Evaluation of Interception in *Astragalus parrowianus*, (Case Study: Gonbad Rangeland of Hamadan Province, Iran)

Nasrin Kolahchi[A], Mohsen Mohseni Saravi[B], Ali Tavili[C], Mohammad Jafari[D], Ghassem Assadian[E]

[A]Assist.Prof. Faculty of Science, Dpt. of Environmental Science Islamic Azad University, Hamadan, Iran.
[B]Prof. Faculty of Natural Resources, university of Tehran, Iran.
[C]Associate. Prof. Faculty of Natural Resources, university of Tehran, Iran.
[D]Prof. Faculty of Natural Resources, university of Tehran, Iran.
[E]Instructor, Agricultural and natural resources research center, Hamadan province, Iran.

Manuscript Received: 04/10/2010
Manuscript Accepted: 13/06/2011

Abstract. Vegetation cover is the first barrier for the raindrops resulting to the interception and infiltration loss. Interception as one of the main components of ecohydrology equation plays a major role in the water balance of rangelands. However, few studies have been done on the interception of rangeland plants in Iran. This study was carried out to find the interception rate in *Astragalus parrowianus* through the rainfall portable simulator devices. In addition, the relationship between plant structural factors such as height, large and small diameters, volume and surface of cover and rangeland physiographic factors including altitude, slope percentage and slope in the interception rate was evaluated. Data were collected and analyzed based on simple linear regression models and multivariate analysis (stepwise approach and descending). Results showed that in first group with a volume of 0.002 to 0.02 m^3 and canopy cover of 642 m^2, 4.421% of total amount of rainfall interception was happened while in second group with volume of 0.02 to 0.087 m^3 and canopy cover of 1640 cm^2, the interception rate was 1.85% out of total precipitation. In the first group, the interception rate showed a significant correlation ($P \leq 1\%$) with large diameter (r=-0.73) and the canopy cover at 5% level (r=-0.51). Interception rate in the second group at 1% significant correlations with canopy cover (r=-0.93), diverse small diameter (r= -0.874), large diameter (r=-0.76) and plant volume size was calculated (r=-0.83). From the regression equations obtained in each group, the interception rate can be measured in *Astragalus parrowianus* without clipping and weighing.

Key words: Interception rate, Ecohydrology, *Astragalus parrowianus*, Gonbad rangeland of Hamadan province-Iran.

Introduction

In the vegetated regions, plant surfaces are considered as one of the first resistances which the precipitation encounters in its journey through the hydrologic cycle. The term "interception" is applied to this phenomenon and includes all processes that affect the catchment, storage and disposition of precipitation on plant and litter surfaces. Interception has been studied for almost a century (Hoppe, 1896) and has probably received more attention than any other components of forest water balance precipitation measurements under the tree crowns (Hoppe, 1896). Vegetation often modifies the intensity and distribution of precipitation falling on and through the leaves and woody structures. The most obvious effect of plants on the falling precipitation is the interception. Interception can be technically defined as the capture of precipitation by the plant canopy and its subsequent return to the atmosphere through evaporation or sublimation. The precipitation rate that is intercepted by plants varies based on leaf type, canopy architecture, wind speed, available radiation, temperature and atmosphere humidity (Pidwirny, 2006). In ecohydrology, quantifying the elements in the water budget and the interception rate in the plants that should be detected are the most important cases. Many models are provided by the researchers in this regard. Horton's (1919) study was one of the first attempts to evaluate the rainfall interception as a physical process. He described the interception loss for an individual tree (exclusive of litter interception) as follows:

$$\mathrm{I} = \mathrm{Sj} + \mathrm{KiE\,rT}$$

Where

I = interception loss in the depth in inch over the projected area of canopy

Sj= interception storage capacity in the depth in inch over the projected area of canopy

Ki= ratio of evaporating surface to the projectional area

E= evaporation rate in the depth in inch per hour during the storm and

T= storm duration in hours.

