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In Situ Sample Dataset of Stem Sap Flow of *Robinia pseudoacacia* Plantation in the Loess Plateau

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Abstract: The artificial *Robinia pseudoacacia* plantation planted in the middle and late 1970 s was selected in the Zhonggou River basin (107°30′E–107°31′E, 35°19′N–35°20′N) in the Loess Plateau of Gansu province. According to the principle of heat balance, the thermal diffusion probe technology was used to continuously monitor the trunk sap flow of the selected sample trees to obtain the in situ sample dataset of stem sap flow of *Robinia pseudoacacia* Plantation on the Loess Plateau. The dataset includes three tables: sap flow data of 8 *Robinia pseudoacacia* plantation in three periods, from May 19 to November 30 in 2017, April 24 to December 13 in 2018, January 13 to December 10 in 2019 (Sap flow data were sampled every ten minutes). The dataset is archived in .xlsx data format in one file with data size of 6.59 MB.

Keywords: sap flow; monitoring data; *Robinia pseudoacacia*; Loess Plateau

1 Introduction

The water balance of forest ecosystem is an important factor affecting local and global climate. The main part of water transport in forest ecosystem is transpiration[1]. Transpiration is the main process of water transport from forest ecosystem to atmosphere, which plays an important role in the process of water transport from soil, vegetation and atmosphere[2]. In the forest ecosystem, tree transpiration and evaporation are the only way for the forest to transport water to the atmosphere, which account for the largest proportion in the forest water cycle[3]. The water absorbed by roots from the soil is continuously transported to the canopy layer through the trunk passage, most of which is lost to the atmosphere through stomata transpiration[4]. Sap flow is the expression form of transpiration at the level of single tree[5], more than 99.8% of sap flow is used for transpiration water consumption[6]. It takes on the soil water absorbed and collected by a huge underground root system, determines the transpiration of the whole crown, and reflects the water transmission in plants[7–8]. Sap flow

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moves from root to stem and leaf along the plant conduit, which is very important to maintain the hydrological connection between soil and atmosphere[9]. It can not only provide oxygen to xylem parenchyma cells, but also promote nutrient absorption[10]. The main power of its transmission includes root pressure, Cohesion of water molecules, gravity of water at different heights, and transpiration tension[11]. Therefore, stem sap flow is closely related to the transpiration of plants and is the most active form of water movement in the SPAC system. Through the monitoring of stem sap flow, tree transpiration can be estimated, which provides basic data for the in-depth study of forest hydrology. With the improvement of trunk sap flow monitoring methods, trunk sap flow has also become the preferred index for automatic long-term monitoring of plant water status[12–13].

In recent years, many domestic scholars have carried out a large number of studies on water consumption characteristics of tree species in different regions of the Loess Plateau by means of trunk sap flow[14–15]. In the loess hilly area of Eastern Gansu province, the climate is dry, and the precipitation distribution is uneven. The forest vegetation coverage is low, and the soil erosion is serious. The state has successively invested a series of forestry ecological projects in this area. Among them, the artificial *Robinia pseudoacacia* forest in the Loess Plateau is mainly pure forest, which has a single structure and sparse vegetation under the forest. After large-scale artificial afforestation, it consumes soil water intensively. In addition, the precipitation cannot supplement the consumption of soil water in time, resulting in the drying of the soil under the forest (soil dry layer)[16]. The formation of dry soil layer weakens the hydrological cycle of the surface ecosystem and has a negative impact on the healthy development of the current plantation vegetation, The result is that the plantation of *Robinia pseudoacacia* will decline in a large area after 30 years[17–18]. However, because *Robinia pseudoacacia* is a typical neophyte, which not only adapts to wet and fertile, but also bears drought and barren, and grows rapidly. It is a good tree species for afforestation[19] and has become one of the main tree species for afforestation of soil and water conservation in the Loess Plateau of China[20]. In the process of early large-scale construction of artificial forest to implement vegetation ecological restoration, the local natural environment conditions and the temporal and spatial distribution characteristics of soil moisture were ignored, and the selection of tree species was not scientific enough, resulting in unreasonable forest structure, single tree species, too large planting density, low survival rate and conservation rate of forest building. Therefore, it is of great theoretical significance for guiding the restoration and sustainable development of plantation vegetation to study the ecological and hydrological process of typical plantation in this area and to understand the transpiration and water consumption of the region.

