivity. In addition, local communities and the environment can benefit from regenerated areas due to exclosures (including grass for livestock, selected tree cutting for construction, etc.). Similarly, introducing biofuel crops in the areas that are less suitable for cultivation due to soil and terrain constraints can restore and improve the productivity of about 0.12 million km^2 of land. This is assuming that the biofuel crops can help prevent and overcome degradation, but also supply fuel energy and sequester carbon. However, the potential of soil mining by the introduced biofuel plants need to be investigated to understand their 'net benefits'. For practical application at landscape/farm level, it will be necessary to conduce trade-off analysis to establish benefits versus costs.

As croplands are the second largest areas experiencing significant productivity decline in SSA, ISFM accounts for the major management option employed in this example (about 0.30 million km^2 of land). This indicates that the application of the ISFM approach for managing croplands in SSA can improve land productivity and food security for about 14 million people. This intervention would be mainly targeted at hotspots where the physical land condition (climate, soils, and terrain) allows for the implementation of ISFM. It is, however, important to recognize that employing ISFM includes input use, such as fertilizer, which can be costly and risky for farmers to adopt. It also should be noted that supplemental irrigation water and soil and water conservation measures may need to be in place for ISFM to be productive and attractive. Once again, the intention of the simulation conducted at the SSA level based on 64 km2 pixel size is to provide an overall indication of the possibility of matching technologies to land conditions and not to offer precise ISFM technology that can be implemented at such broad geographical coverage.

Out of the 1.4 million km^2 of degraded land for which different management measures have been prescribed, about 20% (0.29 million km^2 land) are recommended to be "exclosed." This management option targets those areas whose land condition (climate, soil terrain, or a combination of the two) restricts the feasibility of other land management options, either because the physical implementation of other management options is not possible or the economic return of the interventions will not be worthwhile. However, it is important to note that those areas are still used for cultivation or livestock grazing (46% occupy cultivated and grazing lands), and restricting their utilization will have negative social implications. In that case, it will require planning to find ways of accommodating the needs of about 8.7 million people. That is, the people and livestock using those lands need to be “compensated” if the management option is to be acceptable and successful. One possible option could be to distribute “benefits” from the exclosures to the other areas where people and livestock have been allowed to move and utilize resources. If the land condition allows it, it would be more feasible and attractive to introduce agroforestry systems or fruit crops in the exclosed hotspots so that the benefits could be shared with settlers down slope. Careful analysis of such issues is thus critical when recommending and introducing “new” management solutions to an area.

Figure 5.4 Spatial distribution of hotspots targeted with restoration measures in SSA. Note that the “Target areas and SLM options” legend corresponds to the restoration options designated to the respective land use/cover system, climate zone and land condition shown in Table 5.3

The results of this study demonstrate that targeted allocation of restoration measures might not only reverse land degradation, but also enhance land productivity and food security in the region. Since free grazing can be a hindrance to the implementation of agroforestry and/or exclosure-related options, there is a need to design alternative options for the community when planning to implement land management practices across landscapes. Farmers’ management-assisted regeneration, which has become a success story in the Sahel, could also be a useful intervention (Reij and Steeds 2003, Reij et al. 2005). It is also essential to note that the introduction of management/restoration measures may not automatically achieve the intended results without a cost. Careful analyses of the cost-benefits and trade-offs are therefore necessary, and should be implemented before farmers and other concerned bodies are advised to employ the suggested management measures. In addition, it is essential to conduct a detailed analysis of processes and drivers, focusing on hotspots in order to appropriately identify relevant restoration measures. Detailed literature reviews and research are also needed to establish the length of time each intervention will require to be able to restore or improve the productivity of the respective areas/pixels.

5.4. Conclusions

Land degradation is a serious problem in SSA, which affects livelihoods and food security. In order to overcome the problem of land degradation and improve food security and ecological integrity in the region, information on the severity of the problem, its drivers, and spatial patterns is essential. The results of this study reveal that 8% of SSA is suffering from land degradation due to human-caused processes. This roughly translates to the fact that over 60 million people are living on land that is losing its ability to produce enough food to support life. The areas experiencing significant decline in land productivity stretch across the semi-arid and humid-zones from western to eastern Africa, encompassing the region designated as the “breadbasket of Africa”. Results also show that out of the 1.6 million km^2 of cropland with declining productivity, about 20% is located on good terrain, but with bad soil—soil that can, however, be restored with suitable management measures. Of the 1.18 million km^2 that are degrading, but suitable for cultivation, 0.24 million km^2 are actually farmed and are likely over-exploited or poorly managed. Moreover, half of these are on poor soils, and it may be too costly to restore such lands.

