Ecological Engineering 102 (2017) 374–380

Contents lists available at ScienceDirect

Ecological Engineering

journal homepage: www.elsevier.com/locate/ecoleng

Effect of different canopy management practices on rainfall partitioning in *Morus alba*

R. Kaushal[a,*], Ambrish Kumar[a], N.M. Alam[a], D. Mandal[a], J. Jayaparkash[a], J.M.S. Tomar[a], S. Patra[a], A.K. Gupta[a], H. Mehta[a], P. Panwar[b], O.P. Chaturvedi[a,1], P.K. Mishra[a]

[a] ICAR-Indian Institute of Soil and Water Conservation (ICAR-IISWC), 218, Kaulagarh Road, Dehradun 248 195, India
[b] ICAR-IISWC, Research Centre, Chandigarh, India

ARTICLE INFO

Article history:
Received 5 February 2016
Received in revised form 9 February 2017
Accepted 18 February 2017
Available online 28 February 2017

Keywords:
Coppicing
Gross rainfall
Interception
Lopping
Morus
Stemflow
Throughfall

ABSTRACT

Tree canopies partition rainfall into throughfall (TF), stemflow (SF), and interception loss (I) which have very significant effect on water balance and the nutrient cycle. In this study, we compared throughfall, stemflow and interception in *Morus alba* managed under different canopy management practices/treatments *viz*., coppicing, pollarding and lopping. TF was measured using manual gauges randomly placed beneath the canopies of each treatment. SF was collected from selected trees in each canopy management practices using SF collection collars. Measurements were made on a rainfall event basis. During the study period, 30 rainfall events were identified in the year 2014 and 25 in the year 2015 which delivered a total rain of 685.1 mm and 467.9 mm, respectively in the two consecutive years. Average TF ranged from 80.8% in lopping to 85.1% in coppicing. Relationship of gross rainfall versus throughfall in different canopy management practices indicates that high TF production was measured during high rainfall events and low TF production was measured during low rainfall events. Average SF values showed significant difference between lopping (10%) and pollarding (4.5%) treatments. Both the treatments transmitted less SF as GR event depths increased. As the size of rainfall events increased, intercepted GR by the canopies, decreased. Allometric model was used for fitting the gross rainfall versus SF depth. Total rainfall interception was 9.2% for lopping, 13.0% for pollarding and 14.9% for coppicing. Interception values were higher during small sized GR events.

1. Introduction

Trees play an important role in hydrological cycle by intercepting rainfall, reducing kinetic energy and velocity of rainfall, reducing runoff and soil erosion and its enhancing infiltration (Young, 1990; Negi et al., 1998). The impact of trees on hydrological behaviour are however largely governed by hydrological/rainfall partitioning parameters, such as throughfall (TF), stemflow (SF), runoff and interception loss (I) which plays an important role in water balance on the local and catchment scale (Llorens and Domingo, 2007). TF is the part of the gross rainfall (GR), which drips from canopy (foliage + branches) and reaches the ground (Ahmadi et al., 2009). Stemflow concentrate the rainfall intercepted by leaves and branches to the plant stem and is an important source of soil moisture replenishment (Rao et al., 2012). Stemflow depends on canopy structure, stand density, species composition and bark texture. Apart from the stemflow and throughfall, the rest of the rainfall which is intercepted by, and retained temporarily on leaf surfaces, branches and stem and gradually lost by the process of evaporation is known as interception-loss (I) (Ahmadi et al., 2009). Canopy interception losses of rainfall affect the amount of water reaching the soil in several ways, and are therefore of relevance to many hydrological investigations.

The interactions between vegetation and rainfall are of considerable significance from the physiological, ecological, and hydrological points of view (Aboal et al., 1999; Crockford and Richardson, 2000; Toba and Ohta, 2005; Deguchi et al., 2006; Staelens et al., 2008). Rainfall, amount, intensity and tree architecture plays an important role in rainfall partitioning. Leaf size and the vertical layering of canopies strongly affect throughfall drop size and terminal velocity (Calder, 2001; Nanko et al., 2006; Brandt, 1987). Tree branches having more inclination generate more stemflow with respect to the species having horizontal or nearly horizontal branches (Herwitz, 1987). Tree leaves being concave in orientation, funnel more proportion of the precipitation

* Correspondence to: Division of Plant Science, ICAR-IISWC, Dehradun, India.
E-mail address: kaushalrajesh1@rediffmail.com (R. Kaushal).
1 Present address: ICAR-Central Agroforestry Research Institute, Jhansi, India.

http://dx.doi.org/10.1016/j.ecoleng.2017.02.029
0925-8574/

to their petiole and subsequently to the stem (Crockford and Richardson, 2000; Ahmed et al., 2015). Tree architecture however can be changed using different tree management practices. Tree management practices viz., coppicing, pollarding, lopping, pruning etc changes tree architecture by altering branch density, height and leaf area index and can have significant impact on tree biomass and rainfall partitioning (Thakur and Sehgal, 2001; Thakur and Thakur, 2007).

