Hindawi Publishing Corporation
Dataset Papers in Geosciences
Volume 2013, Article ID 297973, 6 pages
http://dx.doi.org/10.7167/2013/297973

Dataset Paper

A 10-Year Dataset of Basic Meteorology and Soil Properties in Central Sudan

Jonas Ardö

Department of Physical Geography and Ecosystem Science, Lund University, Sölvegatan 12, 223 62 Lund, Sweden

Correspondence should be addressed to Jonas Ardö; jonas.ardo@nateko.lu.se

Received 21 August 2012; Accepted 23 September 2012

Academic Editors: S. L. Forman, K. Wang, and Q. Zhuang

Meteorological data and soil data have been collected at a site in the central Sudan from 2002 to 2012. The site is a sparse savanna in the semiarid region of Sudan. In addition to basic meteorological variables, soil properties (temperature, water content, and heat flux) and radiation (global radiation, net radiation, and photosynthetic active radiation) were measured. The dataset has a temporal resolution of 30 minutes and provides general data for calibration and validation of ecosystem models and remote-sensing-based assessments, and it is relevant for studies of ecosystem properties and processes.

1. Introduction

This paper presents and describes meteorological data and soil data collected at Demokeya in the province of Kordofan, central Sudan, during the period 2002–2012. The main purpose was to collect and provide general environmental data for studies related to ecosystem properties and ecosystem processes, remote sensing, biogeophysics, and the carbon cycle. Long-term series of data of this type of data are not commonly available for sites in Africa, and we hope that the data presented here will be useful and widely utilized. Fluxes of CO_2, H_2O, and energy have also been measured at the site from 2007 to 2009, using the eddy covariance technique (see hereinafter for the availability of these data).

Ecosystem processes such as the assimilation and respiration of CO_2 are significant when quantifying fluxes of carbon (C) between the atmosphere, the biosphere, and the pedosphere and account for major parts of the C budget. Assimilation and respiration are influenced by moisture, temperature, light, and nutrient availability. Their quantification can be based on direct measurements or using various upscaling methodologies such as global dynamic vegetation models [1] or remote-sensing-based models [2], including regional [3], continental, or global assessments [4]. In situ measurements can provide suitable data for the calibration of models and for validation of methods of estimating ecosystem properties and processes. Basic such data as air temperature, relative humidity, and precipitation provide a descriptive background for local and general studies in agriculture, forestry, and environmental science [5, 6].

Studies using subsets of data presented in this paper have been published previously [7–9], sometimes in combination with flux data [10–16].

The measurements presented in this paper were performed in cooperation between Lund University, Sweden, and Agricultural Research Corporation (ARC) in El Obeid, Sudan.

The measurement site is called Demokeya, named after the closest village. It is situated approximately 35 km northeast of El Obeid, which is located at 13.3°N, 30.5°E, in Northern Kordofan, Sudan (Figure 1). The site is located in the Demokeya experimental forest, which is owned and managed by the Agricultural Research Corporation (ARC), a Sudanese governmental research organisation. Research in Demokeya forest is focused on the production of gum arabic (*Acacia senegal*) and agroforestry (Figure 2). A programme including field trials with *Acacia senegal* has been in progress at the site since 1967.

The site is characterized by a sparse Acacia savanna (dominating species include *Acacia nilotica, A. tortilis,* and *A. senegal*) with a canopy cover of 5–10% and a ground cover composed mainly of grasses (dominating species are the perennial *Aristida pallida* and the annuals *Eragrostis tremula*

