Daily rainfall, stream discharge and hydraulic conductivity of soils from catchments dominated by different vegetation types, Western Ghats, India, 2014 - 2016

1 Overview of the data

The dataset described here was used to arrive at the results of the manuscript titled: "Exotic Plantations Increase Risk of Flooding in Mountainous Landscapes". The dataset comprises of two parts:

DailyRainDischarge2014to2016.csv Daily rainfall and discharge for eight small catchments and land cover in the Upper Nilgiris during the rainy seasons between May 2014 and December 2016. The rainfall data is collected in tipping bucket rain gauges which measure the number of tips per minute, which is converted to mm rain. Water level data is collected through stilling wells instrumented with capacitance based water level loggers.

KSatLandCovers.csv Hydraulic conductivity under major land covers in the Upper Nilgiris. This data was manually collected using a mini-disc infiltrometer.

This data has been recorded in the Upper Nilgiris Reserve Forest in south Indian state of Tamil Nadu. The Nilgiris are part of the Western Ghats mountains - a global biodiversity hot-spot (Myers et al. 2000) and the headwaters of the Bhavani river, an important tributary of the Cauvery, one of the largest rivers in South India. The data was collected between 2013 and 2016 as part of a series of eco-hydrology projects that explored the impact of land cover on rain-runoff response, carbon sequestration and nutrient and sediment discharge. Four research agencies have partnered across multiple projects to sustain the data collection efforts that started in June 2013 and continue (May 2020). These are the Foundation for Ecological Research, Advocacy and Learning - Pondicherry, the Ashoka Trust for Research in Ecology and the Environment - Bangalore, the Lancaster Environmental Centre, Lancaster University - UK, and the National Centre for Biological Sciences - Bangalore. Dry season data has not been included in this dataset as its focus is on extreme rain events.

2 Fieldwork and laboratory instrumentation

The dataset presented here was collected by a team of three to five researchers and field assistants who were engaged in the installation of the data loggers and their regular operation and maintenance.

2.1 Rainfall

Tipping bucket, wired rain gauges (`Rainwise`) were installed in grasslands and clearings on ridges in an approximate grid of 1x1 km. Data was recorded at one minute intervals on the logging unit from which it was retrieved approximately every two weeks.

Table 1: Location of the rain gauges.

unit_id	lat	long	z
102	11.28465	76.56707	2351
103	11.27527	76.56266	2332
106	11.27226	76.57786	2325
109	11.28146	76.56077	2402
110	11.2703	76.56022	2400
113	11.2715	76.55173	2347
115	11.27919	76.56896	2321
118	11.27961	76.57993	2364
125	11.29813	76.55673	2575
126	11.31198	76.56031	2250
133	11.26726	76.57699	2302

2.2 Discharge

Water levels were measured at five minute intervals in eleven streams instrumented with stilling wells and capacitance probe based water level recorder (`Dataflow Systems`). For all units except 101, stage values were converted to discharge using the velocity-area method (Shaw et al. 2010). Unit 101 was instrumented with a compound weir and standard equations were used for discharge calculations. The streams were low order (1-3) and the catchment boundary was estimated from a SRTM digital elevation model SRTM (NASA JPL 2013).

Table 2: Location of water level recorders.

unit_id	lat	long	z
101	11.28477	76.56684	2341
102	11.28274	76.56783	2312
103a	11.27516	76.56187	2297
104a	11.27512	76.56195	2289
105a	11.2805	76.56725	2338
106a	11.27305	76.56338	2287
107	11.26814	76.55242	2292
108a	11.30575	76.56429	2062
109	11.30746	76.56857	2011
114	11.27634	76.56896	2290

115	11.26678	76.57693	2295

2.3 Infiltration

Saturated hydraulic conductivity was measured from sample points selected under patches of land cover which were sufficiently flat to place the mini-disk infiltrometer, did not have large stones or roots, were accessible by foot and were at least 25 meters away from the adjacent sample. As points, other than those in grasslands, were under think canopy, errors associated with GPS readings were ~20m. The average coordinates of the sampled land cover patch are therefore provided.

Table 3: Location of the sites where hydraulic conductiivty was measured.

