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1 **Assessment of terrestrial carbon stocks from regional to**
2 **agricultural landscapes using SMAP-L4 Carbon Net**
3 **Ecosystem Exchange dataset: review and application**
4 **(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 CO₂ 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⁻² d⁻¹, $Me=0.88$ gC m⁻² d⁻¹;
31 RH $\bar{x}=0.679$ gC m⁻² d⁻¹; $Me=0.485$ gC m⁻² d⁻¹). This result might be attributed
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⁻²
34 d⁻¹), 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
37 pilot region, for both remote and local understanding of C behavior in agroeco-
38 systems and multiscale counseling.

39 **Keywords:** Niger, Sahel, Maradi, Carbon sequestration, Terrestrial carbon sur-
40 vey, Agro-ecology, Climate change mitigation, Time series analysis

41 **1 Introduction**

42 Arid areas represent nearly $\frac{1}{2}$ 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^{1, 2, 3, 4}. Terrestrial
47 C indicators, such as Global Primary Productivity (GPP), Net Ecosystem Exchange
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^{5,6}. 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*”⁷. Three scopes are bind with it: 1) scientific 2) technical and 3)
54 organizational aspects⁸. Given the ubiquity of C-related issues, it calls for co-construc-
55 tion of consensual indicators, implementable for scientific questionings, policy making,
56 and stakeholders’ listening⁴.

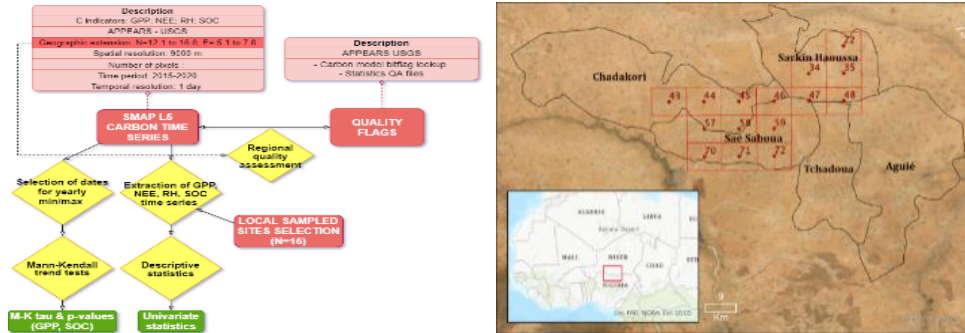
57 Progresses in terrestrial C budgeting with satellite data records/modelling are pecu-
58 liar opportunities, legitimated by sparse ground-based observations. However, ground-
59 truth and stakeholders’ recommendations/feedback are necessary for terrestrial C cycle
60 understanding. SMAP L4 C products,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

67 **2 Materials and Methods**

68 A preprocessing procedure of SPL4CMDL products¹⁷ removed pixels exceeding 3 gC
69 $\text{m}^{-2} \text{ d}^{-1}$ of NEE uncertainty by using the Application for Extracting and Exploring Anal-
70 ysis Ready Samples (AppEARS-USGS) quality flag time series (Fig. 1a). Yearly abso-
71 lute extremums of GPP were taken to select dates of the north-south regional tile, illus-
72 trating the gradient of rainfall. Mann-Kendall (MK) tau (τ) tests and associated p-values
73 were computed for GPP and SOC (Fig. 1a) to detect regional temporal trends.

74 15 local sites were chosen for their agronomical exhaustiveness, mixing mosaics and
75 rainfed croplands. Centroids of 9 km^2 SPL4CMDL pixels are generated to extract GPP,
76 NEE, RH and SOC daily time series. Descriptive statistics were calculated for these C
77 products and studied sites as a first overview of C spatio-temporal variations. All sta-
78 tistical analyses were performed using R software¹⁸, the R packages kendall¹⁹, mo-
79 distsp²⁰, rgdal²¹, rts²² and lubridate²³.

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81



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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- τ 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.

94 **3.2 Local variation of C indicators**

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

101 **Table 1.** Global statistics for C indicators, on the basis of 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

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
 107 ecosystems^{24, 25, 26, 27}. Those two elements of discussion argue for continuing technical
 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.