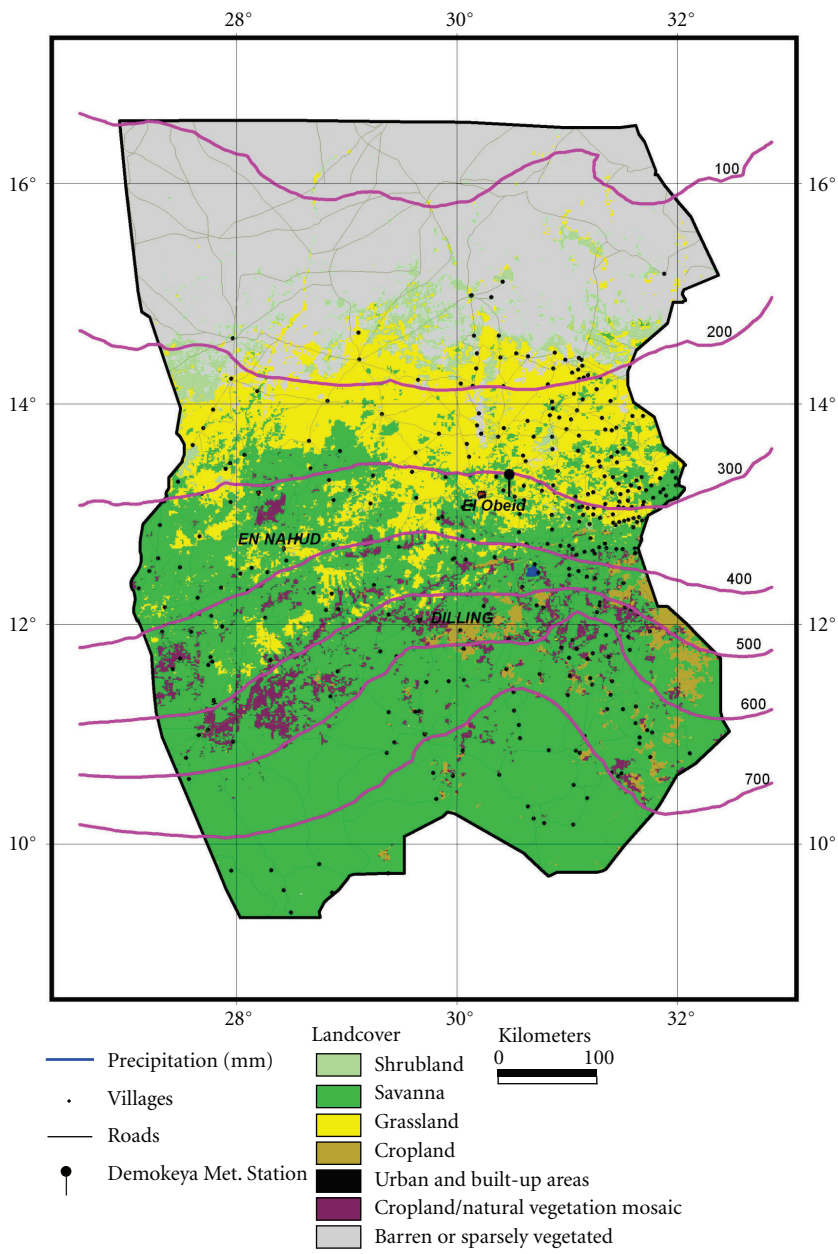

Figure 1: Land use and mean annual precipitation in Kordofan.

and *Cenchrus biflorus*) and some herbs. The maximum tree height is six metres and the major part of the tree canopy is located between three and five metres above the ground. Grasses and herbs reach a maximum height of one metre. Approximately 70% of the vegetation is assumed to be C4 plants and 30% is assumed to be C3 plants [11].

The mean annual precipitation is 320 mm with most falling from June to October. The period from November to May is dry and the seasonality of the precipitation is strong (Figure 4). Mean annual temperature is 28°C. Grazing, cultivation, and forest clearance (i.e., firewood collection) are restricted in the vicinity of the measurements, and an area of about 10 × 10 m around the measurement site is fenced off. The fence protects the equipment from animals and people. There is also a fire line outside the fence to protect the site from bushfires (Figure 3).