Hydrological studies in different broad leaf and conifer species in Himalayan region have revealed that Himalayan catchments are subsurface flow systems (with overland flow <1% for the gross rainfall) and very little of the incident rainfall remains to generate surface wash on the hillslopes (Negi et al., 1998; Pathak et al., 1985; Mehra et al., 1985). Rainfall partitioning studies conducted in the Himalayan foothills revealed that pine forest intercepted 22% of incident rainfall (Dabral and Subba Rao, 1968), whilst densely coppiced Sal intercepted as much as 34% (Ghosh and Subba Rao, 1979). In six different forest sites (pine, mixed oak and sal forests) in Uttarakhand, Pathak et al. (1985) reported that throughfall rates ranged from 75 to 92%, canopy interception from 8 to 25% and stemflow accounted for less than 1% of the total rainfall (0.3–0.9%). Mehra et al. (1985) reported that in central Himalayan forest, throughfall ranged from 71.3 to 81.4 per cent, stemflow from 0.50 to 2.16 per cent and canopy interception from 17.7 to 28.2 per cent of the gross rainfall. Dabral and Subba Rao (1968), however, considered that stemflow in Himalayan pine could reach 4% of the rainfall, and 6–9% in broadleaved forest (Ghosh and Subba Rao, 1979). Negi et al. (1998) reported that in low and high altitude broad and conifer forest, throughfall, canopy interception and stem flow varied from 66.5 to 87%, 13 to 32% and 0.01 to 2% respectively.

Mulberry (*Morus alba* L.) is an important tree cultivated in western Himalaya for rearing silkworms. The total acreage of mulberry in India is around 282,244 ha (Data, 2002). The leaves and young bark are used as fodder for dairy animals (Sánchez, 2002; http://www.fao.org/ag/agp/agpc/doc/gbase/data/morusalba.htm). Wood of the tree is used by sport industry while, twigs and branches are used for basket making by local artisans. The species is widely grown by farmers on farmland, watershed and soil conservation programmes for enhancing productivity and providing livelihood security (Kant et al., 2004; Sharda et al., 2006; Dhyani et al., 2007). Large scale plantation of mulbery therefore can have significant impact on hydrology at field as well as at watershed/catchment scale. The objective of this study was, therefore, to quantify the impact of canopy management practices in *M. alba* on rainfall partitioning. Results of the study can be very useful in recommending suitable management practices in the species for deriving maximum hydrological benefits and to providing scientific basis for undertaking plantation programme for protective function on farmlands and watersheds.

2. Materials and methods

2.1. Site description

The study was carried out at Selakui Research Farm of ICAR-Indian Institute of Soil and Water Conservation (IISWC), Dehradun, India. The farm is located at 30°21′N latitude, 70°52′E longitudes and at an altitude of 517 m above mean sea level. The climate of the region is sub-temperate. The mean annual rainfall for the area is 1625.3 mm with 80% occurring during the rainy season (June–September) (Jana et al., 2015). About 80% of the total annual rainfall is received in 80 rainy days during the monsoon season between mid – June to mid-September. On an average, rainfall of 127.3 mm (standard error 9.57 mm) is also experienced during winter season (December to February). Occurrence of high-intensity storms exceeding 100 mm h^{-1} is a common feature during the monsoon season, leading to severe erosion problems (on an average, at least one event per year). Long-term mean maximum temperature of 37.2 °C and minimum temperature of 3.8 °C have been recorded in May and January respectively.

Table 1
Comparison of rainfall for the studied events at the experimental site and nearby meteorological observatory.

Year	Rainfall (mm)		t Stat	P(T <= t) two-tail
	Experimental Site	Meteorological station		
2014	685.12	688.90	−0.12	0.90
2015	467.99	451.20	1.51	0.14
2014–15	1153.11	1140.10	0.40	0.69

2.2. Tree establishment and canopy management treatments

The present study was conducted in *M. alba* cv. S146 planted in the year 2003 on 9% land slope experimental plots (runoff plot). Trees were maintained in six runoff plots of 25 × 7.5 m. Each plot had 15 trees planted at 5 × 2.5 m spacing. Thus, a total of 90 trees were available for imposing canopy management treatments. Management practices *viz*., coppicing and pollarding were imposed on the existing trees in the year 2011. Coppicing involves cutting of the tree at 15 cm from the ground level to obtain flush of new shoots. For imposing pollarding treatment, trees were cut at 1.0 m height from the ground to obtain flush of new shoots. One set of treatment involves lopping where trees were lopped to 75% intensity and rest of branches were retained on the trees. Thus 30 trees in were maintained for each treatments *viz*., coppicing, pollarding and lopping.

2.3. Field measurements

2.3.1. Growth characteristics

Growth characteristics *viz*., height, live crown length, crown width on each individual were measured at the beginning of the study. The crown radius was measured as the distance from the centre of the tree bole to the edge of the crown by measuring tape. To attain the best estimate of mean crown diameter, the average of 4 main directional crown radii was used (Delphis and Levia, 2004). These measurements were subsequently used to estimate canopy area. Tree diameters were measured to the nearest millimetre with a tape. Leaf area index for each tree was measured with an Accupar PAR-80 ceptometer (Decagon).

2.3.2. Throughfall and stemflow

As the experimental site was away from meteorological observatory; therefore to avoid rainfall variation, gross rainfall (GR) amounts were measured in the neighbouring open area, outside the tree plots using three self-produced cylindrical collectors. Mean rainfall event was determined based on an average of the three collectors. GR was measured after each event. A rainfall event was considered when it delivered >2.5 mm rainfall. Comparison of rainfall between meteorological observatory and experimental site through paired *t*-test however, revealed non-significant difference between the two sites (Table 1).

TF was measured using the same kind of manual rainfall collectors used for measuring gross rainfall. To reduce error, eight collectors were distributed randomly underneath the tree canopies in four directions to permit the sampling of different crown densities and reduce the error. TF value was measured at the same method of GR. Mean TF amount for each event was calculated via the collected TF from all the collectors.