Since the areas with declining productivity support a large number of people, and most are considered “once productive regions”, management measures are required to improve land condition and food security. Analyses of potential restoration measures targeted to serious problem areas show that out of the 1.4 million km^2 of degraded land, for which different management measures have been prescribed, about 20% are recommended for exclosure, meaning that human and livestock intervention will not be allowed. Out of these, about 46% occupy cultivated and grazing lands. This means that the people using those lands need to be compensated, if the management option is to be accessible and successful. One possible option could be to distribute benefits from the exclosures to the other areas where people and livestock are allowed to move and utilize resources. If the land condition allows, it will be more feasible and attractive to introduce agroforestry systems or fruit trees in the exclosed hotspots, so that benefits can be shared with settlers down slope.

Scenarios of preventive and restorative measures show that suitable land management measures can help prevent land degradation and restore degraded areas. However, the assessments presented above should be seen as a first approximation, and the maps and conclusions made here need further verified in the field. It is strongly suggested that detailed data be utilized in order to get a sound picture of the processes involved, along with the necessary tools and their effectiveness. Considerable research efforts should be made to identify the immediate and proximate causes of land degradation, and to develop more sustainable management and farming practices. Additionally, cost-benefit impact assessments and trade-off analyses are necessary to quantify the roles of those management interventions, including their positive and negative externalities (on society and nature) in time and space.

5.5. References

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Analysis of the impact of land management options in tackling land degradation in sub-Saharan Africa: example **study based on long-term remote sensing and climate data**

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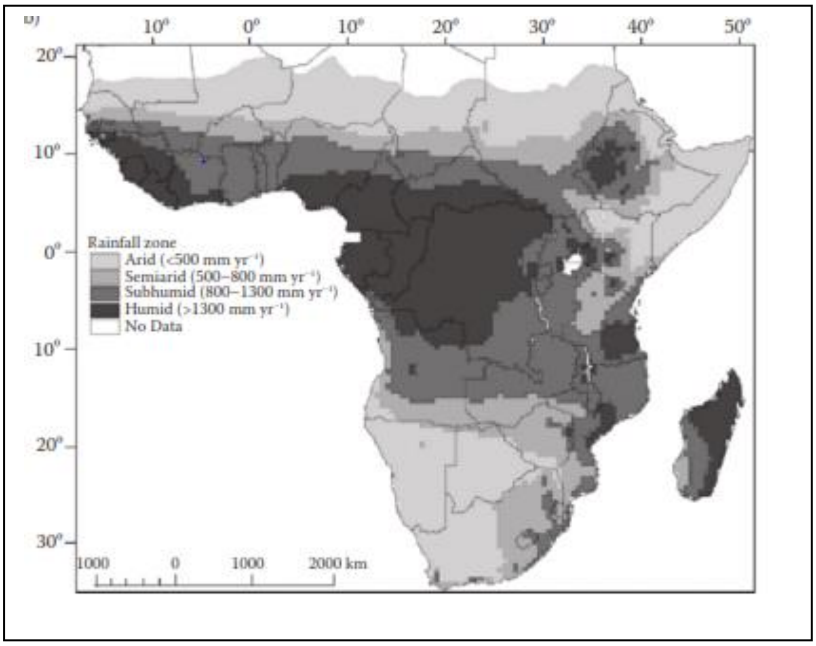

Figure 5.1 Precipitation zones classified using MAP for the period 1981–2002. MAP calculated based on monthly rainfall from the CRU TS 2.1 data (Source: Vlek et al. 2010)