The bedrock in the region is dominated by the so-called basement complex, consisting mainly of ancient igneous and metamorphic rocks including gneisses, metasediments, metagabbro, and foliated granites [17]. The bedrock is covered by sandy soil deposits, mainly derived from Nubian sand stone. The area is flat but gently undulating and dominated by stabilized parallel sand dunes with a north-south orientation. These sand dunes and the soil consist of deep sand, sometimes up to 50-meter deposits.

This sandy soil is classified (using FAO terminology) as a Cambic arenosols. These are coarse-textured soils of aeolian origin, locally named as Qoz (sometimes Goz) soils [18]. The

Figure 2: Photograph showing the general characteristics of the Demokeya site.

Figure 3: The meteorological station is fenced and surrounded by a fire lane.

texture of this reddish light soil is characterized by 60–70% coarse sand, 20–30% fine sand, and a small proportion of clay [19]. The soil is generally poor in nutrients with low soil organic carbon [20] and low cation exchange capacity. The clay content is higher in interdune hollows [19].

Soil samples were collected in the vicinity of the site, revealing the following characteristics: soil texture (sand and silt), 96.5% and 3.5%; soil bulk density, 1.7 kg dm^{-3}; soil organic matter, 0.12%; soil organic nitrogen, 0.03%; pH, 6.7; exchangeable phosphorus, ≈2 mg kg^{-1}; and a calcium carbonate ($CaCO_3$) content, 1.4%. The soil has a wilting point of 5% and a field capacity of 15%, and hence the maximal volumetric plant-available soil moisture is around 10%. The soil is easily cultivated using simple tools and allows easy penetration of roots to deeper levels with higher moisture content. The infiltration rate is around 6 mm min^{-1} [21]. Further details concerning the site have been published previously [22].

2. Methodology

On February 8, 2002, a meteorological station was set up close to Demokeya (13.28692°N latitude and 30.47922°E longitude, WGS84), North Kordofan, Sudan (Figure 3). The station includes sensors for the measurements of precipitation, air temperature, air humidity, wind speed and wind direction, soil moisture, soil temperature, soil heat flux, global incoming radiation, net radiation, and incoming and reflected photosynthetic active radiation. The sensors used at the meteorological station at Demokeya from Julian day 39, 2002 to 2004, are as follows. Water Content Reflectometer CS615 (Campbell Scientific) was used to measure soil moisture at 60 cm and at 30 cm (volumetric (0-1)). Temperature Probe 107 (Campbell Scientific) was used to measure soil temperature at 30 cm and at 60 cm (°C). Pyranometer Sensor CM3 (300–3000 nm) (Kipp and Zonen) was used to measure incoming radiation at 2 m (W m^{-2}). MP100A Temperature and Relative Humidity Probe (Rotronic) was used to measure the average air temperature at 2 m (°C) and relative humidity at 2 m (%). Vapour pressure (kPa) was derived from average air temperature at 2 m and relative humidity at 2 m. Moreover, the tipping bucket ARG 100 (Campbell Scientific) was used to measure precipitation (mm). Wind Monitor Model 05103–5 (RM Young Company) was used to measure the arithmetical mean wind speed at 2.5 m (m s^{-1}), length of the mean wind vector (m s^{-1}), direction of the mean wind vector (degrees), and standard deviation of direction (degrees).

The number and type of sensors were increased in 2005. NR Lite Net Radiometer (Campbell Scientific) was used to measure net radiation at 1.5 m (W m^{-2}). PAR Sensor JYP 1000 (SDEC, France) was used to measure photosynthetically active radiation (PAR), incoming at 1.5 m and outgoing at 1.5 m (μmol m^{-2} s^{-1}). HFP01 (Hukseflux, Norway) was used to measure soil heat flux at 7 cm at the big hole and in the grass (W m^{-2}). Temperature Probe 107 (Campbell Scientific) was used to measure soil temperature above the soil heat flux plate at 3 cm at the big hole and in the grass (°C). Temperature Probe 108, old sensor (Campbell Scientific), was used to measure soil temperature at 30 cm and at 60 cm (°C). In addition, Water Content Reflectometer CS616 (Campbell Scientific) was used to measure soil moisture at 5 cm, 15 cm, 1 m, 1.5 m, and 2 m (volumetric (0-1)). Finally, Water Content Reflectometer CS615, old sensor (Campbell Scientific), was used to measure soil moisture at 60 cm and at 30 cm (volumetric (0-1)). The sensor for air temperature and relative humidity (MP100A) was calibrated annually, and the rain gauge (ARG 100) was calibrated at regular intervals. The remaining sensors have not been calibrated since installation.

