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The Effect of Clear Cutting on Runoff Height (Case Study: Noshahr, Iran)

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Abstract*— Cut and exploitation methods used in forest trees affect hydrologic properties. In this study, clear cutting effects on runoff rate is performed in a 2100 m^2 area and a similar plot is selected beside it as a control plot. Then the rate of runoff was measured during two consequent years within different temporal stages. Mann-Whitney tests were used for the comparison of two groups which was significant and non-significant in the first and second years, respectively. The results of correlation test also showed that the height of runoff in cut plot is higher than the control plot. In the second year, the rate of runoff in cut plot became closer to the rate in control plot because of herbal plants growth so the results were not significant while in the first year, the rate of runoff increased because of plant cover remove.

***Index Terms*— Runoff, Clear cutting, Curve Number, Asympthotic method**

I. INTRODUCTION

Exploiting forest trees has a great importance on hydrological conditions. According to vast clear cutting in northern forests of Iran in annual forestry projects and also soil changes caused by wood cutting and carrying, it is essential to study the rate of these effects. So group cut was carried out and the effects of tree cut and the rate of runoff was investigated in the studied area.

Extensive studies have been carried out on the effects of tree cut on hydrological properties such as runoff height and discharge rate estimate by making use of Curve Number method. Bisely and Granilo (1983) stated that clear cutting increases the rate of superficial runoff in the first year in Arkansas and the peak flow ascends significantly, but it is not observed in group cut. Hawkins (1984) determined curve number by asymptotic method in order to recognize its capability in arid areas of southern Arizona province and compared with the results of standard method and it showed a high correlation between the results of asymptotic method and catchment observed runoff. Riekerk (1989) investigated the effects of forestry activities and hydrological properties in pine flatwoods in Florida and concluded that groundwater aquifer has risen up after exploitation as a result of evapotranspiration decrease. The rate of runoff increased by 150% daily in the first year, decreased by 65% after 6 years and returned to the normal situation after 11 years. Studying in Arizona province, Gottfried and Jerald (1992) stated that wood exploitation had increased the rate of water in catchment covered with conifer. Annual water flow mean increased by 45% for the first 8 year period significantly and most of it was related to runoff increase in winter and the maximum rate of water flow increased by 65%. Having researched in Australia, Cornish stated that superficial runoff increases at the rate of 250-150 mm after transporting and exploiting thick Eucalyptus trees. The increase rate was reported accurate regarding 29-79% exploiting rate. There is no runoff increase in less than 20% reaping. The rate of superficial runoff decreases by Eucalyptus restoring after 2-3 years after exploitation and the decrease rate matches the mean number of set up Eucalyptus. In rapid plant growth during 6 years, superficial runoff disappears or even decreases to less than its rate before cut and it shows that the evapotranspiration rate has increased in new set up plants in comparison with old Eucalyptus forest. It is reported that superficial runoff increase in little cut plots are in the minimum rate in this investigation. Vekinz (1993) obtained three behaviors regarding curve number changes corresponding rainfall height. It is not possible to reach a constant value of CN in first behavior. Second behavior shows a standard situation. In this case, observed CN decreases by rainstorm increase and approaches to a constant rate by increasing more and more rainfall. In third behavior, observed CN suddenly increases by rainfall increase and reaches to a constant rate. Hawkins (1993) presented asymptotic method for determining CN. In this method, rainfall of N years turning period were correlated with runoff of the same turning period. This method is called abundance conformity. This method doesn't need runoff or corresponding rainstorm and just the equal frequency of rainfall and runoff are paid attention. Dan and leopad (1997) stated that exploiting in moist soils causes soil compaction and its repetition will continue runoff increase for about 20 to 30 years. Pringle and Benstead (2001) resulted that compaction caused by exploitation and other human activities in forest decreases root system dispersal and the region flor decreases by infiltration decrease. Cover crown decrease increases water erosion and causes soil particles dispersal. It also obstructs macrospores. These effects decreases infiltration capacity and increases surface flows. Studying the effects of exploiting United States south forests, Sun *et al.* (2001) stated that removing vegetation increases runoff for about 10, 2 and 40 mm in shrub land, deciduous forest and eucalyptus and pine forest respectively and generally forest

