To Observe the Runoff Rate of Areca Plantation on Slopeland

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Abstract

Betel nut is a familiar crop in the middle and southern parts of Taiwan's slopeland. Since the population to chew the betel nut was extended, the consumption and profits were increased. Therefore more slopeland was used to plant areca and would get high quality betel nut. Areca plantations bring the society and natural environment very complicated impacts. There was extensive by different cognition of the soil and water conservation, between proprietor and scholar, recognized about planting areca on slopeland. A number of disasters had taken place on slopeland in recent years. It is unknown whether all the disasters were created by betel nut plantation. As no explicit evidence could be confirmed, it's important to understand the hydrological characteristics of betel nut plantation on slopeland. Experimental watershed was located in Shan-Ann village, Shuli county, Nan-Tao Hsien, Taiwan (elevation=890m; latitude=26°25' N; longitude=122°81' E). The precipitation and runoff were observed by raingauge and H type channel from June 1997 to July 1998. The primary result showed that the runoff coefficient was about 0.53 to 0.76, and mean value was 0.64.

Keywords: Areca plantation, Betel nut, Runoff rate, Slopeland, Watershed

1. Introduction

The farmers are interested in betel nut due to its easy cultivation and high benefit, and that is alleged as the "green gold" in Taiwan. The last phase harvest of betel nut is from April to June every year. The condition of sparse quantity would lead to price rise, and then could earn very high profits for merchant. Not only the low temperatures on the slopeland, but also the slow growth make the period of betel nut harvest delayed, and prolong the prosperous period. A cooler and windless valley plantation is suitable for plating areca with high quality betel nut. Regarding the areca plantation, the farmers would prefer the slopeland in succession. The cultivation of areca and consumption process of betel nut might bring the society and natural environment a really complicated impact. The betel nut industry had occupied the ratio of gross proceeds for the agricultural livestock products in Taiwan was 0.064% in 1961, and the increased tendency from 1981 to 1989 had been up to 3.1% in 1989 (Huang *et al.*, 1991). The cultivated area is shown as, 500-700 ha (in 1962), 1670 ha (in 1971) and 56581 ha (in 1996). During the 25 years (1971-1996), the area increment had reached more 34 times than that in 1971 (Wu, 1998). Especially, the cultivated area was increased rapidly from 11061 ha (in 1986) to 33487 ha (in 1989) and the averaged rate of increment was 5600 ha per year. The areca has been planted extensively, and is a widespread crop in Taiwan (Lin, 2002). The distribution of areca is found

to be planted, 33, 20 and 18 % in the individual proportions of Pingtung, Nantou and Chiayi County, in addition to that of 16 % for both Hualien and Taitung.

Therefore, the slopeland productivity can be obtained by decreasing the area of plantation (Wu *et al.*, 1995). It's necessary to build an experimental watershed in betel nut orchard, and it could be inquired into the hydrological characteristics of planted areca on slopeland (Hsu *et al.*, 1998).

2. Materials and methods

2.1 Experimental site

The experimental site was located in Shan-Ann village, Shuli county, Nan-Tao Hsien, Taiwan (latitude=26°25' N; longitude= 122°81' E). The areca watershed encompasses an area of 6764 m²; the average elevation is 890 m with the slope inclination of about 30°. The plants were 9 years with the mean height of 6-7 m. The soil texture is Clay Loam and within a lot of fragile sandstone and shale.

2.2 Instrumentation

Gross rainfall was measured using a tipping-bucket raingauge (0.5 mm bucket, OTA.502, Japan) positioned outlet from the watershed, and approximately 0.4 m from the ground. The depth of runoff was measured using an H type channel within the pressure stage recorder (see Fig.1), and the rating curve between runoff depth and water stage is shown in Fig. 2. The data were acquired using automatic instruments every 5 minutes, and were stored on a

data logger (CR10X, Campbell Scientific Instrument, USA).

Fig.1 Photography of instrumentation(1:data logger; 2:H type channel; 3:rainfall gauge)

Fig.2 The rating curve of depth and pressure in runoff

2.3 Hydrograph analysis

Chen (1983) recommended that Barnes's method could be analyzed by hydrograph analysis in Taiwan, to match the time interval of 5 minutes, which was adopted in this study. The hydrograph can show the variation of runoff at a semi-logarithmic graph paper with logarithm of discharge in the vertical axis and runoff duration in the horizontal axis. From the curve, the threshold of runoff, base discharge and direct discharge can be predicted. Both the discharges were distinguished by connecting the increased point of runoff and the second turning point of recession hydrograph behind peak flow, in which the lower part was the base flow and the upper part was direct runoff.

When rainfall is exceeded infiltration would lead to runoff, and the moment to time of peak flow (T_p) could be used to count the lag time, T_L (see Fig. 3).

The denser canopy would prolong the time of peak flow and recession, and its contrary was in sparse canopy. The prolonged recession time would make the hydrograph smoother, and decrease the runoff. The variation after rainfall could be predicted by the recession constant (Liang, 1996).