All sensors are set to make measurements every 5 seconds, and average data values are stored on a Campbell CR10X logger every 30 minutes. A tipping bucket rain gauge, which tips after each 0.2 mm of precipitation, is used. Precipitation is the sum of received precipitation stored every 30 minutes.

(a) Dry season, May 5, 2005 (b) Moist season, August 22, 2005

Figure 4: Seasonality is strong and greening from July to September is a function of the timing and amount of precipitation. The same tree is visible in the centre of the two images.

3. Dataset Description

The dataset associated with this Dataset Paper consists of 2 items which are described as follows.

Dataset Item 1 (Table). Meteorological data and soil data collected at Demokeya in the province of Kordofan, central Sudan, for the years 2002–2004. In the table, the format of the Year column is "yyyy". In the Month column, the number ranges from 1 to 12, and in the Day of Month, from 1 to 31. Julian Day ranges from 1 to 365 (366). The format of the column Time of Day is "hhmm".

Column 1: Year
Column 2: Month
Column 3: Day of Month
Column 4: Julian Day
Column 5: Time of Day
Column 6: Battery Voltage (V)
Column 7: Soil Moisture at 60 cm
Column 8: Soil Moisture at 30 cm
Column 9: Soil Temperature at 30 cm (°C)
Column 10: Soil Temperature at 60 cm (°C)
Column 11: Incoming Radiation at 2 m (W m^{-2})
Column 12: Average Air Temperature at 2 m (°C)
Column 13: Relative Humidity at 2 m (%)
Column 14: Vapour Pressure (kPa)
Column 15: Precipitation (mm)
Column 16: Arithmetical Mean Wind Speed at 2.5 m (m s^{-1})
Column 17: Length of the Mean Wind Vector (m s^{-1})
Column 18: Direction of the Mean Wind Vector (°)
Column 19: Standard Deviation of Direction (°)

Dataset Item 2 (Table). Meteorological data and soil data collected at Demokeya in the province of Kordofan, central Sudan, for the years 2005–2012. In the table, the format of the Year column is "yyyy". In the Month column, the number ranges from 1 to 12, and in the Day of Month, from 1 to 31. Julian Day ranges from 1 to 365 (366). The format of the column Time of Day is "hhmm". Soil Temperature at 3 cm at the Big Hole and in the Grass was above the soil heat flux plate.

Column 1: Year
Column 2: Month
Column 3: Day of Month
Column 4: Julian Day
Column 5: Time of Day
Column 6: Battery Voltage (V)
Column 7: Logger Temperature (°C)
Column 8: Arithmetical Mean Wind Speed (m s^{-1})
Column 9: Length of the Mean Wind Vector (m s^{-1})
Column 10: Direction of the Mean Wind Vector (°)
Column 11: Standard Deviation of Direction (°)
Column 12: Precipitation (mm)
Column 13: Air Temperature at 2 m (°C)
Column 14: Relative Air Humidity at 2 m (%)
Column 15: Water Vapour Pressure (kPa)
Column 16: Incoming Global Radiation at 2 m (W m^{-2})
Column 17: Net Radiation at 1.5 m (W m^{-2})

Column 18: Incoming Photosynthetically Active Radiation (μmol m^{-2} s^{-1})