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clear cut will increase runoff for at least 8 years. Nassaji Zavareh (1999) used asymptotic and standard method (SCS) for Emameh catchment in the north of Iran and resulted that asymptotic method gives more precise CN in comparison with SCS tables. Malekian (2004) used Asymptotic method, standards tables and observed data for Lighvan catchment in the Northwest of Iran and the results showed that asymptotic method estimates more precise CN values with lower error. The goal of this study is determination of runoff changes caused by forest trees group cut by using asymptotic method to determine CN.

II. METHODS

A.Study Area Choice

The study area (Fig.1) is located in Nam-Khaneh series and a part of Parcel 218 in Kheiroodkenar Research Forest in about 7 km of Noshahr in Mazandarn Province in Iran. The small control plot was chosen beside 2100m^2 cut plot with the same conditions and extent. The soil of Nam-Khaneh section is generally lied on calcareous parent rock and seldom on calcareous marl or schist. The area has leached brown soil with clay to loamy clay soil. The catchment is climatically semi-humid to humid. According to the 26 year rainfall statistics taken from Noshahr climatologic station, the mean annual precipitation is 1330.48mm with no drought period. Ombrometer was set up in the study area, so rainfall statistics of 2003 and 2004 are available. The mean maximum and minimum temperature are 29.3^{o}C and 2.6^{o}C, respectively. The mean annual temperature is also about 15.9^{o}C.

All tree species including Beech (*Fagus orientalis*) were cut by chain saw after labeling. Then they were all collected by Onimac and extracted from the skidding path. The most suitable place was chosen as cut plot. It was placed in a small convex basin in general 25% slope and southwest aspect. Another plot, with the same exact slope, aspect and physiographic properties, adjacent to the first one was chosen as control plot. Welts and numbers were installed around the plots. Then the welt distance and azimuth were surveyed. Before cutting, tree diameters were labeled and cover crown percentage was measured in two cut and control plots and was 90% in both of them. Then sampling and measuring was performed in order to reach the raw data. Finally, all the labeled trees and foliage were cut by 8 horsepower power saw and onimac, then they were carried out totally. After each precipitation event, hydrologic properties were measured in two cut and control plots, such as:

-Measuring runoff rate in 2*1m^2 plots in five repetitions harvested in specific dishes.

-Measuring the rate of rainfall in order to determine runoff percentage using set up normal ombrometer.