117 **References**

- 118 1. Shukla, P. R., Skea J., Calvo Buendia E. et al. "IPCC, 2019: Climate Change and Land: an
 119 IPCC special report on climate change, desertification, land degradation, sustainable land
 120 management, food security, and greenhouse gas fluxes in terrestrial ecosystems." (2019).
- 121 2. Rumpel, C., Amiraslani F., Chenu C. et al. "The 4p1000 initiative: Opportunities, limitations
 122 and challenges for implementing soil organic carbon sequestration as a sustainable develop-
 123 ment strategy." *Ambio* 49.1 (2020): 350-360.
- 124 3. Schimel, D. "Carbon cycle conundrums." *Proceedings of the National Academy of Sciences*
 125 104.47 (2007): 18353-18354.
- 126 4. Chevallier, T. Loireau M., Courault R. et al. "Paris Climate Agreement: Promoting Interdis-
 127 ciplinary Science and Stakeholders' Approaches for Multi-Scale Implementation of Conti-
 128 nental Carbon Sequestration." *Sustainability* 12.17 (2020): 6715.
- 129 5. Bojinski, S., Verstraete M., Peterson M. et al. "The concept of essential climate variables in
 130 support of climate research, applications, and policy." *Bulletin of the American Meteorolo-
 131 gical Society* 95.9 (2014): 1431-1443.
- 132 6. Kraak, M.. Challenges of mapping Sustainable Development Goals indicators data. *ISPRS*
 133 *international journal of geo-information* vol. 7, no 12 (2018): p. 482.
- 134 7. Bourgeron, P., Kliskey A., Alessa L. et al. "Understanding large-scale, complex, human-
 135 environmental processes: a framework for social-ecological observatories." *Frontiers in*
 136 *Ecology and the Environment* 16.S1 (2018): S52-S66.
- 137 8. Loireau, M., Fargette M., Desconnets J.-C. et al. "Observatoire scientifique en appui aux
 138 gestionnaires de territoire, entre abstraction OSAGE et réalité ROSELT/OSS." *Revue Inter-
 139 nationale de Géomatique* 27.3 (2017): 303-333.
- 140 9. Xiao, J., Chevallier F., Gomez C. et al. "Remote sensing of the terrestrial carbon cycle: A
 141 review of advances over 50 years." *Remote Sensing of Environment* 233 (2019): 111383.
- 142 10. Ouédraogo, M., Barry S., Zougmore R.B. et al. "Farmers' willingness to pay for climate
 143 information services: Evidence from cowpea and sesame producers in Northern Burkina
 144 Faso." *Sustainability* 10.3 (2018): 611.