The ecohydrology may be defined as a branch of hydrology that seeks to describe the hydrologic mechanisms underlying the ecologic pattern and processes. During the resent year, several ecohydrological models which were characterised by different goals have been developed improved. All the ecohydrological models are based on a soil water balance that is one of the purposes of previous work to be solved in the simplest and most accurate manner (Pumo *et al.*, 2007).

Description of Existing Ecohydrological Models

Newman *et al*. (2002) considered the water balance vertically averaged over the root zone under the simplifying assumption that the lateral water contributions can be neglected due to the topographic effects. With the above conditions, the soil moisture balance can be expressed as:

$$\mathrm{n} \cdot \mathrm{Zr} \cdot \mathrm{ds/dt} = R(t) - I(t) - Qe(s(t)) - L(s(t))$$

Where

n= the porosity,

Zr = the rooting depth,

s = the relative soil water content or soil moisture and

t = time.

The right side of the equation includes rainfall *R (t),* infiltration *I (t),* evapotranspiration (*E),* runoff *(Q),* the soil moisture content *s (t)* and the amount of $(0 \le s(t) \le 1)$, the amount of water loss from the surface and subsurface layers (root access, L (s (t)) and the canopy interception and evapotranspiration rates are considered together. In this equation, the factors affecting the ecohydrological conditions of areas are proposed and the framework and major variables are clarified in the study. In rangelands and forests, vegetation through the interception process has a significant impact on the hydrological cycle.

Although the interception loss is considered for a watershed, in some coastal areas and high altitude areas with low clouds and fog comes, interception can add moisture to the soil. Canopy cover of trees absorbs the fog and then interconnects and converts it into the soil humidity. In such cases, the water input to the soil is higher. Some elements including plant properties, rate, duration, intensity, rainfall pattern, evaporation from the surface and roughness at the plant level affect the interception rate (Brooks *et al*., 1997). The first studies in the United States showed that the interception rate of needle leaf forest canopy was 10 to 35% of total annual precipitation (Zinke, 1967) and in the forests of Pacific Northwest with needle leaves, there has been a high and negative correlation with increasing the diameter of raindrops and interception (Rothacher, 1963). Height of trees influences the interception so that in a forest with low trees, the interception rate varies from 8 to 60% (David *et al*., 2005). In the study conducted by Xiao *et al*. (1998) in the Sacramento area in California, the average annual rate of interception in summer with LAI was obtained. To estimate the forest interception rate, Horton equation (Horton, 1919) and some models such as Gash analysis model (based on linear regression model in low-density forest) have been used (Gash *et al*., 1979). Measured interception in the rangelands and vegetative omnifarious forms requires high skill and time during the growing season. The study conducted by researchers at Regina University indicated that the interception rate in broad-leaved plants and grasses had a variable length in growing seasons, after the eruption period, the interception rate was reduced in annual and perennial plants and biomass loss so that the interception rate in spring wheat during the vegetative stage and before harvest was 11 to 19% of total precipitation. In the study done by Corbett (1968) in San Dimas rangelands of southern California, the interception rate and Gross annual were 12.8% and 7.9% of total rainfall in a Chaparral plant community, respectively and if grass was converted to Chaparral, approximately 1.3 inches of total annual interception would be stored. Wood *et al*. (1998) in China studied the interception rate of 10 dominant range species with vegetative forms of grass, broadleaf plants and shrubs using the immersion method and found that there was a high correlation among plants, structural factors and interception. In the study performed by Wang *et al*. (2005) in Shabato desert region of China, the interception rate in sagebrush plant communities (*Artemisia ordosica* Krasch) and *Karagana* (*Caragana korshinskii* Kom) was investigated. This study measured the interception rate during the coronal in individual rainfall and studied the relationships of various rainfall factors with interception rates. Results showed that with the rainfall intensity of 2 mm on time, the interception rate in the community with 30% crown cover of *Artemisia* and average of 0.8 m is less than *Karagana* community. Water budget modeling usually requires the quantification of all possible processes of hydrological cycle. Precipitation as the sole source of water replenishment in the semiarid area plays a pertinent role in sustaining the areas. Thus, the measurement of rainfall interception is of high importance. The purposes of this study were to: a) measure the interception loss on shrub canopies (*Astragalus parrowianus*) through individual rainfall events, b) determine the canopy storage capacity of individual plants and c) explore the relationship between interception and plant morphology in *Astragalus parrowianus*.

