Method for estimating daily precipitation at 15 NPP locations

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Daily precipitation at 15 net primary production (NPP) locations was estimated for period 1980-2010, using daily and monthly data collected from rain gauges located at or near each location (Table 1, Fig 1).

Table 1. Name, duration (year to year), and collection frequency of the rain gauges that were used for estimation of daily precipitation. The exact duration (date to date) for each rain gauge is recorded in the Microsoft Excel file daily_estimate_periods_of_gauge_usage.xlsx.

Gauge name	Duration	Collection frequency	Owner
NPP[1] graduated rain gauges	1989 - ongoing	~ monthly	JRN LTER[2]
NPP tipping bucket rain gauges	2000 - 2010	daily	JRN LTER
LTER weather station	1983 - ongoing	daily	JRN LTER
Biodiversity site tipping bucket rain gauges	1996 - ongoing	daily	JRN LTER
USDA JER[3] headquarters weather station	before 1980 - ongoing	daily	USDA JER
USDA JER weighing rain gauges	varies	daily	USDA JER
CDRRC[4] standard rain gauges	before 1980 - ongoing	After every event	CDRRC

[1] NPP: Net Primary Production Project
[2] JRN LTER: Jornada Basin Long Term Ecological Research Project
[3] USDA JER: US Department of Agriculture, Agricultural Research Service, Jornada Experimental Range
[4] CDRRC: New Mexico State University Chihuahuan Desert Rangeland Research Center

