

Technical Note

A New Compendium of Soil Respiration Data for Africa

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Abstract: The objective of this paper is to present to the scientific community a new dataset derived from existing literature on soil respiration in Africa. The data has thus been obtained by searching for records in peer review papers and grey literature. The main search engines used are: Scientific Citation Index (SCI) database, ISI Science web and Google scholar. This data description paper has greatly advanced the number of data points on soil respiration in Africa from 4 in 2010 to 62 in 2014. The new data points are culled from 47 peer review publications and grey literature reports. The data lends its self to a lot of possible analytical methods such as correlation analysis, multiple linear regressions, artificial neural network analysis and process base modeling. The overall conclusion that can be drawn here is that this paper has greatly advanced the availability of soil respiration data in Africa by presenting all the available records that before now were only reported in different studies.

Keywords: soil respiration; database; Africa

1. Introduction

Soil carbon is a vital component of the global carbon budget [1]. Due to its pertinent role in ecosystem carbon attenuation, soil respiration (R_s) has become a valuable part of the global carbon cycle [2]. The concept of ecosystem carbon attenuation is used in this context to explain the fact that the higher the levels of carbon stored in soils without disturbance, the lesser the potential amounts of carbon emitted from the soil into other terrestrial ecosystems. Even though it has not been sufficiently documented and measured, it is the second largest terrestrial carbon flux [3,4]. Evidence of this is seen as about 8%–10%

of atmospheric carbon dioxide originates from the soil. Globally, soils have a carbon pool that is twice as large as the atmospheric pool of carbon [5].

In Africa, inadequacies in R_s data seem to be most pronounced when compared to other regions of the world. In 2010 most studies that had attempted to assemble data on R_s had not been able to suggest more than four observations for the entire African continent. For example, Chen *et al.* [6], Bond-Lamberty and Thomson [7] published the most up to date global and regional databases of R_s with only one [6] and four [7] data observation points respectively for Africa (Figure 1a). R_s has been defined as the flux of carbon dioxide from soil surfaces to the atmosphere [7]. Though this current study used essentially the same methods as these earlier studies, minor differences (they did not include older papers that are not available from the web of science and grey literature) might account for the differences in the number of data points obtained on Africa.

As such, this study aims at verifying from existing literature, all possible studies with seasonal and annual data on R_s in Africa. This data will be important to researchers because it will go a long way in providing data that will be used to verify critical questions. The availability of the data in itself does not answer any critical questions but provides an opportunity for researchers to use it and find answers to critical questions. Therefore, future studies that will make use of the data will respond to critical questions such as whether the surge in new data on R_s significantly impacts the current climate debates through enhanced feedbacks. Such feedbacks will generally have repercussions on regional and global carbon cycles as well as on policies that will impact some of our current climate change adaptation strategies [8–12].

It is certain that thousands of R_s observations have been collected globally over the decades yet, this effort itself has advanced very little or nothing on Africa. However, a regional database on R_s in Africa will make available data that will not only impact the pace of research in this domain but will also affect existing climate change debates and ultimately enhance the predictability of existing global climate models [13–15]. The current shortage of adequate observations on R_s based on Africa is indeed a mighty gap and this study is the first to establish a more comprehensive database on R_s in Africa.

2. Methods

2.1. Data Collection and Inclusion Criteria

An elaborate literature survey of both peer review papers and grey literature that contain seasonal and annual measurements of R_s was conducted. The studies included were either based on articles that covered R_s research on a global scale and more specifically research that had been published on parts of Africa. We aimed at including studies published up to 2014. All laboratory incubation studies were left out. All the papers consulted were written in English or French and were obtained through the Scientific Citation Index (SCI) database, ISI Science web and Google scholar. All studies in other languages were excluded. The key search terminologies used were: soil respiration, global soil respiration, soil respiration studies in Africa, African soil CO₂ evolution and flux. Once a paper was acquired, the title and abstract were used to verify if it could be of relevance to Africa. However, field measurements that were based on elevated CO₂ experiments were excluded from this study. The data were either obtained from the text, tables and or figures. In the case of figures, estimates were obtained by reading the