Materials and Methods

Study area

The Gonbad basin located in the southwest of Hamadan province is 28 km far from Hamadan city. This basin is located between two northern latitudes of 48°41′5″and 48°43′17″and two eastern longitudes of 34°41′34″ and 34°42′16″. The location of Gonbad basin is shown in Fig.1. The mean annual precipitation of this region is 304 mm. The area of Gonbad basin is about 300 hectars. Minimum and maximum elevations were 2080 to 2440 m above sea level, respectively and the slope was 5 to 42%. Rainfall intensity varies from 0.1 to 7.9 mm in hours. Irregular distribution of rainfall is occurred from mid- November to mid-April. The average annual temperature and relative annual rate of humidity were 5.89°C and 58.7% and annual evapotranspiration is greater than rainfall. Using Domartan method, study area climate is steppe. Soil texture varies from moderate to heavy land and its elements refer to the Second Age of Geology. Based on field observations, aerial photographs and satellite images, three physiographic units including mountain, hill and dale are detectable in the plateau region.

Study method

Direct measurement of interception in rangeland plants is rare and most of estimations are based on indirect methods such as Horton equation (1919). In the present study, the interception rate was directly measured in yellow milk-vetch (*Astragalus parrowianus*). The genus of *Astragalus* has numerous species, namely 804 species in Iran (Ramak Masumi, 2007) in forms of shrubs and forbs. This species is often seen as spine scent of mountainous regions and arid and semi arid lands in Iran. Study on the structural features and resulting tragacanth from *Astragalus* species has been done by different researchers and different regression equations are presented in this area (Assadian *et al*., 2009). Also, this plant has an important role in the water balance in the watershed ranges (Fig. 2).

In the field study, sampling was done in late September to mid October. In this short period, the growth of range plants is completed and there is a short interval to the onset of autumn rain. According to the plant classification done for more than 90% of the area, milk-vetch with some other plants has been seen (Table 1). After combining the layers of slope, slope percentage, elevation and vegetation types using ARCGIS software, the working class was identified for sampling. Plot size was determined according to the size and distribution of plant species and number of plots was identified on the basis of vegetation and physiographic changes in each class. For each plot from 54 plots, percentage of canopy cover, plant height, large diameter, small diameter, cover percentage of each plant and topographic factors including altitude, slope percentage and aspect were recorded by Garmin model GPS device.

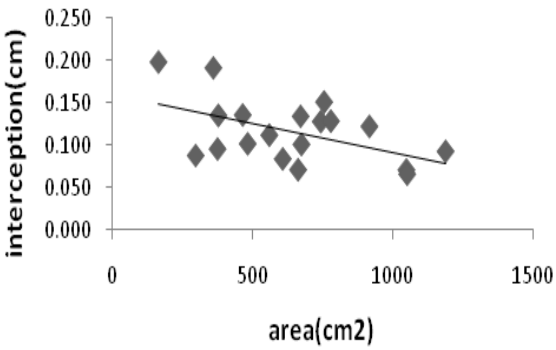

Fig. 1. Relation between interception and canopy cover of area (group1)