2 Metadata of the Dataset

The information of authors, geographical region, data size, dataset composition, data publishing and sharing service platform, data sharing policy and other information of the dataset are shown in Table 1[21].

3 Methods

3.1 Study Area

The study area is located in Zhonggou River basin (35°19′N–35° 20′N, 107°30′E–107°31′E) of the Loess Plateau of Gansu province, covering an area of 2.09 km^2, with an altitude of 1,072–1,351 m, which is a typical loess hilly and gully area (Figure 1). The gully is fully developed, the slope is steep, and the soil erosion is relatively serious, the erosion modulus is 4,500–4,800 $t \cdot km^{-2}$[23]. The soil parent material is primary loess and secondary loess, and the typical soil type is black lossiah soil, yellow loamy soil and brown soil. This region has a typical continental climates with annual average temperature of 10.7 ℃, annual sunshine hours of 2,315.4 h, frostless period of 174d, annual average rainfall of 555 mm, annual evaporation of 1,181.6 mm, dryness of 0.95–1.28[24].

Table 1 Metadata summary of "*In situ* sample dataset of stem sap flow of *Robinia pseudoacacia* plantation in the Loess Plateau"

Items	Description
Dataset full name	*In situ* sample dataset of stem sap flow of *Robinia pseudoacacia* plantation in the Loess Plateau
Dataset short name	StemSapFlowR.pseudoacaciaLoessPlateau
Authors	Zhang, J. AAA-5731-2019, Gansu Agricultural University, zhangjun@gsau.edu.cn Di, L., Gansu Agricultural University, dili@gsau.edu.cn Chen, Z. N., Gansu forestry research institute, chen.zhengni@gmail.com Wang, A. M., Pingliang Institute of Soil and Water Conservation, 593928177@qq.com Ni, F., Gansu Agricultural University, 1356159486@qq.com Ren, Y. B., Longdong College, 171344121@qq.com Fei, J. E., Gansu Agricultural University, 943416926@qq.com Wu, X. Z., Lanzhou City University, wxz315@163.com Wang, Z. G., Guyuan Branch of Ningxia Academy of Agricultural And Forestry Sciences, 1731967640@qq.com Han, F., Pingliang Institute of Soil and Water Conservation, 455573021@qq.com Ru, H. L., Pingliang Institute of Soil and Water Conservation, 1175332809@qq.com Jing, G. Y., Gansu Agricultural University, 960249539@qq.com
Geographical region	Longdong Loess Plateau Zhonggou watershed (107°31′E, 35°20′N)
Year	2017, 2018, 2019
Data format	.xlsx Data size 6.59 MB
Data files	SAP flow data of 8 sample trees from May 19, 2017 to November 30, 2017; SAP flow data of 7 sample trees from April 24, 2018 to September 10, 2019, because the probe of sample trees No.0663 was damaged; SAP flow data of 6 sample trees from September 11, 2019 to December 10, 2019, because the probe of sample trees No.0665 was damaged
Foundations	National Natural Science Foundation of China (41461112, 31660235)
Data publisher	Global Change Research Data Publishing & Repository, http://www.geodoi.ac.cn
Address	No. 11A, Datun Road, Chaoyang District, Beijing 100101, China
Data share policy	***Data*** from the Global Change Research Data Publishing & Repository includes metadata, datasets (data products), and publications (in this case, in the *Journal of Global Change Data & Discovery*). ***Data*** sharing policy includes: (1) ***Data*** are openly available and can be free downloaded via the Internet; (2) End users are encouraged to use ***Data*** subject to citation; (3) Users, who are by definition also value-added service providers, are welcome to redistribute ***Data*** subject to written permission from the GCdataPR Editorial Office and the issuance of a ***Data*** redistribution license; and (4) If ***Data*** are used to compile new datasets, the 'ten percent principal' should be followed such that ***Data*** records utilized should not surpass 10% of the new dataset contents, while sources should be clearly noted in suitable places in the new dataset [22]
Communication and searchable system	DOI, DCI, CSCD, WDS/ISC, GEOSS, China GEOSS, Crossref

