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### ▶ To cite this version:

Romain Courault, Abou-Soufianou Sadda, Maud Loireau, Cécile Gomez, Tiphaine Chevallier, et al.. 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). 1st Annual Meeting of the Mediterranean Geosciences Union - Springer, Nov 2021, Istanbul, Turkey. hal-03345957v1

## HAL Id: hal-03345957 https://hal.science/hal-03345957v1

Submitted on 16 Sep 2021 (v1), last revised 4 Oct 2021 (v2)

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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 (Maradi, Republic of Niger)

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17 Abstract. Continental carbon (C) sequestration plays a major role in climate 18 change resilience, mitigation, and agro-ecological intensification. Soil Moisture 19 Active Passive Global Daily Carbon Net Ecosystem Exchange dataset (SMAP 20 L4) is used for monitoring daily terrestrial C stocks, given the high potential of 21 semiarid areas for Sustainable Goals achievements, in terms of human issues and 22 surface areas. Inter- and intra-annual variation of Global Primary Productivity 23 (GPP), Net Ecosystem CO<sub>2</sub> Exchange (NEE), Soil Heterotrophic Respiration 24 (RH) and Soil Organic Carbon (SOC) were analyzed from 2015 to 2020, across 25 the region of Maradi (Niger) and 15 sites with rainfed crops and vegetal mosaics. 26 To quantify temporal trends of C indicators across years, Mann-Kendall were 27 conducted based on yearly GPP days of min/max. It underlined declines of SOC 28 in the northern part of Maradi ( $\tau > -0.6$ ), rising in the south ( $\tau > +0.6$ ). Univariate 29 monitoring (e.g. 2162 daily measurements) of GPP and RH showed asymmetries 30 in their distribution (positive skews, GPP  $\bar{x}$ =1.19 gC m<sup>-2</sup> d<sup>-1</sup>, Me=0.88 gC m<sup>-2</sup> d<sup>-1</sup> <sup>1</sup>; RH  $\bar{x}$ =0.679 gC m<sup>-2</sup> d<sup>-1</sup>; *Me*=0.485 gC m<sup>-2</sup> d<sup>-1</sup>). This result might be attributed 31 32 to local variations of Plant Functional Types and microbial activities. Averaged 33 NEE stressed a slightly negative C balance among sites (overall  $\bar{x}$  = -0.003 gC m<sup>-</sup> 34 <sup>2</sup> d<sup>-1</sup>), suggesting their storage capacity. Processing aspects being set up, a con-35 solidation of those first results should be done. Satellite data records analysis ar-36 gue for the implementation of Man-Environment observatories in Maradi as a pilot region, for both remote and local understanding of C behavior in agroeco-37 38 systems and multiscale counseling.

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

#### 41 **1** Introduction

42 Arid areas represent nearly 1/2 of emerged land on Earth. The Sahel region is submitted 43 to several pressures, such as climate change and population growth, leading to land 44 degradation. Landscape management and changes in agricultural practices, e.g. agro-45 ecological intensification, in co-construction with all stakeholders, have been suggested 46 to prevent land degradation and improve large scale C sequestration<sup>1, 2, 3, 4</sup>. Terrestrial C indicators, such as Global Primary Productivity (GPP), Net Ecosystem Exchange 47 48 (NEE), Heterotrophic Respiration (RH) or Soil Organic Carbon density (SOC) are Es-49 sential Climate Variable (ECV) to survey, insightfully resuming resources management 50 and environmental protection<sup>5,6</sup>. In such conditions, implementation of C sequestration 51 observatories in semiarid areas is relevant. Socio-ecological observatories are material 52 and numerical networks insuring "long-term, large scale and integrated social and eco-53 logical observations"<sup>7</sup>. Three scopes are bind with it: 1) scientific 2) technical and 3) organizational aspects<sup>8</sup>. Given the ubiquity of C-related issues, it calls for co-construc-54 55 tion of consensual indicators, implementable for scientific questionings, policy making, 56 and stakeholders' listening<sup>4</sup>.