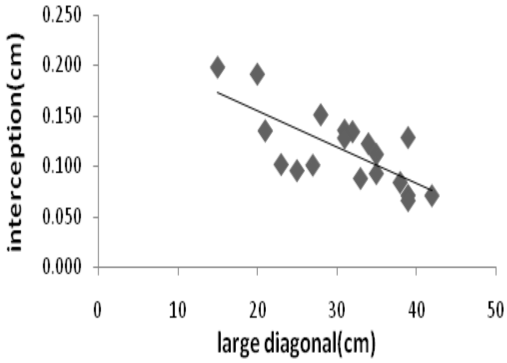

Fig. 2. Relation between interception and large diagonal (group1)

Table 1. Plant types in study area

Vegetation types	Area of vegetation types
Astragalus-Stipa-Eryngium	20.24 ha
Astragalus-Artemisia-Acantholimon	8.47 ha
Astragalus-Acanthophyllum-Verbascum	13.52 ha
Astragalus-Acantholimon-Artemisia	22.16 ha
Juncus-Eryngium	4.86 ha
Astragalus-Acantholimon-Acanthophyllum	29.9 ha
Astragalus-Acanthophyllum-Acroptilon	40.44 ha
Astragalus-Acantholimon-Stipa	42.57 ha
Astragalus-Acroptilon-Acanthophyllum	45.5 ha
Acroptilon-Acanthophyllum-Gundelia	15.37 ha
Astragalus-Stipa-Acroptilon	34.74 ha
Astragalus-Eryngium-Stipa	15.00 ha
Juncus-Eryngium	8.00 ha

Implementation Process of Precipitation with Rainfall Simulator

Portable rainfall simulator device is capable to produce the precipitation with 5 mm based on hour intensity through 36 nozzles with a diameter of 0.5 mm and height of 1.04 m from the ground level (Fig. 7). During the rainfall, the raindrops were distributed uniformly in the entire plot and all plants were equally resaving the rain (Figs. 3 and 4). Immediately after the rainfall, the aerial biomass of plants was cut and placed separately in thick plastic bags. Samples were collected from each plot after weighing the wet state, placed in the open air and weighed in several stages until the weight was constant (Figs. 5 and 6). Finally, the difference between wet and dry weights divided to the canopy cover of area is the interception rate of plants in gram and percentage of total precipitation. Based on volume size, the plant samples were collected in two classes. First class were and second grade range of 0.002 to 0.02 m^3 and second one was range of 0.02 to 0.087 m^3, respectively.

Primary data collected from rainfall simulator of each plot consist of diverse plant physiological parameters (Table 2). Columns 1 to 8 are physiologic parameters; the interception level is shown in columns 9 and 10 and columns 11 to 13 are the environmental characteristics in the first group. The analysis of available data with Minitab software (simple linear regression models and multivariate statistical step by step approach and descending) and their relationships were correlated (Table 3). Simple linear regression and multivariate models based on the highest correlation coefficients were obtained and thereby the charts 1 to 3 for the highest correlation coefficients were drawn in excel software for the first group.

(Table 4) Initial data collected from the rainfall simulator of each plot consist of diverse plant physiologic parameters (columns 1 to 8), environmental characteristics (columns 11 to 13) and interception level (columns 9 and 10) that were provided in a volume group. Correlation tables of data and graphs 4 to 8 are presented. So, the following equations can be offered to predict the interception rate in *Astragalus parrowianus*. Univariate and multivariate equations are to estimate the interception rate in which the diverse range is 0.002 to 0.02 m^3 (volumes) are as follows:

$Y = -0.0036X + 0.2278$ $r = -0.73$ Equation1

In Equation 1, Independent variable is the plant large diagonal (cm) and the dependent variable is the interception rate.

$Y = -7E - 05X + 0.1595$
$r = -0.51$ Equation2

In Equation 2, Independent variable is crown cover (square cm) and the dependent variable is the interception rate.

$Y = 0.0157 - 0.0059X_1$ -
$0.01 X_2 + 0.00024 X$ Equation3

In Equation 3, the dependent variable, interception level and dependent variables are as follows:

Large diagonal X_1, crown cover X_2, small diagonal X_3

Univariate and multivariate equations are to estimate the interception rate in which the diverse range is 0.02 to 0.087 m^3 (volume) are:

$Y = -9E - 07X + 0.0887$ $r = -0.83$ Equation4

In Equation 4, independent variable is plant volume in cubic centimeters and the dependent variable is the interception rate.