The vegetation was damaged seriously and the vegetation coverage is low due to the long-term cultivation and excessive human interference. Since the middle and late of 1970s, a large area of farmland has been converted to forest in this area. The existing vegetation has been artificially constructed in the past 40 years. At present, the forest area covers 5,420 km^2 in this region, and 37.13% of forest coverage. Locust is the main tree species in this area, accounting for 92% of the total forest area. Other afforestation tree species include *Populus davidiana*, *Saliz matsudana*, *Paulownia fortunei*, *Biota orientalis* and *Larix principis-rupprechtii*. There are few undergrowth herbs, mainly including *Artemisa vestita*, *Stipa breviflora*, *Hippophae rhamnoides linn*, *Bothriochloa ischaemum*, *Setaria faberii*, *Lespedeza* *fioribunda*, etc[25].

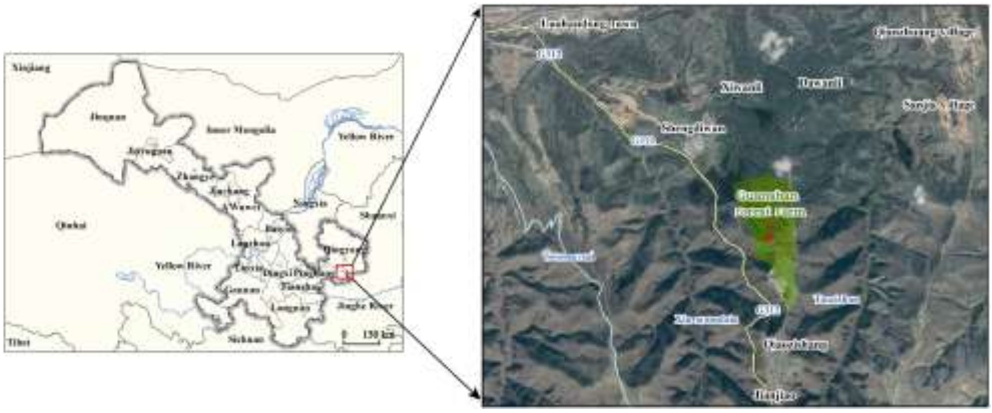

Figure 1 Map of the study area

On the premise of preliminary investigation in May 2017, standard plots (20 m×20 m) were set up in typical sections of small watershed to investigate the stands (Table 2). It was found that the density of 25-year artificial *Robinia pseudoacacia* with 750 trees·hm^{-2} of stand density, and the average height of trees was 14.88 m, the average DBH was 16.81 cm, and the canopy density was 0.8. Considering the influence of the cable length on the monitoring results, 8 standard trees with good growth of different diameter grades, straight and complete trunk and moderate crown are selected as the sample trees in the relatively concentrated areas in the sample plots (Table 3).

Table 2 Description of sample land

Sample type	Stand age	Geographic location	Landform	Aspect	Altitude (m)	Density (trees·hm^{-2})	Average DBH (cm)	Height (m)	Canopy density
Acacia plantation	25	35°20′41.4″N 107°31′11.5″E	Tableland surface	332° Semi-shady slope	1,237	750	16.81	14.88	0.8

Table 3 The information of the sample plots

Sample plots	DBH (cm)	Height (m)	Crown diameter (m)	Sapwood thickness (cm)
0666	16.7	13.2	5.4×5.2	1.0
0662	14.2	15.1	6.5×7.8	1.5
0660	12.9	16.8	6.5×8.4	1.6
0665	20.0	15.7	4.2×5.3	1.7
0658	15.2	13.9	4.2×5.6	0.7
0663	17.6	16.5	5.8×6.3	2.3
0659	19.4	13.7	5.2×6.1	2.0
0664	18.5	14.2	4.5×7.6	1.3