Fig. 3 The diagram of lag time (T_L)

The recession constant (K_r) is the gradient of recession curve in the hydrograph, and therefore K_r can be calculated as:

$$\begin{aligned} Q_1 &= K_r Q_0 \\ Q_2 &= K_r Q_1 = K_r^2 Q_0 \\ Q_3 &= K_r Q_2 = K_r^3 Q_0 \\ &\vdots \\ Q_t &= K_r Q_{t-1} = K_r^t Q_0 \end{aligned}$$

Where Q_0 is the threshold discharge of recession curve, $Q_1, Q_2, Q_3, \dots, Q_t$ denote the discharge of recession curve in various periods. Taking the logarithm of both sides of the equation $Q_t = K_r^t Q_0$, we obtain

$$\log(Q_t) = t \cdot \log(K_r) + \log(Q_0)$$

Then $\log(K_r) = [\log(Q_t) - \log(Q_0)] / t$

Thus, by taking the inverse of the logarithmic equation can provide K_r .

We can also plot $Q_0, Q_1, Q_2, Q_3, \dots, Q_t$ of hydrograph in the logarithmic graph paper, and K_r can be diagrammatized by the gradient between $Q_t - Q_0$ and t (see Figs.4 and 5).

Fig. 4 Recession flow in hydrograph

Fig. 5 The logarithmic recession flow in hydrograph

3. Results and discussion

3.1 The gross rainfall of areca watershed

Since the typhoons appeared during the study period damaged the instrumentations, there were only 12 rain events that could be used to analyze from June 1997 to July 1998. All the individual rainfalls are listed in Table 1.

Table 1 The effective rainfall of areca watershed from June 1997 to July 1998.

Date	Duration	Rainfall (mm)
1997.6.10	11:00~19:15	12.5
1997.6.11	12:20~14:50	11.5
1997.6.12	10:20~18:25	11.0
1997.6.13	15:55~21:45	23.5
1997.6.14	03:45~17:30	11.0
1997.6.15	15:20~21:45	16.0
1997.6.23	18:50~21:15	22.0
1997.6.26	18:05~02:10	52.0
1997.6.27	15:50~19:05	14.5
1997.6.28	17:30~21:10	29.5
1998.7.01	13:50~17:45	15.5
1998.7.09	15:45~21:45	29.5

3.2 The surface runoff of areca watershed

Both base-flow separation and effective rainfall were used to analyze the surface runoff. The base-flow separation adopted single-peak hydrograph. The effective rainfall was defined by the individual rainfall which was more than 10 mm at an interval of six hours. To comprehend the runoff, lag time and recession constant by the individual hydrograph in the observed period, we summarized those results as shown in Tables 2 and 3; where June 11, 1997 and July 9, 1998 are plotted in Figs. 6 and 7.

Since the continuous rainfall from June 11-14, 1997 would gradually decrease the lag time from Table 3, can find June 11 is 23 min but June 14 being reduced to 5 min. A different situation was appeared on June 23, 1997. There were eight days without rainfall before June 23, and the resulting lag time was 34 minutes. After three days two continuous separate rainfall events were occurred on June 26 and 27, the

individual rainfall were found to be 52 and 14.5 mm, and we could know the lag time was apparently reduced to 2 minutes on the second day, i.e., continuous rainfall would decrease the infiltration and shorten the duration of peak flow. The calculated recession constants would be increased with recession time (or rate), and its extent was about 0.27 to 0.47, with an average value of 0.35.

Table 2 Hydrological analyses for 12 individual rainfalls in watershed of betel nut orchard

Date	Duration	Discharge (cms)	Rainfall (mm)	Runoff coef.
1997.6.10	11:00~19:15	0.014	12.5	0.61
1997.6.11	12:20~14:50	0.014	11.5	0.62
1997.6.12	10:20~18:25	0.015	11.0	0.70
1997.6.13	15:55~21:45	0.028	23.5	0.64
1997.6.14	03:45~17:30	0.014	11.0	0.68
1997.6.15	15:20~21:45	0.020	16.0	0.67
1997.6.23	18:50~21:15	0.025	22.0	0.60
1997.6.26	18:05~02:10	0.074	52.0	0.76
1997.6.27	15:50~19:05	0.016	14.5	0.59
1997.6.28	17:30~21:10	0.037	29.5	0.67
1998.7.01	13:50~17:45	0.015	15.5	0.53
1998.7.09	15:45~21:45	0.035	29.5	0.62
Mean		0.025	20.6	0.64

Table 3 To analyze lag time in watershed of betel nut orchard

Date	Duration	Lag time (min)
1997.6.11	12:20~14:50	23
1997.6.13	15:55~21:45	11
1997.6.14	03:45~17:30	5
1997.6.23	18:50~21:15	34
1997.6.27	15:50~19:05	2
1997.6.28	17:30~21:10	15
1998.7.01	13:50~17:45	60
1998.7.09	15:45~21:45	52
Mean		25

4. Conclusion

The results from this study indicate that the runoff coefficient occurred was between 0.53 and 0.76, and mean value was about to 0.64, which is more than that of normal forest (0.51) in Taiwan. The damage to water resources conservation by planting areca on slopeland has already been reported (Chen, 1999). During the observed periods, the recession constants obtained were about 0.27 to 0.47, which are smaller than that of forest (0.95 to 0.99). As remarked, while recession time is shorter, the effect of water resources conservation would be decreased.

Fig. 6 Hydrograph for watershed of betel nut orchard was on the June 11,1997.

Fig.7 Hydrograph for watershed of betel nut orchard was on the July 9,1998.

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