Column 19: Outgoing Photosynthetically Active Radiation (μmol m^{-2} s^{-1})

Column 20: Soil Heat Flux at 7 cm at the Big Hole (W m^{-2})

Column 21: Soil Heat Flux at 7 cm in the Grass (W m^{-2})

Column 22: Soil Temperature at 3 cm at the Big Hole ($^{\circ}$C)

Column 23: Soil Temperature at 3 cm in the Grass ($^{\circ}$C)

Column 24: Soil Temperature at 30 cm ($^{\circ}$C)

Column 25: Soil Temperature at 60 cm ($^{\circ}$C)

Column 26: Soil Moisture at 5 cm

Column 27: Soil Moisture at 15 cm

Column 28: Soil Moisture at 60 cm

Column 29: Soil Moisture at 30 cm

Column 30: Soil Moisture at 1 m

Column 31: Soil Moisture at 1.5 m

Column 32: Soil Moisture at 2 m

4. Concluding Remarks

The collected dataset has already contributed to several studies related to geoscientific issues in semiarid areas [7–16]. As the number of remote-sensing-based studies and modeling studies increases, the need for calibration and validation datasets increases as well. This is especially true for remote areas in continents such as Africa. Through putting the current dataset from Sudan in the public domain, we try to help fulfilling this need.

Dataset Availability

The dataset associated with this Dataset Paper is dedicated to the public domain using the CC0 waiver and is available at http://dx.doi.org/10.7167/2013/297973/dataset. In addition, parts of this dataset are already available in the European Fluxes Database Cluster (formerly the CARBOAFRICA database) (http://gaia.agraria.unitus.it/home). The database contains eddy covariance flux data together with some meteorological data as these are commonly used together. Data from the European Fluxes Database Cluster are not fully publicly available but data can be requested from the principal investigators of the included sites via the database web page.

Conflict of Interests

The author declares that he has no competing interests or conflict of interests.

Acknowledgments

Data collection was financed by Lund University, Sweden, the Swedish National Space Board, ARC, Sudan, and the Swedish Research Council. Hatim Abdalla Mohammed El-Khidir, Abdel Rahman Ahmed Khatir Ismael, Imadeldin Ahmed Ali Babiker, and Basir Awad El-Tahir at ARC in Sudan helped with the installation and maintenance of the equipment. Andreas Persson and Meelis Mölder helped with the installation and configuration of the equipment.

References

[1] U. Weber, M. Jung, M. Reichstein et al., "The interannual variability of Africa's ecosystem productivity: a multi-model analysis," *Biogeosciences*, vol. 6, no. 2, pp. 285–295, 2009.

[2] M. Zhao and S. W. Running, "Drought-induced reduction in global terrestrial net primary production from 2000 through 2009," *Science*, vol. 329, no. 5994, pp. 940–943, 2010.

[3] J. G. Canadell, P. Ciais, K. Gurney et al., "An international effort to quantify regional carbon fluxes," *EOS*, vol. 92, no. 10, pp. 81–82, 2011.

[4] A. P. Ballantyne, C. B. Alden, J. B. Miller, P. P. Tans, and J. W. C. White, "Increase in observed net carbon dioxide uptake by land and oceans during the past 50 years," *Nature*, vol. 487, no. 7409, pp. 70–72, 2012.

[5] B. A. El-Tahir, *Nutrient balances in traditional farming systems involving Acacia senegal (L.) Willd. in semi arid sandy soils of Northern Kordofan, Sudan [Ph.D. thesis]*, University of Khartoum, Khartoum, Sudan, 2006.

[6] A. R. Ahmed Khatir Ismael, *Application of Resource Assessment and Management Support for Pastoral Systems (RAPS) model to analyze pastoral systems in North Kordofan State, Sudan [Ph.D. thesis]*, Department of Forestry and Range Sciences, Faculty of Natural Resources and Environmental Studies University of Kordofan, Kordofan, Sudan, 2012.