3.2 Data Collection

The transpiration of the whole tree can be estimated by measuring the stem sap flow[26]. Because the sapwood part of a tree is a channel for water transfer from the root system to the crown, the sap flow through the trunk can be approximately equal to the transpiration water consumption of the tree canopy, and the transpiration water consumption of the whole tree can be obtained by measuring the sap flow of the trunk[4]. At present, stem sap flow has become one of the key indicators to analyze the water consumption characteristics of trees and study the water transmission mechanism of trees[27]. Thermal method is an advanced method to study the water transfer and consumption of plants in the world. It can realize continuous and automatic monitoring on living fluid flow of the tree, with high time resolution, generally without damaging the normal physiological activities of plants, changing the original environment and tree structure, and has the advantages of simple and economic, repeated monitoring, and convenient field operation[28]. According to different principles, it can be divided into three methods: heat pulse velocity method (HPV), stem surface heat balance method (SHB), thermal dissipation probe method (TDP), laser heat pulse method (LHPG) and heat deformation method (HFD). The thermal diffusion probe (TDP) method used in this study can realize automatic data collection with high accuracy and reliability. Therefore, TDP has become one of the most commonly used research methods in the research of water consumption of trees.

3.2.1 Working Principle of TDP

The TDP method is a sap flow measurement system for sapwood of trees invented by Granier in 1985[29–30]. A linear heating probe is inserted into the xylem of the trunk, and the other unheated probe is inserted into the xylem at a certain distance below it as a reference probe, and the temperature difference between the two probes is measured. The heat of the heated probe diffuses upward with the flow of sap, which leads to the cooling of the heated probe. When the density of trunk sap flow is zero or minimum, the temperature difference (DT) between the two probes is the largest. With the increase of SAP density, the thermal conductivity of the xylem will increase, and the temperature difference between the two probes will decrease.

Figure 2 The sap flow monitoring instrument

In Figure 2, TDP probes consists of a pair of cylindrical probes, one installed on the upper side of the trunk, which is a heating probe (including heating elements and thermocouples), and the other installed on the lower side of the trunk, which is a reference probe (only including thermocouples). In this experiment, a 1 cm long thermal diffusion probe was used to monitor the sap flow density of the outer sapwood (Figure 2). The distance between the reference probe and the heating probe is 15 cm. A special current regulating device is used to connect the 12 V DC power to supply a constant current of the heating probe to achieve a continuous heating of 0.15 w. In order to avoid the measurement error caused by solar radiation, the probe is installed on the north side of the trunk and covered with radiation proof aluminum platinum. Rr-1016 data collector is used to measure and read a group of data every 10 min. The flux density of sap flow is calculated according to the general Granier empirical formula.

3.2.2 Specific Installation of Instrument

(1) Trees of different sizes, straight and complete trunk, non-eccentric and moderate crown was used as the standard sample wood (the trunk tissue is uniform, no abnormal nodule, no mechanical or biological damage or other obstacles), and then the thickness of bark and phloem was measured (if the thickness is not uniform, polish the trunk.).

(2) At the 1.3 m position of the sample tree trunk, a knife was used to scrape the bark along the vertical direction of the trunk into two 4 × 5 cm rectangles (to prevent damage to the trunk phloem when scraping the bark). The upper and lower spacing between the two probes is 10 cm.

(3) Drill two holes with a diameter of 1.5 mm in two rectangles, and insert the heat source probe and the induction probe into the upper and lower holes respectively.

(4) The gap between the probe and the trunk was sealed with glass glue to prevent the impact of rainwater infiltration.

(5) 12 V battery was used to supply power for heater, and solar panel is installed in the field to connect solar cell controller as standby charging.

(6) DTU900c data collector was installed at one end of the probe[4].

3.2.3 Measurement of Trunk Sap Flow

DTU900c produced by Beijing Rainroot Scientific Limited has been installed since May 2017. In order to avoid the measurement error caused by direct sunlight, the probe was evenly installed on the north side of 1.3 m black locust trunk. Drill a hole with a diameter of 1.5 mm along the distance of 10 cm in the vertical direction of the trunk with a certain specification of drill bit, and insert the TDP probe. After the probe was fixed, the whole probe and its adjacent area were covered with radiation proof aluminum foil, and the upper and lower ends shall be fixed with adhesive tape. The upper end of the covering layer and the bark shall be sealed with transparent glass glue to prevent the impact of environmental temperature change and rainwater infiltration on the measurement results. The automatic weather station installed in the sample plot was used to collect the effective solar radiation, air temperature, wind speed, air relative humidity and other meteorological elements such as soil temperature and soil humidity monitored at the same time.