corresponding values from the figures using a software called Getdata Graph Digitizer version 2.26 (<http://www.getdata-graph-digitizer.com/>). In cases where more than one data point was presented for different ecosystem types for the same site, the two data points were included in the database based on the ecosystem types. This is the reason why in some cases the database has more than one measurement for different ecosystems in the same site. Most of the seasonal data included covered both the dry and the rainy season measurements and were made of two data points; in all cases where such seasonal data for both seasons were provided, the annual averages were calculated with ± 0.5 SD. The rest of the data were presented in this database exactly as they appear in the original text and only in cases in which seasonal data was provided that averages were calculated. For purposes of uniformity, the climate data associated to the various sites has been standardized [16]. Figure 1a,b was produced with the aid of Arc Map 10. This was achieved by uploading the data into the software and using the spatial distribution option to spatially represent the data on the maps. Basically, two main systems of soil nomenclatures have been used to classify the soil types presented in this study following the USDA and the FAO; these are the genetic and taxonomic nomenclatures. Firstly, the genetic classification considers climate as a major distinguishing factor. Here, the soils are classified as zonal soils and occur in the tropical humid climates; ferralitic soils belong to this category. Volcanic soils have also been classified under the genetic classification but differ because they are based on their poorly developed profile characteristics and could be presented as azonal soils. Finally, the taxonomic system of soil nomenclature is also vital. This is based on the soil textural characteristics and color. Most of the sandy soils, clay and loam soils belong to this group. Generally, for a paper to have been included in this study, it had to report at least one of the following:

- Mean/average seasonal soil respiration;
- Annual or mean annual soil respiration data;
- Q_{10} and related temperature variations;
- R_{10} with R_s at 10 °C.

2.2. Technical Validation

Some basic quality control has been performed on the data. This is seen as maps have been used to make sure that the data plots referred to in the papers are in the correct locations. To verify cases of inaccuracy in the data, this paper has verified for cases where ecosystem respirations total is below R_s and all such entries have been left out. Also, any data observations that are not in seasonal or annual format have been ignored. In cases where several observations are provided by the same study, duplication has been avoided as the specific latitudinal and longitudinal locations have been identified. However, whenever the same location coordinates have several observations, care has been taken to either discard the data if it is a duplicate or include it if it represents data for different ecosystems or soil types for the same site. The former being possible if we observe that several measurements were undertaken in the same transects. In cases where the temperature and rainfall data for a given region are not given, the location coordinates have been used to determine these variables. We have also employed Arc map analysis and “bird’s eye view” techniques to present the data points on a map. This has been most useful in cases in which the actual location coordinates where the data was measured have not been

given. Here, the “bird’s eye view” technique helps in determining the location of the measurements by determining the general location of the sites on the map.