[7] L. M. Möllerström, *Modelling Soil Temperature & Soil Water Availability in Semi-Arid Sudan: Validation and Testing*, Seminar Series 101, Department of Physical Geography and Ecosystem Analysis, Lund University, Lund, Sweden, 2004.

[8] B. A. El Tahir, D. M. Ahmed, J. Ardö, A. M. Gaafar, and A. A. Salih, "Changes in soil properties following conversion of Acacia senegal plantation to other land management systems in North Kordofan State, Sudan," *Journal of Arid Environments*, vol. 73, no. 4-5, pp. 499–505, 2009.

[9] C. Wu, J. M. Chen, J. Pumpanen et al., "An underestimated role of precipitation frequency in regulating summer soil moisture," *Environmental Research Letters*, vol. 7, no. 2, Article ID 024011, 2012.

[10] J. Ardö, M. Mölder, B. A. El-Tahir, and H. A. M. Elkhidir, "Seasonal variation of carbon fluxes in a sparse savanna in semi arid Sudan," *Carbon Balance and Management*, vol. 3, article 7, 2008.

[11] L. Merbold, J. Ardö, A. Arneth et al., "Precipitation as driver of carbon fluxes in 11 African ecosystems," *Biogeosciences*, vol. 6, pp. 1027–1041, 2009.

[12] M. Sjöström, J. Ardö, L. Eklundh et al., "Evaluation of satellite based indices for gross primary production estimates in a sparse savanna in the Sudan," *Biogeosciences*, vol. 6, no. 1, pp. 129–138, 2009.

[13] M. F. Garbulsky, J. Peñuelas, D. Papale et al., "Patterns and controls of the variability of radiation use efficiency and primary productivity across terrestrial ecosystems," *Global Ecology and Biogeography*, vol. 19, no. 2, pp. 253–267, 2010.

[14] M. Sjöström, J. Ardö, A. Arneth et al., "Exploring the potential of MODIS EVI for modeling gross primary production across African ecosystems," *Remote Sensing of Environment*, vol. 115, no. 5, pp. 1081–1089, 2011.

[15] T. Akkermans, D. Lauwaet, M. Demuzere et al., "Validation and comparison of two soil-vegetation-atmosphere transfer models for tropical Africa," *Journal of Geophysical Research G*, vol. 117, no. 2, Article ID G02013, 15 pages, 2012.

[16] N. Ghilain, A. Arboleda, G. Sepulcre-Cantò, O. Batelaan, J. Ardö, and F. Gellens-Meulenberghs, "Improving evapotranspiration in a land surface model using biophysical variables derived from MSG/SEVIRI satellite," *Hydrology and Earth System Sciences*, vol. 16, no. 8, pp. 2567–2583, 2012.

[17] J. H. G. Lebon, "The land and water use survey of North-Central Kordofan (1961–66)," *The Geographical Journal*, vol. 134, no. 4, pp. 546–550.

[18] A. Warren, "Dune trends and their implications in the Central Sudan," *Zeitschrift für Geomorphologie*, vol. 10, supplement, pp. 154–180, 1970.

[19] G. M. Craig, *The Agriculture of the Sudan*, Centre for Agricultural Strategy Series, Oxford University Press, 1991.

[20] L. Olsson and J. Ardö, "Soil carbon sequestration in degraded semiarid agro-ecosystems—perils and potentials," *Ambio*, vol. 31, no. 6, pp. 471–477, 2002.

[21] A. G. Mohamed, *Improvement of traditional Acacia senegal agroforestry: ecophysiological characteristics as indicators for tree-crop interaction on sandy soil in western Sudan [Ph.D. thesis]*, Faculty of Agriculture and Forestry. University of Helsinki, Helsinki, Finland, 2005.

[22] J. Ardö, B. A. El-Tahir, H. Elkhidir, and K. Abdelrahman, Field Description Demokeya, the Sudan, Lund University, 2009.