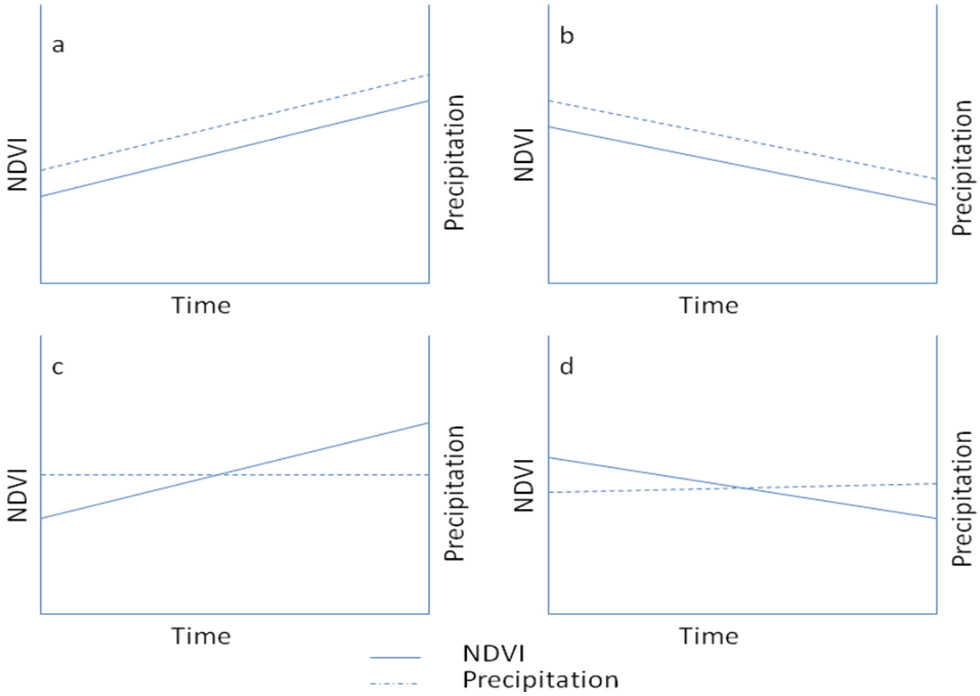

Figure 5.2 Scenarios of a possible long-term relationship between NDVI and precipitation (a) improving NDVI due to increasing precipitation (b) declining NDVI due to declining precipitation (c) improving NDVI despite declining precipitation (d) declining NDVI despite improving precipitation