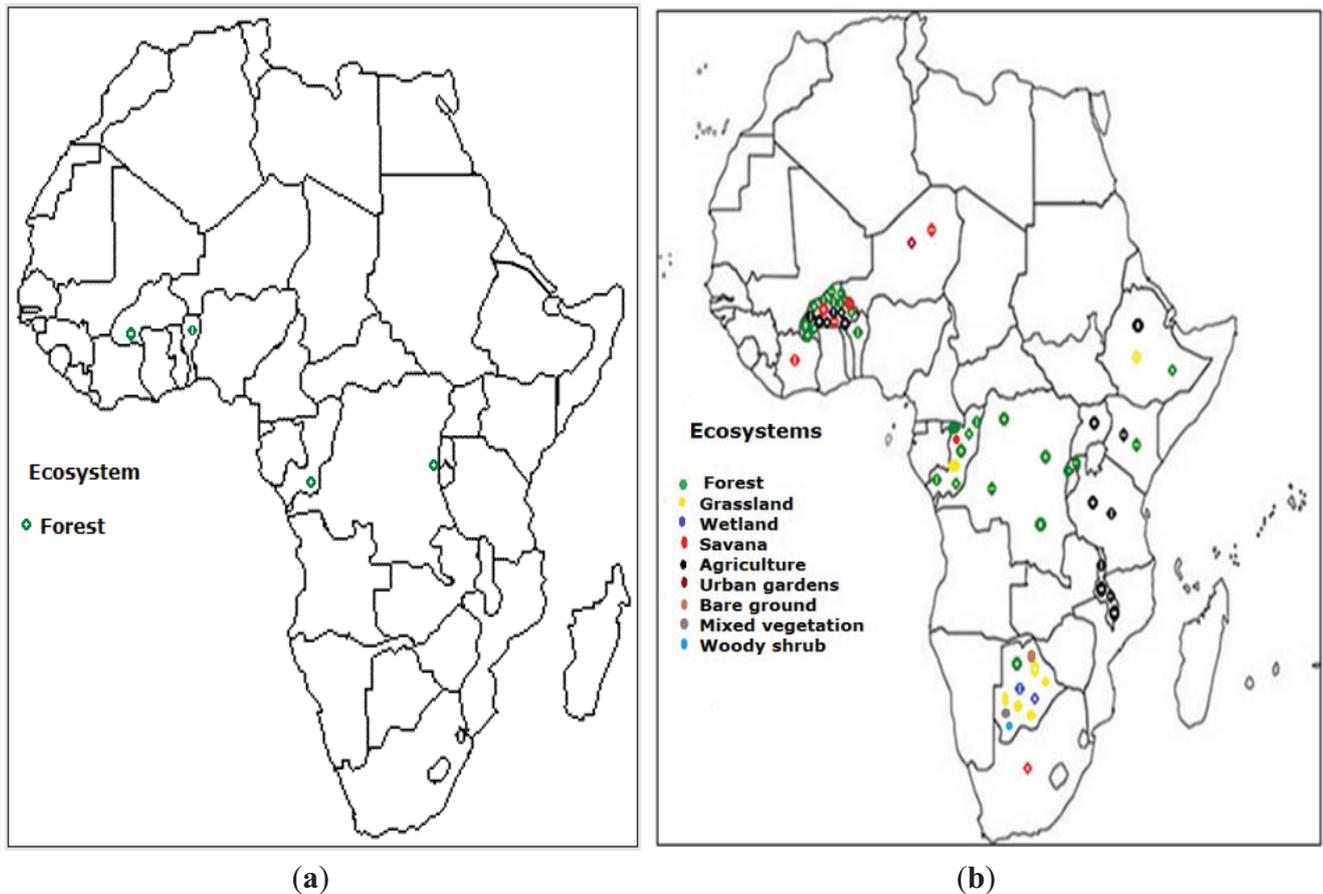


Figure 1. The evolution and spatial distribution of soil respiration observations for different African countries from (a) 4 observations in 2010 to (b) 62 observations in 2014 inspired by data collected for this study. The dots represent soil respiration measurements for different ecosystems and have been drawn using Arc Map 10 software.

3. Results and Discussion

Before this current study, previous studies [6,7] on R_s in Africa have only presented 4 measurements (Figure 1a). This current study presents 62 published measurements of R_s from 47 publications [1–47] (Figure 1b). Some of the publications reported multiple estimates or observations of R_s . The sites extended from Niger in the north ($13^{\circ}32' N$ and $2^{\circ}3' E$) to South Africa in the south ($25^{\circ}01' S$ and $31^{\circ}23' E$). From west to east we have Cote d’Ivoire ($6^{\circ}13' N$ and $5^{\circ}02' W$) and Ethiopia ($7^{\circ}06' S$ and $38^{\circ}37' E$).

