SENSITIVITY ANALYSIS OF LAND PRODUCTIVITY CHANGE CALCULATION IN MOZAMBIQUE

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ABSTRACT

Land productivity change is one of three indicators used to assess land degradation for reporting on Sustainable Development Goal (SDG) 15.3.1. This study aimed to analyze the sensitivity of this indicator to three parameters (i) the period of analysis, (ii) the rainfall dataset used for climate correction, and (iii) the annual NDVI integration period (civil year vs climatic year). We observed that the spatial pattern and values of the resulting land productivity indicators greatly differ according to these three parameters, questioning the comparability of SDG indicator 15.3.1 between countries in different agroclimatic zones.

***Index Terms*—** Trend analysis, NDVI time series, RESTREND analysis, land degradation, SDG, LDN

1. INTRODUCTION

Over the last five years, a number of global and regional targets and commitments have been agreed by national governments to halt and reverse land degradation and restore degraded land. These include the United Nation Convention to combat desertification (UNCCD), the Land degradation neutrality (LDN) initiative of the Sustainable Development Goals (SDG), in particular SDG target 15.3 dedicated to the restauration of degraded land and soil and achieving LDN. Each of these initiatives has set up ambitious target to reduce poverty, increase food security and nutrition and reduce land degradation for the next decades. To restore degraded lands, the countries must be able to locate and measure land degradation at national level. However, despite international guidelines and political and scientific recognitions of the importance of land degradation, many countries, including Mozambique, are lacking current and reliable estimates of the state of land degradation [1]. Due to differences in definitions, methodologies and perceptions, estimates of land degradation differ considerably worldwide, ranging from 15% to 66 % of the World's land [2], [3], and [4].

The latest report of UNCDD on land degradation provides methodological guidance on the choice of land degradation indicators, and how to measure and monitor them [5]. It suggests expressing land degradation as the status of three main sub-indicators (i) land productivity, (ii) land cover and land cover change, and (iii) carbon stocks above/below ground. These sub-indicators can be quantified in a spatially explicit manner using remote sensing data and/or ancillary data from national to sub-national databases.

As, in the near future, several countries will adopt this methodology to design national and local relevant land degradation mitigation policies or programs, it is necessary to analyze how certain parameters of this analysis can influence results. Focusing on the land productivity change, and from Mozambican example, the objective of this study is to analyze the sensitivity of this indicator to the three following parameters (i) the period of analysis (first and last years of the time series), (ii) the rainfall dataset used for climate correction, and (ii) the annual NDVI integration period (civil year vs climatic year).

2. MATERIALS AND METHODS

2.1. Study area

Mozambique is located on the southeast coast of Africa. The climate is tropical to subtropical, with a semi-arid region in the southern provinces. The country has an area of 799 380 km² and a population of 28 million people in 2015 [6]. It still has a large proportion of natural forest, mainly Miombo woodland, covering more than 40% of the country, and the arable land more than 10% [7], [8]. However, Mozambique's natural resources are rapidly depleting: about 267 000 ha per year of forests have been deforested between 2003 and 2013, mainly for subsistence agriculture (slash and burn), and urban expansion [8]. In addition, some areas are prone to high soil fertility depletion, which reduces the potential for productive agriculture [9].

2.2. Dataset

Land productivity change was assessed from long-term series of Earth Observation data on net primary production, using NDVI (Normalized Difference Vegetation Index) trends calculated using 16-day MODIS NDVI time series

(MOD13Q1 product, 250 m resolution, Collection 6 [10]). The image time series was pre-processed using a Savitzky-Golay filter to reduce the residual noise, and then the sum of NDVI was calculated over a 12-month time period (civil or climatic year).

The monthly rainfall data were obtained from six databases that cover the 2000-2016 period (the data spatial resolution is given in parenthesis): The Climate Hazards group InfraRed Precipitation with Station data (CHIRPS; 0.05°), the Global Precipitation Climatology Centre (GPCC v7; 1°), the Global Precipitation Climatology Project (GPCP v2.3.1; 2.5°), the Precipitation Estimation from Remotely Sensed Information using Artificial Neutral Networks - Climate Data Record (PERSIANN–CDR; 0.25°), the Tropical Applications of Meteorology using SATellite data and ground observation (TAMSAT; 4 km), and the Tropical Rainfall Measuring Mission (TRMM 3B43v7; 25 km).

2.3. Methods

The land productivity change were analyzed using a statistical trend analysis based on an ordinary-least square regression over different periods, applied to annual NDVI time series. Each pixel was then classified regarding the direction of change (increase or decrease in productivity) using the sign of the slope coefficient and its significance (statistically significant at the 95% level, p-value < 0.05). To distinguish rainfall-induced changes alone from the effects induced by other factors such as the human factors, the rainfall component is removed from the NDVI trends. This procedure consists of (i) fitting a linear model between the annual NDVI and the annual rainfall and (ii) performing a new trend analysis on the model residuals. This method is referred hereafter as RESTREND [11].