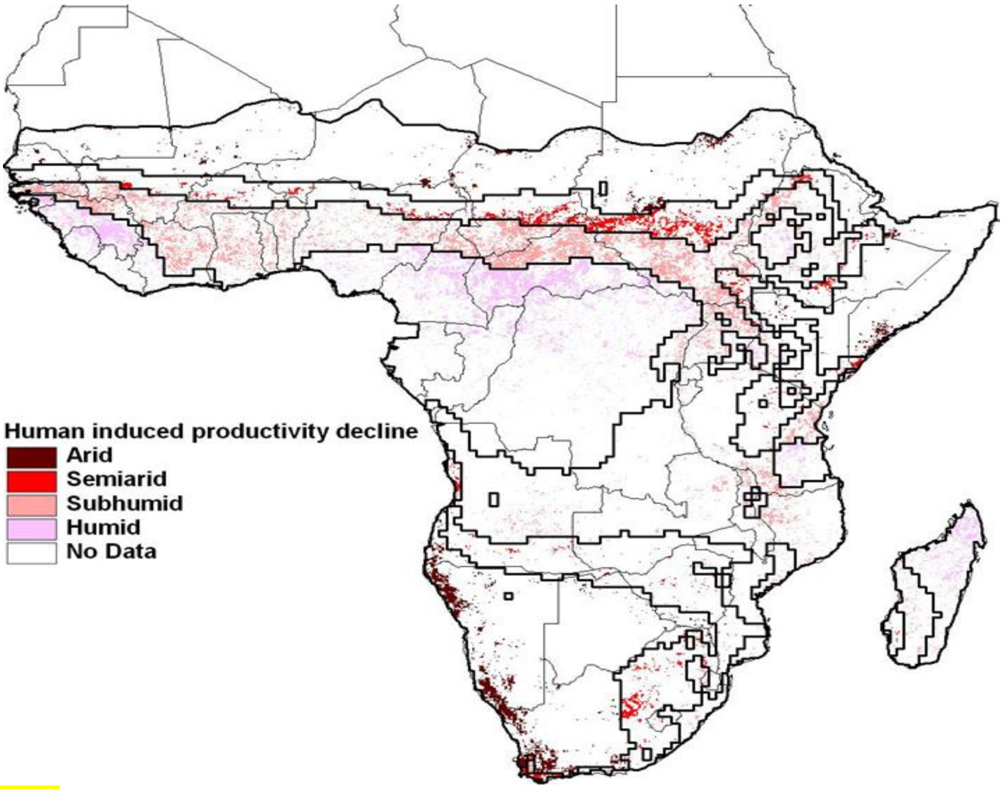

Figure 5.3 Hotspot areas of human-induced land productivity decline in SSA for different climate zones based on satellite and climate data for the period 1982 – 2003 (Reproduced based on Vlek et al. 2010). Note that the “contours” inside represent climate zones. No data category represents areas that do not suffer from “human inducted land degradation”

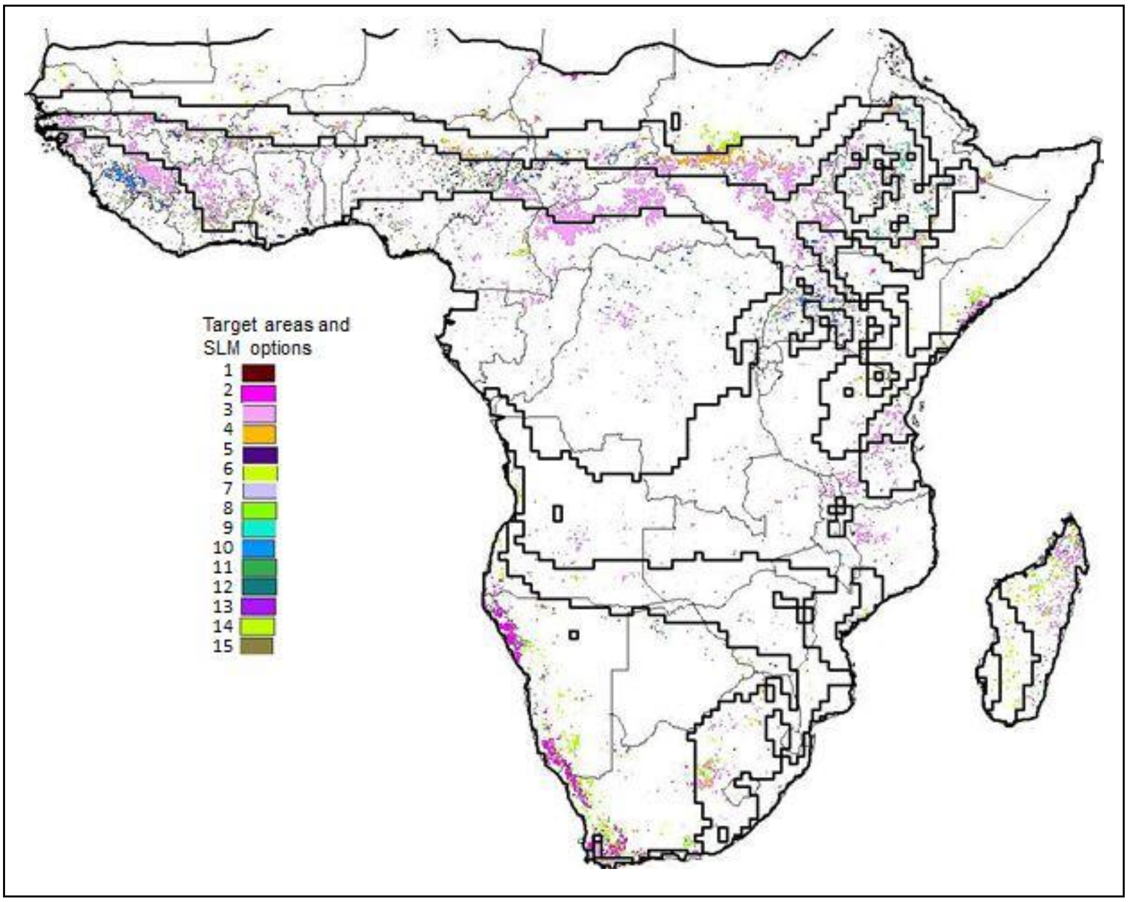

Figure 5.4 Spatial distribution of hotspots targeted with restoration measures in SSA. Note that the "Target areas and SLM options" legend corresponds to the restoration options designated to the respective land use/cover system, climate zone and land condition shown in Table 5.3