- 145 11. AMS Homepage, [https://journals.ametsoc.org/view/journals/bams/94/8/bams-d-11-](https://journals.ametsoc.org/view/journals/bams/94/8/bams-d-11-00049.1.xml)
 146 00049.1.xml, last accessed 2021/07/28
- 147 12. McNally, A., Husak G.J., Brown M. et al. "Calculating crop water requirement satisfaction
 148 in the West Africa Sahel with remotely sensed soil moisture." *Journal of Hydrometeorology*
 149 16.1 (2015): 295-305.
- 150 13. Piles, M., Entekhabi D., Konings A.G. et al. "Monitoring the phenology of global agroeco-
 151 systems using SMAP multi-temporal vegetation optical depth retrievals." *AGU Fall Meeting*
 152 *Abstracts*. (2016): p. H23N-07
- 153 14. Karlsson, J., Serikova S., Vorobyev S.N. et al. "Carbon emission from Western Siberian
 154 inland waters". *Nature communications*, vol. 12, no 1, (2021): p. 1-8.
- 155 15. Myrstener, M., Gomez-Gener L., Rocher-Ros G. et al. "Nutrients influence seasonal meta-
 156 bolic patterns and total productivity of Arctic streams." *Limnology and Oceanography* 66
 157 (2021): S182-S196.
- 158 16. Umair, M., Kim D., Ray R.L. et al. "Evaluation of atmospheric and terrestrial effects in the
 159 carbon cycle for forest and grassland ecosystems using a remote sensing and modeling ap-
 160 proach." *Agricultural and Forest Meteorology* 295 (2020): 108187.
- 161 17. Kimball, J. S., Jones L.A., Kunding T. et al. 2020. SMAP L4 Global Daily 9 km EASE-
 162 Grid Carbon Net Ecosystem Exchange, Version 5. GPP, NEE, RH, SOC means. Boulder,
 163 Colorado USA. NASA NSIDC, last accessed 2021/07/28
- 164 18. R Core Team (2020) R: A language and environment for statistical computing. Vienna, Aus-
 165 triaR Foundation for Statistical Computing. Retrieved from <http://www.R-project.org/>
- 166 19. McLeod A.I. The Kendall Package. Kendall Rank Correlation and Mann-kendall Trend
 167 Test. R Package Version 2.0 (2005), p. 10, last accessed 2021/07/28
- 168 20. Busetto L., Ranghetti L. MODISsp: an R package for automatic preprocessing of MODIS
 169 Land Products time series. *Computers and Geosciences* 97 (2016) : 40-48
- 170 21. Bivand R., Keitt T., Rowlingson B. rgdal: bindings for the geospatial data abstraction li-
 171 brary, (2015). R package version 1.1-3. <https://CRAN.Rproject.org/package=rgdal>, last ac-
 172 cessed 2021/07/28
- 173 22. Naimi B. rts: raster time series analysis. R package version 1.0-10. [https://CRAN.R-](https://CRAN.R-project.org/package=rts)
 174 [project.org/package=rts](https://CRAN.R-project.org/package=rts), (2015), last accessed 2021/07/28
- 175 23. Spinu V., Grolemond G., Wickham H. et al. R: Package 'lubridate'. [https://CRAN.R-](https://CRAN.R-project.org/package=lubridate)
 176 [project.org/package=lubridate](https://CRAN.R-project.org/package=lubridate), (2017), last accessed 2021/07/28
- 177 24. Tagesson, T., Fensholt R., Cappalaere B. et al. "Spatiotemporal variability in carbon ex-
 178 change fluxes across the Sahel." *Agricultural and Forest Meteorology* 226 (2016): 108-118.
- 179 25. Alam, S.A., Starr M. [https://www.researchgate.net/profile/Syed-Ashraful-Alam/publica-](https://www.researchgate.net/profile/Syed-Ashraful-Alam/publication/266929796_Modelled_woodland_biomass_and_soil_carbon_sequestration_across_Sudanese_drylands_current_and_future_climate_change_scenario-based_estimates/links/543f7ae60cf21c84f23cd8b3/Modelled-woodland-biomass-and-soil-carbon-sequestration-across-Sudanese-drylands-current-and-future-climate-change-scenario-based-estimates.pdf)
 180 [tion/266929796_Modelled_woodland_biomass_and_soil_carbon_sequestra-](https://www.researchgate.net/profile/Syed-Ashraful-Alam/publication/266929796_Modelled_woodland_biomass_and_soil_carbon_sequestration_across_Sudanese_drylands_current_and_future_climate_change_scenario-based_estimates/links/543f7ae60cf21c84f23cd8b3/Modelled-woodland-biomass-and-soil-carbon-sequestration-across-Sudanese-drylands-current-and-future-climate-change-scenario-based-estimates.pdf)
 181 [tion_across_Sudanese_drylands_current_and_future_climate_change_scenario-based_esti-](https://www.researchgate.net/profile/Syed-Ashraful-Alam/publication/266929796_Modelled_woodland_biomass_and_soil_carbon_sequestration_across_Sudanese_drylands_current_and_future_climate_change_scenario-based_estimates/links/543f7ae60cf21c84f23cd8b3/Modelled-woodland-biomass-and-soil-carbon-sequestration-across-Sudanese-drylands-current-and-future-climate-change-scenario-based-estimates.pdf)
 182 [mates/links/543f7ae60cf21c84f23cd8b3/Modelled-woodland-biomass-and-soil-carbon-se-](https://www.researchgate.net/profile/Syed-Ashraful-Alam/publication/266929796_Modelled_woodland_biomass_and_soil_carbon_sequestration_across_Sudanese_drylands_current_and_future_climate_change_scenario-based_estimates/links/543f7ae60cf21c84f23cd8b3/Modelled-woodland-biomass-and-soil-carbon-sequestration-across-Sudanese-drylands-current-and-future-climate-change-scenario-based-estimates.pdf)
 183 [questration-across-Sudanese-drylands-current-and-future-climate-change-scenario-based-](https://www.researchgate.net/profile/Syed-Ashraful-Alam/publication/266929796_Modelled_woodland_biomass_and_soil_carbon_sequestration_across_Sudanese_drylands_current_and_future_climate_change_scenario-based_estimates/links/543f7ae60cf21c84f23cd8b3/Modelled-woodland-biomass-and-soil-carbon-sequestration-across-Sudanese-drylands-current-and-future-climate-change-scenario-based-estimates.pdf)
 184 [estimates.pdf](https://www.researchgate.net/profile/Syed-Ashraful-Alam/publication/266929796_Modelled_woodland_biomass_and_soil_carbon_sequestration_across_Sudanese_drylands_current_and_future_climate_change_scenario-based_estimates/links/543f7ae60cf21c84f23cd8b3/Modelled-woodland-biomass-and-soil-carbon-sequestration-across-Sudanese-drylands-current-and-future-climate-change-scenario-based-estimates.pdf), last accessed 2021/07/28
- 185 26. Woomer, P., Touré A. & Sall M., "Carbon stocks in Senegal's Sahel transition zone." *Journal*
 186 *of arid environments* 59.3 (2004): 499-510.
- 187 27. Mchunu C., Lorentz S., Jewitt G. et al. "No-till impact on soil and soil organic carbon erosion
 188 under crop residue scarcity in Africa". *Soil Science Society of America Journal*, vol. 75, no
 189 4, (2011): p. 1503-1512.