Assessment of terrestrial carbon stocks from regional to agricultural landscapes using SMAP-L4 Carbon Net Ecosystem Exchange dataset: review and application (Maradi, Republic of Niger)

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Assessment of terrestrial carbon stocks from regional to agricultural landscapes using SMAP-L4 Carbon Net Ecosystem Exchange dataset: review and application in the Sahel

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Abstract. Continental carbon (C) sequestration plays a major role in climate change resilience, mitigation, and agro-ecological intensification. Soil Moisture Active Passive Global Daily Carbon Net Ecosystem Exchange dataset (SMAP L4) was used for monitoring daily terrestrial C stocks, given the high potential of semiarid areas for Sustainable Goals achievements, in terms of human issues and surface areas. Inter- and intra-annual variation of Global Primary Productivity (GPP), Net Ecosystem CO_2 Exchange (NEE), Soil Heterotrophic Respiration (RH) and Soil Organic Carbon (SOC) were analyzed from 2015 to 2020, across the region of Maradi (Niger) and 15 sites with rainfed crops and vegetal mosaics. To quantify temporal trends of C indicators across years, Mann-Kendall were conducted based on yearly GPP days of min/max. It underlined declines of SOC in the northern part of Maradi ($\tau > -0.6$), rising in the south ($\tau > +0.6$). Univariate monitoring (e.g. 2162 daily measurements) of GPP and RH showed asymmetries in their distribution (positive skews, GPP $\bar{x}$=1.19 gC m^{-2} d^{-1}, *Me*=0.88 gC m^{-2} d^{-1}; RH $\bar{x}$=0.679 gC m^{-2} d^{-1}; *Me*=0.485 gC m^{-2} d^{-1}). This result might be attributed to local variations of plant functional types and microbial activities. Averaged NEE stressed a slightly negative C balance among sites (overall $\bar{x}$= -0.003 gC m^{-2} d^{-1}), suggesting their storage capacity. Processing aspects being set up, a consolidation of those first results should be done. Satellite data records analysis argued for the implementation of Man-Environment observatories in Maradi as a pilot region, for both remote and local understanding of C behavior in agroecosystems and multiscale counseling.

Keywords: Niger, Sahel, Maradi, Carbon sequestration, Terrestrial carbon survey, Agro-ecology, Climate change mitigation, Time series analysis

1 Introduction

Arid areas represent nearly half of emerged land on Earth. The Sahel region is submitted to several pressures, such as climate change and population growth, leading to land degradation. Landscape management and changes in agricultural practices, e.g. agro-ecological intensification, in co-construction with all stakeholders, have been suggested to prevent land degradation and improve large scale C sequestration [1,2,3,4]. Terrestrial C indicators, such as Global Primary Productivity (GPP), Net Ecosystem Exchange (NEE), Heterotrophic Respiration (RH) or Soil Organic Carbon density (SOC) are Essential Climate Variable (ECV) to survey, insightfully resuming resources management and environmental protection [5,6]. In such conditions, implementation of C sequestration observatories in semiarid areas is relevant. Socio-ecological observatories are material and numerical networks insuring "*long-term, large scale and inte-*

grated social and ecological observations” [7]. Three scopes are bind with it: 1) scientific 2) technical and 3) organizational aspects [8]. Given the ubiquity of C-related issues, it calls for co-construction of consensual indicators, implementable for scientific questionings, policy making, and stakeholders’ listening[4].

Progresses in terrestrial C budgeting with satellite data records/modelling are peculiar opportunities, legitimated by sparse ground-based observations. However, ground-truth and stakeholders’ recommendations/feedback are necessary for terrestrial C cycle understanding. SMAP L4 C products, with daily records of global ecosystem productivity on a large scale since 2015-03 can temporally mimic farming techniques and productivity evolution. It is valuable for rainfed agro-forestry systems, prone to strong hydrological and biological variability [9, 10]. Given the comparative performance of SPL4CMDL time series concerning the survey of water, soil, and vegetation in various agroecosystems [11, 12, 13, 14, 15, 16], our study attempts to assess and describe C indicators in the geographical context of Maradi region, Niger (Fig. 1).

2 Materials and Methods

A preprocessing procedure of SPL4CMDL products [17] removed pixels exceeding 3 g C m^{-2} d^{-1} of NEE uncertainty by using the Application for Extracting and Exploring Analysis Ready Samples (AppEARS-USGS) quality flag time series (Fig. 2). Yearly absolute extremums of GPP were taken to select dates of the north-south regional tile, illustrating the gradient of rainfall. Mann-Kendall (MK) tau (τ) tests and associated p-values were computed for GPP and SOC (Fig. 2) to detect regional temporal trends.