Progresses in terrestrial C budgeting with satellite data records/modelling are pecu-57 58 liar opportunities, legitimated by sparse ground-based observations. However, ground-59 truth and stakeholders' recommendations/feedback are necessary for terrestrial C cycle 60 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 61 62 productivity evolution. It is valuable for rainfed agro-forestry systems, prone to strong hydrological and biological variability<sup>9,10</sup>. Given the comparative performance of 63 SPL4CMDL time series concerning the survey of water, soil, and vegetation in various 64 agroecosystems<sup>11, 12, 13, 14, 15, 16</sup>, our study attempts to assess and describe C indicators in 65 66 the geographical context of Maradi region, Niger (Fig. 1b).

#### 67 2 Materials and Methods

A preprocessing procedure of SPL4CMDL products<sup>17</sup> removed pixels exceeding 3 gC m<sup>-2</sup> d<sup>-1</sup> of NEE uncertainty by using the Application for Extracting and Exploring Analysis Ready Samples (AppEARS-USGS) quality flag time series (Fig. 1a). 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 ( $\tau$ ) tests and associated p-values were computed for GPP and SOC (Fig. 1a) to detect regional temporal trends.

15 local sites were chosen for their agronomical exhaustiveness, mixing mosaics and rainfed croplands. Centroids of 9 km<sup>2</sup> 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<sup>18</sup>, the R packages kendall<sup>19</sup>, modistsp<sup>20</sup>, rgdal<sup>21</sup>, rts<sup>22</sup> and lubridate<sup>23</sup>.

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83 Fig. 1a and 1b. General view of data processing, studied areas and sampling (R.Courault, 2021).

#### 84 **3 Results**

#### 85 3.1 Regional trend tests

86 The MK trend tests applied on Min and Max GPP were not statistically significant 87 (every pixels' p-values of the regional tiles having p >0.05). For Max SOC, pixels were 88 significant, with 53% of pixels having p-value <0.0003. Significance of Max SOC trend 89 test underlined MK- $\tau$  splitting areas on both sides of the 600 mm of yearly rainfall ( $\tau$  > 90 0.6 for SOC southern of the isohyet;  $\tau > -0.6$  in the northern arid and under-inhabited 91 parts). It signals a rise in temporal amount of max SOC in the south. The same pattern 92 is seen for Min SOC, but number of significant pixels counted as one half lesser than 93 Max SOC.

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#### 95 **3.2** Local variation of C indicators

Overall descriptive statistics among all sites for C indicators show positive skews
for GPP and in particular RH (table 1). Given averaged means and medians, NEE and
SOC are normally distributed. In spite of the sampling sites vicinity, SOC and RH appear to be more heterogeneous compared to other C indicators (inter-sites variation coefficients for GPP, RH and SOC are respectively of 0,91; 0,68; 0,02).

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

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Table 1. Global statistics for C indicators, on the basis of the 15 sampling sites

#### 102 4 Discussion and conclusions

103 MK trend tests suggests the proneness of SOC' rapid evolution in Maradi, compared to 104 other C indicators. Seasonally-adjusted MK tests on longer time series would improve 105 first descriptions made. Daily measurements of C outputted by SMAP L4 records ap-106 pear to be consistent with the literature and on-field measurements, led in comparable ecosystems<sup>24, 25, 26, 27</sup>. Those two elements of discussion argue for continuing technical 107 108 process of such datasets. Crossing other satellite records (e.g. MODIS GPP) and ground 109 measurements would improve these encouraging results, considering the novelty of the 110 SMPL4CMDL product and its applications. Besides, reduction of the scientific and 111 technical uncertainties due to the coarse spatial resolution has to be included. Local 112 sampling of time series will be expanded at the administrative scale of the Maradi re-113 gion to better grasp C temporal behavior related to climatic and agro-socio-economic 114 variability. Local sites selected by stakeholders will insure that implementation of 115 Farmer Managed Natural Regeneration techniques can be observed and valued with 116 SPL4CMDL products.

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