In terms of major biomes, this database has mainly tropical and temperate biomes. However, the various ecosystems on which these observations have been carried out are more varied. Of the 62 observation acquired, 25 were on forest ecosystems, 15 on agricultural ecosystems, 7 on savannah ecosystems, 7 on grassland ecosystems, 2 on wetlands, 3 on mixed vegetation, 1 on bare ground, 1 on woody shrub and 1 on urban gardens [6–47] (Figure 2). Mixed vegetation refers to a situation in which several vegetation types co-exist in the same site, for example trees, grasses and shrubs co-existing together

in mixed stands. Burkina Faso had the highest number of observations (19) [6–47] indicating that more *Rs* research has been published.

In addition, this study has obtained the site names of the observations, their latitudinal and longitudinal locations, their elevations above sea level, the dominant biome type (which is either tropical or temperate), ecosystem type (which could be any of the following: forest, grassland, wetland, savannah, agriculture, mixed vegetation, bare ground and urban gardens). Ecosystem state is based on the level of natural or human interference in the ecosystem; in this case, this study has identified natural or undisturbed ecosystems and managed or disturbed ecosystems. Species refer to the various types of trees, shrubs and grasses found in the various study sites. The specific species identified are: *Eucalyptus*, *Gilbertiodendron spp*, *Scorodophoeus spp*, *Brachystegia spp*, *Elaeis guineensis spp*, *Andropogon gayanus*, *Loudetiopsis kerstingii*, *C4 grass-Loudetia (Nees)*. Mixed species refer to scenarios in which several species listed already are found on the same site. Dry/arid species refer to those that thrive in harsh environments while wet species are those plants that are water tolerant. Leaf habit refers to the response of the vegetation to the various seasons; in this case this study has identified either plants that maintain their leaves all year round (evergreen) or those that shed their leaves during adverse seasons (deciduous). Stage is either described as aggrading, which refers to reductions in the productive capacity of the forest or mature, which refers to trees that have attained full productivity and harvest age.

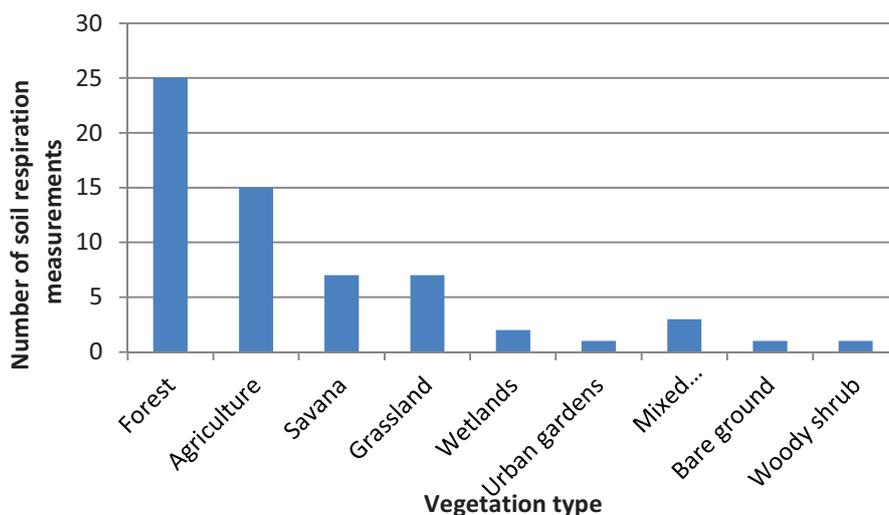


Figure 2. Main vegetation types and number of soil respiration measurements.