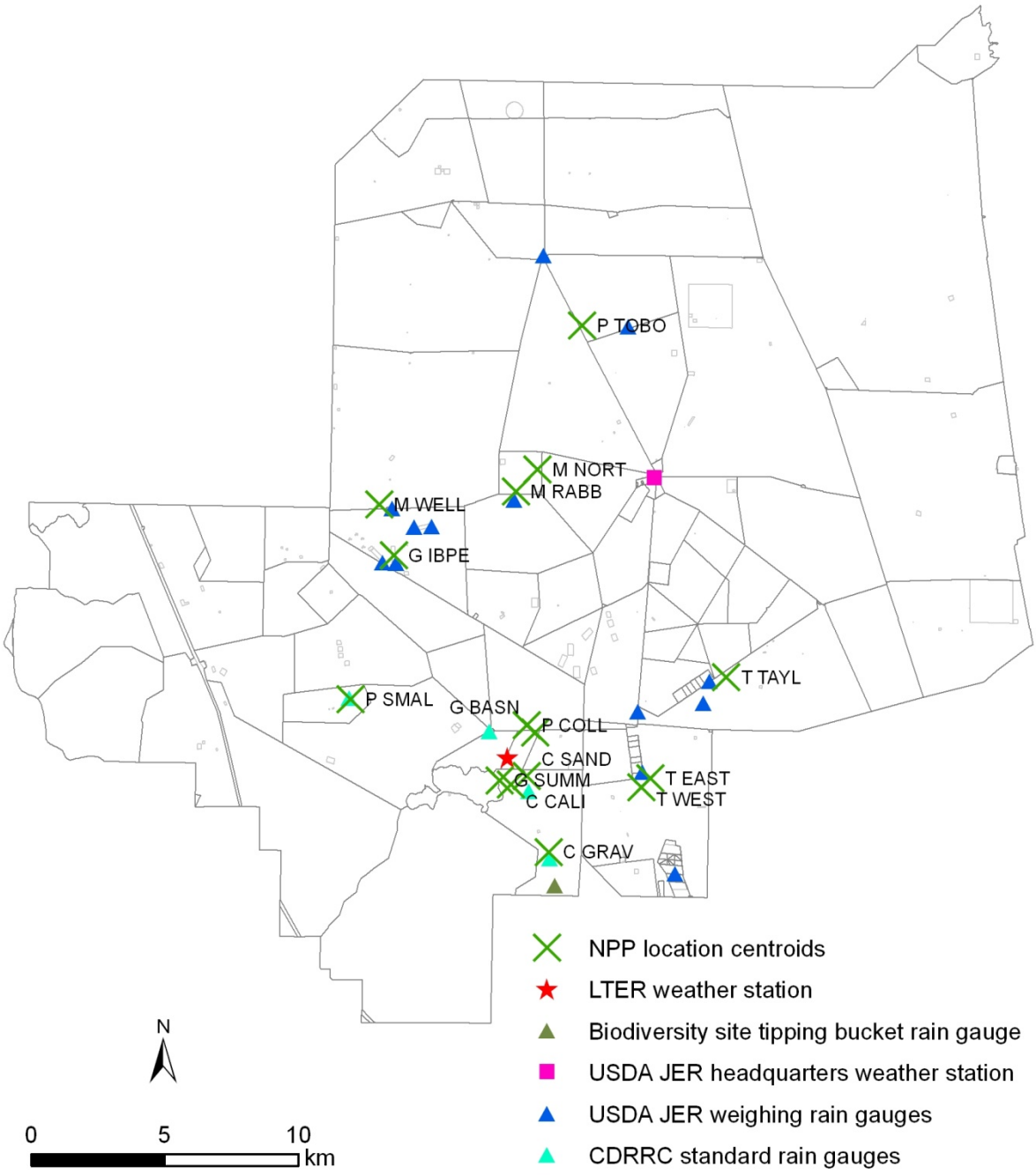

Fig 1. Locations of the rain gauges that were used for estimation of daily precipitation. Locations of NPP graduated rain gauges and tipping bucket rain gauges are represented by NPP location centroids.

Treatment of CDRRC data

Precipitation data at four NMSU Chihuahuan Desert Rangeland Research Center (CDRRC) rain gauges (EMTN, EMTS, HDQS, and VMPL) were provided by Rob McNeely at New Mexico State University, Animal and Range Sciences Department. Introduction of the CDRRC rain gauges and data can be found at http://chihuahuansc.nmsu.edu/climate.html. The original dataset provided by Rob McNeely contains date(s) of collection and amount of each rainfall event, though on occasion this may include multiple day events. We converted the data to a format that was the same as the rest of daily precipitation datasets, with at least a column for date and a column for rainfall amount. For a rainfall event that was recorded to occur in a period of more than one day, the daily rainfall was calculated as (total rainfall amount of the event/ number of days in the period).

1980 - before NPP graduated rain gauge (GRG) data started in spring 1989

The NPP project was initiated in the spring of 1989. Most of the GRGs at the NPP locations were set up between Jul 1989 and Jan 1990. We used the start dates of the NPP GRG data in the web-published dataset (http://jornada-www.nmsu.edu/datacat.php#DSL2002005). From Jan 1, 1980 to the day before the GRG start date, the daily precipitation values at a location are exactly the same as those from the nearest daily rain gauges with available data. Distance between an NPP location and a daily rain gauge was calculated as the straight linear distance between the center quadrat (quadrat #25) at the NPP location and the rain gauge. Distance from NPP GRG and NPP TBRG to NPP center quadrat is assumed to be zero, though the 2 gauges are actually located on the periphery of the 70m x 70m NPP site. Distance between an NPP location and the nearby daily rain gauges, and the start and end dates of the rain gauges are recorded in Microsoft Excel file daily_estimate_periods_of_gauge_usage.xlsx. Distance ranged from 62 to 2842 m between an NPP location and a daily rain gauge from which data were used for this period, with occasionally use of rain gauges 3005-4671 m away.

When NPP GRG data started in spring 1989 – 2010

The GRG data were collected starting in 1989. Collection frequency was > 1 per month at the beginning, but gradually turned into roughly once per month. The GRG rainfall dataset contains collection dates and the rainfall amount accumulated between two consecutive collection dates. Starting in 2000, tipping bucket rain gauges (TBRGs) were installed at NPP

locations and daily precipitation was recorded. After some preliminary data analysis, we determined that the GRG data were reliable, because the data matched or showed same patterns as those collected in the nearby rain gauges. However, the daily amount of TBRG data was not reliable, because during some events the TBRG daily data did not match or show same patterns as those collected in the nearby rain gauges, with large discrepancies in some cases. This seemed to be related to rainfall intensity. The TBRG located at each of the NPP sites is calibrated to 0.1 mm per tip. The TBRG tipping buckets are a different size from a model of TBRG calibrated to 0.01 inches per tip. Close evaluation of data and working with the gauges suggest that the TBRG calibrated to 0.1 mm per tip does not reliably record high intensity rainfall events consistently for the duration of all events. Below is the method we used to estimate daily precipitation for the period after NPP GRG data started.