Cover	lat	long	z
Shola	11.29259	76.58463	2099
Shola	11.30584	76.56381	2077
Grassland	11.26884	76.55880	2337
Grassland	11.26895	76.55173	2297
Grassland	11.27233	76.56247	2316
Pine	11.30142	76.58952	2018
Pine	11.26832	76.57601	2317
Pine	11.26759	76.56362	2312
Wattle	11.29011	76.56138	2485
Wattle	11.28365	76.56893	2373
Wattle	11.27568	76.56519	2348

3 Calibration steps and values

3.1 Water level recorder

Calibration of the water level recorder was performed as per directions provided by the sensor manufacturers (Dataflow Systems PTY Ltd, n.d.).

3.2 Rain gauge

The rain gauge was calibrated by pouring fixed volumes of water at a rate of 3 - 4 tips a minute through a burette with a stopcock. This was done three times to obtain an average volume of water per tip. Calibration was done each year at the end of the dry season and before the monsoon.

3.3 Mini-disk infiltrometer

Methods for the use of the apparatus and analysis of the data were performed as per the manufacturer's manual (METER Group Inc. 2018).

4 Analytical methods

The data was imported as CSV files into R and aggregated to daily time-steps. Scripts used for the analysis are provided. A summary of the scripts and functions contained in the scripts is provided in the table below. Note that the serial number with an alphabet suffix indicates a function contained within a script.

Table 4: Sequence of scripts and functions run for processing data from the tipping bucket rain gauges and water level recorders.

Sl.No.	Name of file/function	Function
	Tipping Bucket Rain Gauges	
1	tbrg_nlg.R	Sets environment and calls all scripts to process rain gauge data.
2	myfuncts.R	All functions to process the data. Note some of these are vectorised and the number of cores need to be specified by the user.
2a	tips (function in myfunts.R)	Lists the first six readings of rain gauges to check for errors.
2b	fx.tbrg.yrs (function in myfunts.R)	Fixes dates in old rainwise loggers (Rainlog version 1) which doesn't count after 2015
2c	import.tbrg (function in myfunts.R)	Imports dat files (raw data) from tbrg units, calls the calibration function and files to convert tips to mm
2d	fill.null (function in myfunts.R)	Fills in null values to remove errors, reads the null files created for the purpose - see section on quality assurance.
2e	agg.data (function in myfunts.R)	Aggregates rainfall data to intervals of 1 min,15 min, 30 min, 1 hour, 6 hour, 12 hour, 1 day, 15 day and 1 month. Data is exported as csv file and plotted as png file.
2f	control.funct (function in myfunts.R)	Master function to sequence and call the other

		functions.
	Water Level Recorders	
1	wlr.nlg.R	Master script, sets environment and calls other scripts
2	wlr_calib.R	Calculate calibration for the WLRs. Only run when needed.
3	wlr_import.R	Import, calibrate and gap fill data
4	wlr_null.R	Insert null values from error logs
5	wlr_mergenull.R	Merge the nulls with the calibrated values
6	wlr_aggreg.R	Aggregate and output the data
7	functions.R	Collection of functions to replace the above scripts (not implemented yet)
	Discharge Calculations (velocity area)	
1	dis.control.R	Master script to set environment and call other routines.
2	dis.functs.R	Functions as described below:
2a	calc.disch.areastage (in dis.functs.R)	Calculate dischcharge from a rating curve using a non linear least square fit
2b	calc.disch.flume (in dis.functs.R)	calculate discharge of a two inch montana flume (not relevant for this dataset)
2c	calc.disch.weir (in dis.functs.R)	calculate discharge of a v-noth weir (not relevant for this dataset)
2d	stn.names (in dis.functs.R)	Assign names to files for reporting results.
2e	mk.nullfile (in dis.functs.R)	Generate a null file from start and end timestamps of errors recorded in field notes.
2f	dis.plot (in dis.functs.R)	Plot discharge from data.
2g	fill.na (in dis.functs.R)	Insert NAs where timesequence is missing
3	dis.reptime.R	Set time period for reporting discharge.
4	stn_101.R to stn_109.R, stn_105a.R and stn_106a.R.	Discharge calculations for specific loggers based on their respective rating curves.
5	stn_110.R to stn_113.R	Discharge calculations for water level recorders in flumes to measure dry season stream-flow (not included in data set). Correspond to locations of water level recorders 107, 106, 102 and 103 respectively.
6	Readme_discharge.md	Description of the code.
	Rating Curve Calculations	
1	disch_nlg.R	Master script to set the environment and call routines.
2	useful.functs.R	Utility functions