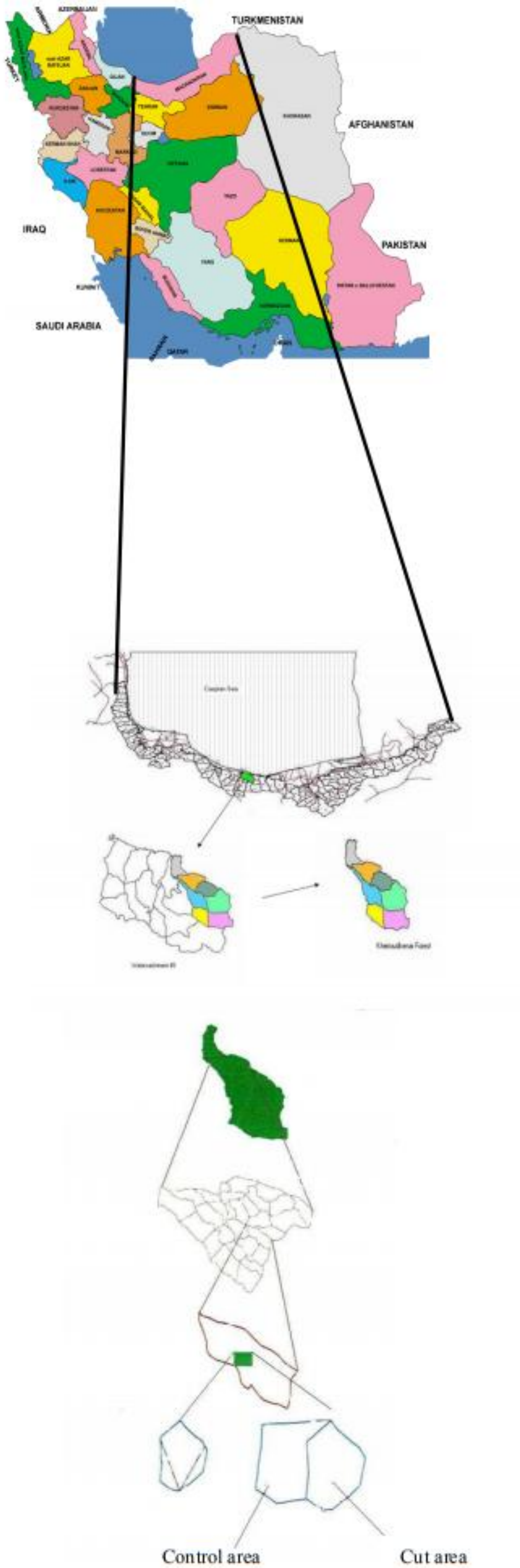

Figure 1. Location map of the study area (Kheiroudkenar forest)

The height of rainfall was measured and recorded by normal ombrometer from May 23th in 2003 through july 24th in 2004. Five plots were installed in cut section and 5 were set up in control section in slope direction in order to measure runoff rate in the studied area. The plot size was 2*1m^2 prepared of metal. They are completely inserted into the ground, so that the runoff harvested from 2m^2 area doesn't leak out of the plot and gives the real runoff rate. A kind of pipe is placed in the ending part of plot, conducts flowing water of plot area to the linked basin. After each rainfall, accumulated water volume in basins which shows runoff rate in 2m^2 area in plot place is measured in order to compare produced runoff volume in cut and control plots.

Runoff depth is classified separately on the basis of ordering rank in the form of P:Q pairs with the same return period. Then the rate of S is calculated for each specific rate of P and Q according to equation (1) and finally CN will be obtained on the basis of equation (2).

(1) $S=5[P+2Q-(4Q+5PQ)^{0.5}]$

where :

P: Rainfall height (mm), Q: Runoff height (mm), S: Total losses (mm)

(2) $S=(25400/CN)-254$

B. Catchment curve number determination by Asymptotic method

In this method, it does not need knowing runoff and corresponding storm rate for curve number determination and only the same runoff and rainfall frequency is needed. Runoff rates are classified separately on the basis of regular order in the form of runoff-rainfall pairs by the same return period. Then the rate of S is calculated for each P:Q pair and so that CN will be obtained. In this case and according to curve number changes with each catchment rainfall, one of three below behaviors are shown [1]:

B.1. Standard behavior:

In this case, observed CN decreases by rainfall rate increase, but in this situation, CN approaches to a constant rate if more storm occurs and so equation (3) is obtained:

(3) $CN_p=CN_\infty+(100-CN_\infty)\exp(-k_1P)$

where:

CN_p : rainfall curve number, CN_∞ : constant rate of curve number (when rainfall inclines to infinity)

B.2. Self satisfied behavior:

Although it seems simple but it is really complicated and it needs to realize standard asymptotic concept completely. In this case, curve number decreases with rainfall increase but it doesn't reach to a constant situation so it is a difficult case and curve number is lower estimated.

B.3. Harsh behavior:

In this case, the observed CN suddenly increases and reaches a constant rate by storm increase. Equation 4 is presented for such case.

CNp=CN

(4) $CN_P = CN_\infty[1-\exp(-k_2P)]$

where:

CN_p: Rainfall curve number, CN_∞ : Constant rate of curve number (when rainfall inclines to infinity), K_2: Constant rate of curve.