In this paper, the method of reference is the annual NDVI RESTREND method applied to a 16-year period (2001-2016), and using CHIRPS rainfall data. To analyze the sensitivity to the period of analysis, we calculated the NDVI trend and RESTREND over two 11-years periods (2001-2011 and 2006-2016). To test the sensibility of the method to the monthly rainfall dataset, we used six different data sets. Finally, we tested the period of NDVI integration by calculating the annual sum of monthly NDVI over the civil year (January_*n* to December_*n*), and over the climatic year (August_*n-1* to July_*n*).

3. RESULTS AND DISCUSSION

3.1. Period of analysis effect

The annual land productivity trends and RESTREND statistics for Mozambique, and for the 2001-2011 and 2006-2016 periods, are presented in Figure 1 and Table 1.

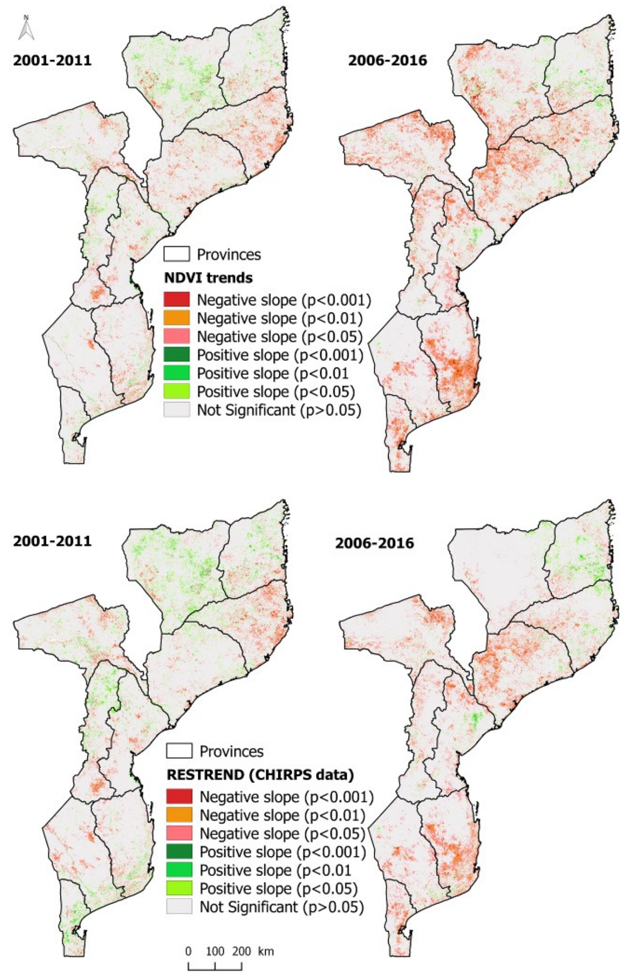

Figure 1. Maps of the annual NDVI trends (upper maps) and RESTREND (lower maps), calculated for Mozambique for the 2001-2011 and 2006-2016 periods.

The NDVI trend and RESTREND show similar moderate significant positive trends for the 2001-2011 period (between 3.8% and 6.4%). In all configurations, the negative trends are higher than the positive ones, but it is especially true for the 2006-2016 period with 15.9% and 10.6% for NDVI trend and RESTREND, respectively. This result indicates that the land conditions have been worsened in Mozambique during the last decade, due in a large part to unfavorable rainfall conditions for vegetation productivity, such as the different drought events recorded in Mozambique [12].

Table 1. Proportion of land in Mozambique with significant annual land productivity trends, calculated for the 2001-2011 and 2006-2016 periods.

	NDVI trends (%)		RESTREND (%)	
Classes	01-11	06-16	01-11	06-16
Decrease (p<0.05)	6.6	15.9	6.4	10.6
Increase (p<0.05)	3.8	2.0	5.3	2.1
Stable	88.4	82.1	88.3	87.3

These results illustrate the high sensitivity of the method to the period of analysis considered. Differences in the reference period may explain the contradictory information regarding the assessment of land degradation estimations [13].

3.2. Rainfall dataset effect

The annual land productivity trends, for the 2001-2016 period for each rainfall dataset are presented in Figure 2. RESTREND analysis results show that the proportion of the country characterized by significant trends due to other factors than rainfall over the 2001-2016 period differs in a large way, from 10.5% to 18.5 % for land productivity decline, and from 2.5% to 4 % for land productivity increase.