2a	substrLeft (in userful.functs.R)	Get string for x characters from left
2b	substrRight (in userful.functs.R)	Get string for x characters from right
2c	is.even (in userful.functs.R)	See if number is even
2d	is.odd (in userful.functs.R)	See if number is odd
2e	.ls.objects (in userful.functs.R)	List R objects
2f	lsos (in userful.functs.R)	List R objects
2g	delfiles (in userful.functs.R)	Delete all files in a given folder
2h	fix.time (in userful.functs.R)	Fix timestamp
2i	writeshape (in userful.functs.R)	Write to shape file.
3	disch_managefiles.R	Set file names for output figures and data
4	disch_libs.R	Load required libraries
5	disch_ExtractStage.R	Get stage values from water level recorder
6	Slug.R	Process data from salt dilution, slug method
7	disch_pyg.R	Process pygmy current meter data.
8	disch_appendSDG.R	Append data from salt dilution gauging to velocity area readings
9	disch_fig.R	Draw figures of discharge curves
10	PlotCleanRatingCurves.R	Only to be used to identify potential outliers that distort the rating curve
11	disch_pyg_figs.R	Draw velocity profiles for cross checking and manually correcting errors - only to be used when necessary
12	Readme_curve.md	Markdown file describing the code.

5 Quality assurance

All the data-logs retrieved from the water level recorders and rain gauges were checked for errors which typically were due to power supply interruptions during changing of batteries or occasional short circuits caused by weak contacts. Timestamps for the interval of battery replacement and errors were recorded and corresponding data readings were replaced by NULL values. All stilling wells were paired with a permanent scale which provided a benchmark against which any errors due to incorrect placement of the capacitance probes were corrected. Salt dilution gauging using both the slug and the constant release methods were used in parallel with velocity area calculations on all stations to ensure the results were similar as an added system for quality control. Data collection using the mini-disk infiltrometer involved the collection of at-least three consecutive readings per sample, taken within a five meter radius of the sampling point. All readings with potential errors due to air-leaks were discarded. Furthermore, samples were only collected from locations where stones or sticks did not obstruct the placement of the infiltrometer.

6 Details of data structure

6.1 Rain/runoff data

Rainfall was recorded in tips per minute and was converted into mm during calibration as described above. Water level recorder readings were in capacitance values and were converted to mm using the manufacturer's software. Descriptions of the data structure are provided in table 5.

Table 5: Description of data structure for rain/runoff dataset.

Field/Column Header	Description
dt.tm	Timestamp (IST) of the sample
wlr	Water level recorder number
Discharge	Discharge in m^{nil3}s^{-1nil}
DepthDischarge	Depth of discharge in mm
flowD	Daily flow in mm
mm	Daily rain (mm)
PeakDischarge	Peak Discharge for the day in m^{3}s^{-1nil}
PeakDepthDischarge	Depth of discharge during peak flow in m
AMI	Antecedent moisture index, cumulative rain - total stream flow during the past 14 days.
area	Area in hectares
CircularityIndex	Circularity Index (no units) CI = Ab/Ac, where Ab is the area of the basin and Ac is the area of a circle with the same length of perimeter as the basin [**Error! Reference source not found.**]
slopeSteep	Slope steepness factor as defined for Universal Soil Loss Equation [**Error! Reference source not found.**].
drainDensity	Drainage density (m/m^{2})
catchment	Land cover of catchment: i) Wattle (*Acacia mearnsii*) an exotic invasive species; ii) natural montane grasslands and iii) shola (natural montane evergreen forests)

6.2 Saturated hydrologic conductivity data

Data was recorded in time taken for a fixed volume of water to percolate into the soil. This was converted to m s^{-1} as per the methods in the manufacturer's documentation. Structure of the data is provided in table 6. Note: Blank cells indicate that no data are available. Also note, multiple measurements of hydraulic conductivity were conducted from different sites on the same date.

Table 6: Description of saturated hydrolgic conductivity dataset.

Field/Column Header	Description
Date	Date of sample collection
Land.Cover	Land cover under which samples were collected (wattle, pine (*Pinus patula*), shola and grasslands)
LSAT	Saturated hydrologic conductivity in m s^{-1}
K	Hydrologic conductivity m s^{-1}

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