It must be mentioned that it is similar to last behavior in small storms.

III. RESULTS & DISCUSSION

A. Curve number determination by Aasymptotic method

In this method, catchment curve number is calculated using runoff and rainfall data and then catchment behavior was obtained. Figures 2 and 3 show the relationship between CN and rainfall in the cut and control plots in 1th and 2th years.

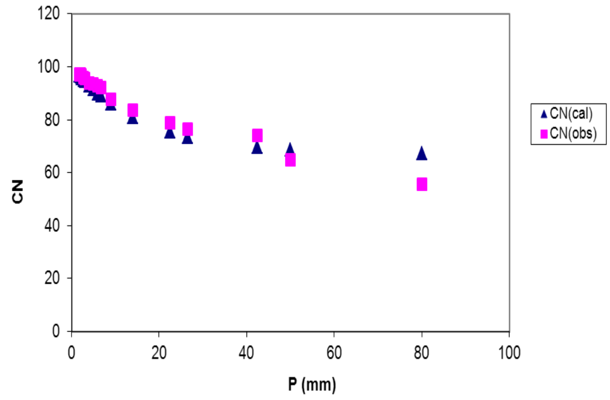

Fig. 2- Relationship between rainfall and CN cal. & obs. in cut plots in 1nd year

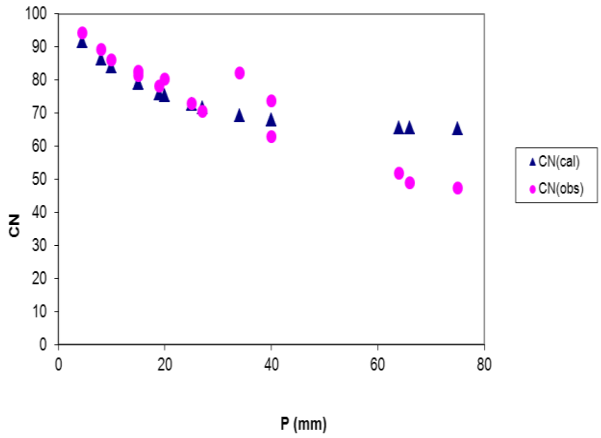

Fig. 3- Relationship between rainfall and CN cal. & obs. in cut plots in 2nd year

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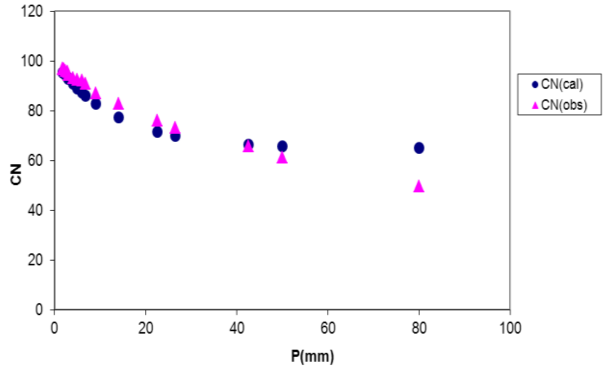

Fig. 4- Relationship between rainfall and CN cal. & obs. in control plots in 1st year

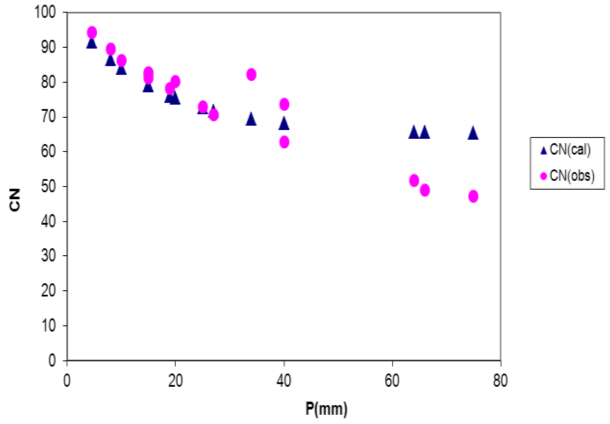

Fig. 5- Relationship between rainfall and CN cal. & obs. in control plots in 2nd year