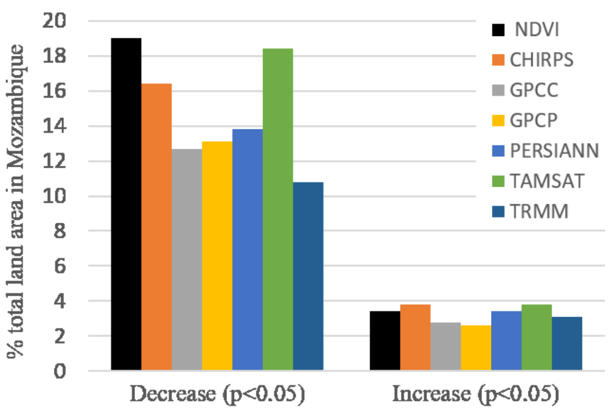

Figure 2. Percentage of significant decrease and increase NDVI trends (black bars), and RESTREND calculated with different rainfall datasets (colored bars), for Mozambique over the 2001-2016 period.

This results show that the rainfall dataset used in the RESTREND analysis has an impact on the detection of significant trends. The rainfall dataset impact is even larger than the rainfall correction itself. We suggest that rainfall dataset derived from satellite should be compared with local rain gauge data when possible, or to consult climatic experts, in order to choose the best dataset to perform RESTREND analysis.

3.3. Integration period effect

The land productivity trends with and without rainfall correction for the 2001-2016 period, are compared for different NDVI 12-month integration period for civil year and climatic year and presented in Figure 3 and Table 2. Surprisingly, the difference between the two results is not negligible, especially when considering the decreasing NDVI trends with values of 19% and 24.6% for the civil year and the climatic year, respectively. Once corrected from the rainfall variability, as expected, the difference is smaller (16.4% and 18.8%, respectively). This result means that the civil year may not be the best NDVI integration period to calculate the annual vegetation productivity using NDVI trends.

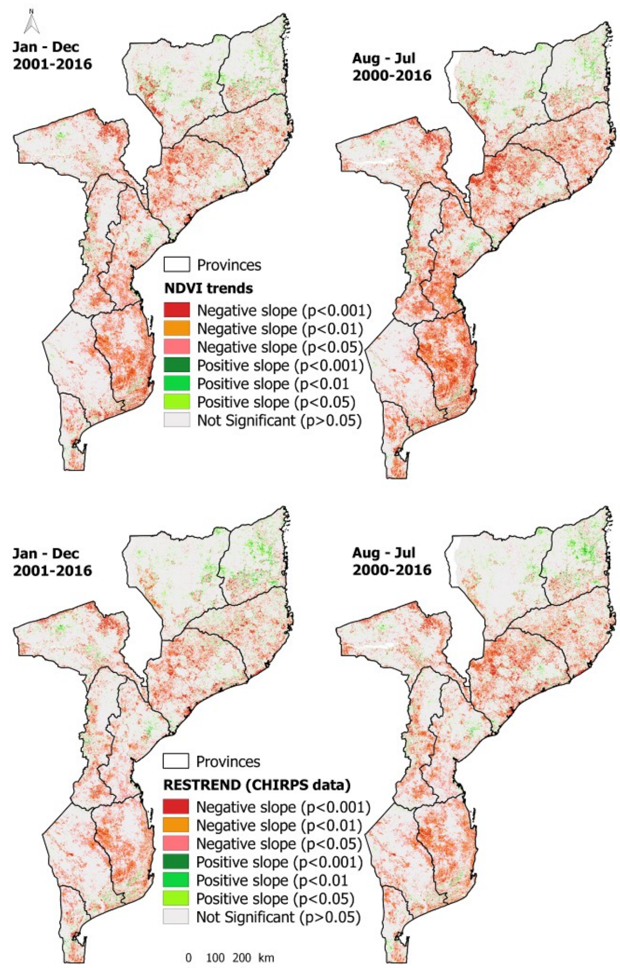

Figure 3 : Maps of the annual NDVI trends (upper maps) and RESTREND (lower maps), calculated for Mozambique over the civil year (January to December) and the climatic year (August to July).

Table 2. Area and proportion of land in Mozambique with significant annual land productivity trends, calculated over January-December (between 2001 and 2016) and August-July (between 2000 and 2016) 12-month periods.

Trends classes p-value < 0.05	NDVI trends		RESTREND	
	Area (km²)	%	Area (km²)	%
January - December				
Decrease	152 076	19.0	131 004	16.4
Increase	27 088	3.4	30 381	3.8
Stable	608 484	76.1	625 502	78.2
August - July				
Decrease	196 581	24.6	150 553	18.8
Increase	22 037	2.8	24 918	3.1
Stable	554 560	69.4	600 602	75.1

4. CONCLUSION

In this study, we showed that the SDG land productivity trends indicator was very sensitive to the three parameters tested: the period of analysis for the NDVI trends calculation, the rainfall dataset used for RESTREND analysis, and the annual integration period (civil or climatic year). This argue for a prior analysis of the best parameters for each countries or to define a unique framework for every country if one want to compare land degradation mitigation measures. We recommend to integrate the annual NDVI over the climatic year and not over the civil year, the former being more representative of the land dynamics.

5. REFERENCES

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