4 Results

The data analysis in 2017 showed that: (1) there was a trend of high in the day and low in the night in the daily variation of sap flow of *Robinia pseudoacacia* forest; (2) the variation of sap flow rate of *Robinia pseudoacacia* forest was single peak in sunny days, multi peak (in cloudy days and irregular fluctuation in rainy days); (3) the monthly mean value of sap flow rate of *Robinia pseudoacacia* forest was low-high-low. The sap flow rate of *Robinia pseudoacacia* forest in October was the lowest (193.19 $g \cdot h^{-1}$), and that in August was the highest (652.31 $g \cdot h^{-1}$); (4) There were significant seasonal differences in the start time, peak time and decline time of sap flow in different growth periods. Generally, sap flow starts at about 7:00 in the early growth period and reaches the peak time at about 13:00, which is one hour behind the middle growth period. However, sap flow starts at 6:00 in the peak growth period and reaches the peak value at 11:00–12:00, and the law of change in the late growth period is basically the same as that in the early growth period; (5) the factors influencing sap flow were different in growth periods, but they were significantly related to air temperature, solar radiation and air humidity. Other factors have different effects on sap flow with seasonal changes. Table 4 is an excerpt of the continuous monitoring data of trunk sap flow on May 19, 2017, in which Fd_1 is the monitoring data of No. 666 sample tree, Fd_2 is the monitoring data of No. 662 sample tree, Fd_3 is the monitoring data of No. 660 sample tree, Fd_4 is the monitoring data of No. 665 sample tree, Fd_5 is the monitoring data of No. 658 sample tree, Fd_6 is the monitoring data of No. 663 sample tree, Fd_7 is the monitoring data of No. 659

sample tree, and Fd_8 is the monitoring data of No. 664 sample tree.

Table 4 The continuous monitoring data of sap flow on May 19, 2017 (partly)

Time	Battery voltage (V)	Fd_1 (℃)	Fd_2 (℃)	...	Fd_8 (℃)
2017/5/19 17:30	12.899	5.101,9	5.231,5	...	5.251,6
2017/5/19 17:40	12.878,9	5.110,9	5.216,3	...	5.230,4
...	...	...	...	...	...
2017/5/19 23:40	14.201,8	5.540,3	6.048,1	...	5.839,9
2017/5/19 23:50	14.201,8	5.545,9	6.061,0	...	5.838,2

5 Discussion and Conclusion

In this study, TDP was used to monitor the stem sap flow of *Robinia pseudoacacia* Plantation. The effective solar radiation, air temperature, relative humidity, wind speed and other meteorological factors were monitored simultaneously. The continuous observation data for many years can be regarded as an important index data of the regional ecological environment change and the basic data of vegetation growth and change analysis. The ranking of influence of single environmental factor on the sap flow rate in daytime was temperature (0.839) > relative humidity (–0.747) > solar radiation (0.721) > vapor pressure deficit (0.718) > wind speed (0.260); the ranking of influence on the sap flow rate in nighttime was vapor pressure deficit (0.615) > air temperature (0.608) > relative humidity (–0.505) > wind speed (0.048). The correlation between solar radiation and sunny and cloudy days was the most significant (0.837 and 0.855, respectively) ($P < 0.01$). Under rainy days, the air temperature was the most significant, and the correlation coefficient was 0.220 ($P < 0.01$).

The sap flow rate of the artificial *Robinia pseudoacacia* forest in the peak growth period showed a single peak curve trend, with the daily average sap flow rate of 22.09, 22.43 and 20.66 $g{\cdot}h^{-1}$, respectively, and the daily average sap flow rate of the artificial *Robinia pseudoacacia* forest in the peak growth period was 17.07 $g{\cdot}h^{-1}$. The sap flow rate per unit sapwood area was positively correlated with air temperature, solar effective radiation and water vapor pressure deficit, and negatively correlated with relative humidity. The absolute value of correlation degree was shown as photosynthetic effective radiation > water vapor pressure deficit > air temperature > relative humidity > wind speed. The sap flow rate per unit sapwood area decreased with the increase of DBH.

Author Contributions

Di, L. designed the algorithms of the dataset. Chen, Z. N., Wang, A. M., Ren, Y. B., Fei, J. E., Wu, X. Z., Wang, Z. G., Han, F., Ru, H. L., Jing, G. Y. contributed to the data processing and analysis. Zhang, J., Di, L. and Ni, F. wrote the data paper.

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