The principal soil types identified include arenosol, ferralitic, sandy soils, loam soils, granite, kandic rhodustaff, ustic quartz, clay-kanhaplic haplustults and volcanic soils; their main systems of classification has been presented above. Mean standardized annual precipitation and mean annual temperature were also computed [16]. However, in cases where ranges were given, the mean of the upper and lower range values was calculated. For studies that did not provide any temperature and rainfall information, we verified the missing rates from Hijmans [16]. The above procedure of calculating the mean values from ranges was used throughout the database where ranges were suggested by the consulted studies.

For future analysis, this study is suggesting that authors use correlation analysis, coefficient of determination, artificial neural networks, structural equation modeling and odd ratios inter alia to verify

the degree of correlation between R_S and variables such as rainfall and temperature as well as to map the distribution of R_S . Multiple linear regression and structural equation models could also be used to verify the impact of several variables on R_S at the same time. This data is also usable in process based modeling. Authors are allowed to use this data in global and regional models to verify the effects of a surge in new data on previous models. However, caution has to be taken as the raw data will have to be converted into the same units to facilitate handling and manipulation. The data is presented in its original units for two reasons: (1) To provide users with the liberty of using it however they desire and (2) Due to strict instructions from our donors to have the data in its original form to preserve originality.

In the case of seasonal data, the annual means or averages have been calculated. This database has been uploaded on figshare. A digital object identifier (Doi) of doi:10.6084/m9.figshare.924740 [47] has been provided. Also, the database has been added to this current study as supplementary material. As such, with the freely available nature of this data in its original form, researchers have full access and can use it for various analyses as well as provide updates and corrections.

What do we gather from the 62 data points of R_S presented in this study? The increase in the number of R_S data points that this study has advanced shows that more studies on R_S have been conducted in Africa. The rates of R_S vary a lot within and among major vegetation biomes as can be seen on the dataset [6–46]. The lowest rates of R_S occur in the coldest and driest biomes such as the tundra and northern bogs while the highest rates are recorded in the tropical moist forests where annual temperature and moisture are high all year round and where the standard error of the R_S data is >10% of the mean value. This goes a long way to show the coarse relationship between R_S and vegetation type [46]. Generally, there are limited measurements of CO₂ efflux from arid soils, natural savannas, woodlands, deciduous forests and deserts. In the midst of this, arid landscapes still cover close to one third of terrestrial land surface. This means that the shortage in measurements from such areas as revealed by the data presented in this study makes obvious a major deficiency in global R_S estimation and simulation. So far, most R_S studies are based on the temperate parts of the world at the detriment of the tropics that cover more than one third of the global landscape. This includes a rich plethora of diversified biomes with very high rates of R_S , yet not given adequate attention. Therefore, as seen by the database presented here, in spite of the abundance of global measurements of soil R_S , the global coverage is weak and this study is one effort at bringing the sparsely available data on Africa into a single source.

Based on the literature sources cited above, [6–46], the rates of R_S in Africa are controlled by mean annual air temperatures and mean annual precipitation. Temperature for example is a great predictor of R_S but adding precipitation increases the predictive capacity of most predictive models [46]. The variations in the rates of R_S measurements have been observed for different vegetation types as seen in the data presented in this study [6–47]. In the literature, it is still unclear whether microbial decomposition rates (heterotrophic) are more responsible for the observed surges in R_S than the activities of vascular plants (autotrophic).

4. Conclusions

This study has advanced the existing collection of R_S measurements in Africa. At the end, 62 published estimates of R_S were obtained from 47 publications; up from only 4 in 2010. The implications of this improved dataset are that African soils still have a great potential of serving as major

carbon stocks. Understanding the current trends in the flux of such soil carbon will go a long way to enhance our understanding of the rates of soil carbon flux into the atmosphere and consequently enhance the measures and options for better carbon sequestration and measurements. Before now, emphasis has been on the carbon stocks of flora at the expense of soils. Perhaps the lack of emphasis of previous research in this area is a weakness, but this study certainly describes the current state of research on R_s measurements in Africa.

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Conflicts of Interest

The author declares no conflict of interest.

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