According to obtained figures, CN behavior is standard and as a result, CN_∞ and k is obtained as asymptotic equation related to each cut and control method in first and second years and finally asymptotic equations were determined as below:

the equation of control plot in 1st year

(5) CN(p)=65+35exp(-0.075P)

the equation of control plot in 2nd year

(6) CN(p)=59+41exp(-0.078P)

the equation of cut plot in 1st year

(7) CN(p)= 67+33exp(-0.061P)

the equation of cut plot in 2nd year

(8) CN(p)= 65+35exp(-0.061P)

Where :

P: the rate of rainfall (mm)

According to CN equations, the height of runoff is calculated by using equation (2) and (9).

(9)

$$Q = \frac{(P-0.2S)^2}{(P+0.8S)} \qquad P \geq 0.2S$$

P and Q are runoff and rainfall in mm and S is maximum water reservation potential in mm which is related to curve number by equation (2).

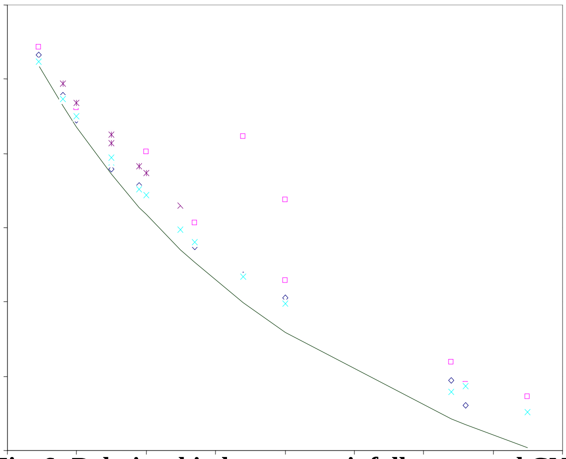

Fig. 6- Relationship between rainfall event and CN

According to the results, there is a significant correlation between observed and estimated runoff height in control plots in the first (76%) and second year (64%) and cut plots in the first year (74%), but there is a low correlation between cut plots in the second year (0.03%). Control and cut plot runoff mean was compared with different tests. The runoff height of control and cut plots had significant difference (1%) in 2003 but it was not significant in 2004 . However runoff height histogram shows that the rate of runoff is increased in cut plot. In the first year, runoff rate in cut plot is 18.59mm and in the second year, 17.51mm. In control plot, it is 7.96mm in the first year and 2.29mm in the second year. Results show that the rate of runoff in cut plot is 4 times more than control plot during two years but because of high variance of the samples, it was not significant statistically. High variance of the samples was first caused by measuring runoff height during 17 measurements in 2003 and 16 measurements in 2004 and in different temporal stages, and second by samples establishment (runoff measuring plots) in different situations because of establishing runoff measurement plots in places of different soil conditions in the case of compactness.

Mann-whitney test was used for comparison and the differences between these two groups were significant in the first year but non-significant in the second year. The results of runoff coefficient test also showed that the height of runoff obtained from rainfall in cut plot is more than control plot. In second year, the height of runoff in cut plot became closer to the rate in control plot because of herbal plants growth so the results were not significant while in the first year, the height of runoff increased because of plant cover remove.

These results correspond with the results of investigation of Granilo, Gottfried, Hawkins, Cornish … . Granilo (1983) stated that clear cutting increases the rate of superficial runoff in Arkansas.

Gottfried (1992) stated that wood exploitation has increased the rate of water in the catchment covered with conifer. Cornish stated superficial runoff increase at the rate of 150-250 mm after transporting and exploiting thick Eucalyptus trees. Also, Hawkins (1993) determined curve number by asymptotic method in arid areas of southern Arizona province and Vekinz (1993) obtained three behaviors regarding curve number changes corresponding rainfall height.

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