A total of 15 local sites were chosen for their agronomical exhaustiveness, mixing mosaics and rainfed croplands. Centroids of 9 km² SPL4CMDL pixels are generated to extract GPP, NEE, RH and SOC daily time series. Descriptive statistics were calculated for these C products and studied sites as a first overview of C spatio-temporal variations. All statistical analyses were performed using R software [18], the R packages kendall [19], modistsp [20], rgdal [21], rts [22] and lubridate [23].

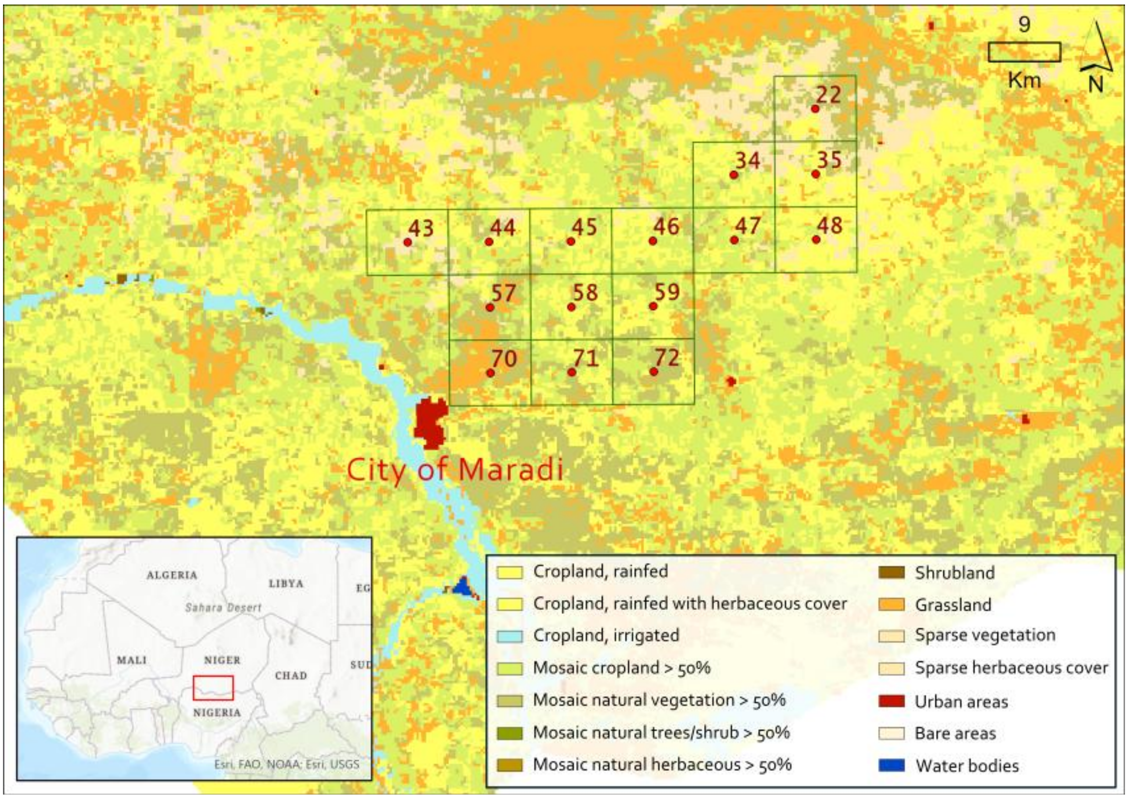

Fig. 1. Location of studied areas and sampling sites

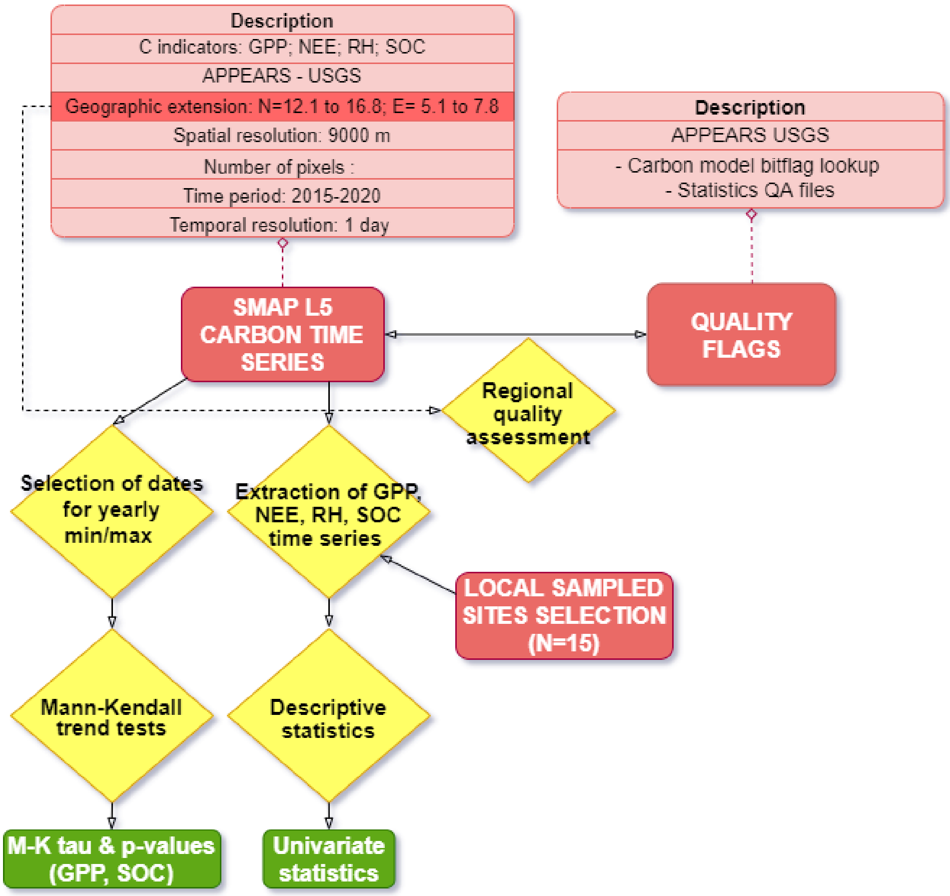

Fig. 2. Flowchart representing a general view of data processing

3 Results

3.1 Regional trend tests

The MK trend tests applied on Min and Max GPP were not statistically significant (every pixels' p-values of the regional tiles having $p > 0.05$). For Max SOC, pixels were significant, with 53% of pixels having p-value <0.0003. Significance of Max SOC trend test underlined MK-τ splitting areas on both sides of the 600 mm of yearly rainfall ($\tau > 0.6$ for SOC southern of the isohyet; $\tau > -0.6$ in the northern arid and under-inhabited parts). It signaled a rise in temporal amount of max SOC in the south. The same pattern was seen for Min SOC, but number of significant pixels counted was one half lesser than Max SOC.

3.2 Local variation of C indicators

Overall descriptive statistics among all sites for C indicators showed positive skews for GPP and in particular RH (Table 1). Given averaged means and medians, NEE and SOC were normally distributed. In spite of the sampling sites vicinity, SOC and RH appeared to be more heterogeneous compared to other C indicators; inter-sites variation coefficients for GPP, RH and SOC were 0.91, 0.68 and 0.02, respectively.