For each GRG collection period, starting from the day after a collection date to the next collection date, we distributed the NPP GRG rainfall amount based on the daily rainfall proportion at the nearest rain gauge with available daily or event-based rainfall. The daily rainfall proportion was calculated as (daily rainfall at a rain gauge / total amount of rainfall at the same rain gauge during the GRG collection period). The estimated daily rainfall at an NPP location was calculated as (GRG rainfall amount in a collection period * daily rainfall proportion). Within a GRG collection period, if there was a missing data point (or more missing data) at the nearest daily rain gauge, we discarded the daily data from the rain gauge and used the daily data from the next nearest daily rain gauge with no missing data. For a GRG collection period when there was > 0 rainfall at an NPP GRG, but daily precipitation at the nearest daily rain gauge was 0 every day in the period, we discarded the estimated daily data from the rain gauge and used estimated daily data from the next nearest daily rain gauge with at least one day's rainfall > 0.

In general, we used daily rainfall information from the nearest rain gauge with available data. In other words, the daily rain gauge located at shortest distance to an NPP location was assigned the highest priority when we determined which rain gauge's data to use. There was one exception to this general rule: when CDRRC rain gauges and (LTER weather station or Biodiversity site rain gauge) were taken into account for an NPP location, the LTER weather station or Biodiversity site rain gauge had the priority over the CDRRC rain gauges, because the CDRRC data was typically collected 1 (2-3) day after an event. This exception affected 3 of 15

locations: C CALI, C GRAV, and C SAND. The priority ranks of the daily rain gauges for each NPP location are recorded in Microsoft Excel file daily_estimate_periods_of_gauge_usage.xlsx. The distance ranged from 0 (NPP tipping bucket rain gauges) to 6323 m between an NPP location and a daily rain gauge from which data were used for this period.

Brief explanation of the SAS programs used

The programs are listed in the order of being executed during the estimation process.

1. importExcel.sas
    - Import various rainfall datasets
2. estimate_daily_?????.sas
    - Estimate daily rainfall at an NPP location using data from various daily rain gauges for period 1980-2010. The use of NPP GRG data was coded in every program.
    - ?????: daily rain gauge name.
    - cdrrc: for any of the three CDRRC rain gauges, EMTN, EMTS, VMPL
    - hdqs: for CDRRC HDQS rain gauge
    - jerhq: for USDA JER headquarters weather station
    - jerwrg: for any USDA JER weighing rain gauge
    - lter: for LTER weather station
    - tbrg: for any NPP tipping bucket rain gauge
    - tbrg_biodiv: for the Biodiversity site tipping bucket rain gauge
3. handle_*****.sas
    - Assign the appropriate estimated daily rainfall data to an NPP location, based on the priority ranks of the daily rain gauges associated with the NPP location
    - ****: NPP location name, for example, CCALI.
4. check_discrepancy.sas
    - Aggregate estimated daily rainfall by GRG collection periods, and calculate difference between the aggregated rainfall amount and the GRG amount.
    - Generate a dataset listing the GRG collection periods with absolute difference > 1 mm.
5. handle_****2.sas

- Generate a dataset containing estimated daily rainfall data from all nearby daily rain gauges, with manual input of the collection periods with absolute difference > 1 mm (result from #4)
- Fix only one type of problems that cause the difference. For a GRG collection period when there was > 0 rainfall at an NPP GRG, but daily precipitation at the nearest daily rain gauge was 0 every day in the period, we discarded the estimated daily data from the rain gauge and used estimated daily data from the next nearest daily rain gauge with at least one day's rainfall > 0.
- Other problems causing difference were not solved. But these problems were negligible.
- ****: NPP location name, for example, CCALI

6. exportExcel.sas
    - Export four SAS datasets into an Excel file for each NPP location. Sheet "dat_clean" contains date, NPP location, and estimated daily rainfall (mm). The other sheets are saved in case we will need to double-check our calculation process.