Table 1. Global statistics for C indicators computed based on the 15 sampling sites

	GPP	NEE	RH	SOC
Unit	gC m^{-2} d^{-1}			gC m^{-2}
Averaged min	0	-1.365	0.158	1378
Averaged max	4.694	1.791	2.229	1495
Overall mean	1.192	-0.003	0.679	1435
Overall median	0.878	0.016	0.485	1435
Averaged SD	1.09	0.419	0.461	28.9

4 Discussion and conclusions

MK trend tests suggests the proneness of SOC rapid evolution in Maradi, compared to other C indicators. Seasonally-adjusted MK tests on longer time series would improve first descriptions made. Daily measurements of C outputted by SMAP L4 records appear to be consistent with the literature and on-field measurements, led in comparable ecosystems [24, 25, 26, 27]. Those two elements of discussion argue for continuing technical process of such datasets. Crossing other satellite records (e.g. MODIS GPP) and ground measurements would improve these encouraging results, considering the novelty of the SMPL4CMDL product and its applications. Besides, reduction of the scientific and technical uncertainties due to the coarse spatial resolution has to be included. Local sampling of time series will be expanded at the administrative scale of the Maradi region to better grasp C temporal behavior related to climatic and agro-socio-economic variability. Local sites selected by stakeholders will insure that implementation of Farmer Managed Natural Regeneration techniques can be observed and valued with SPL4CMDL products.

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