$Y = 0.0011X - 0.0271$ $r = 0.81$ Equation5

In equation 5, Independent variable is the difference of dry and wet weights and the dependent variable is the interception rate.

$Y = -5E - 05X + 0.1222$ $r = -0.90$ Equation6

In equation 6, independent variable is crown cover in square meters and the dependent variable is the interception rate.

$Y = -0.0026X + 0.1413$ $r = -0.87$ Equation7

In equation 7, independent variable is small diagonal (cm) and the dependent variable is the interception rate.

$$Y = -0.0032X + 0.1913 \qquad r = -0.76$$
Equation8

In equation 8, Independent variable in the equation is large diagonal (cm) and the dependent variable is the interception rate.

$$Y = -0.02 + 0.00091X_1$$ Equation9

In equation 9, Independent variable is plant height and dependent variable is the interception rate.

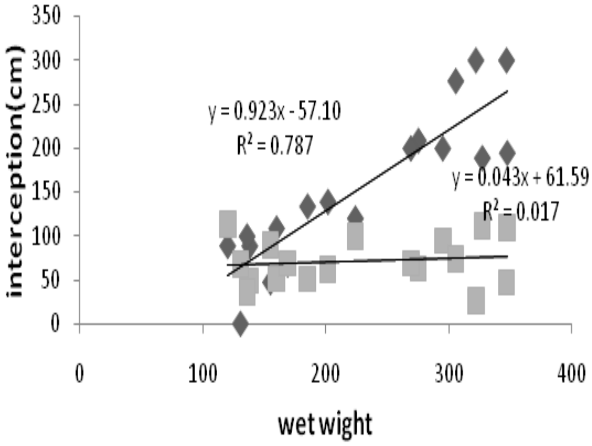

Fig. 3. Relation between interception and difference of wet and dry weights (group1)

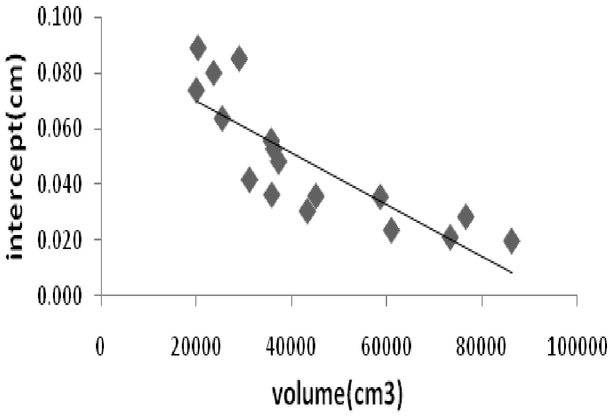

Fig. 4. Relation between interception and plant volume (group2)

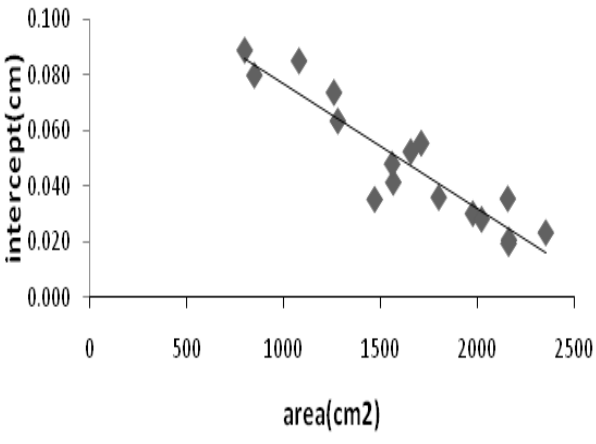

Fig. 5. Relation between interception and canopy cover of area (group2)

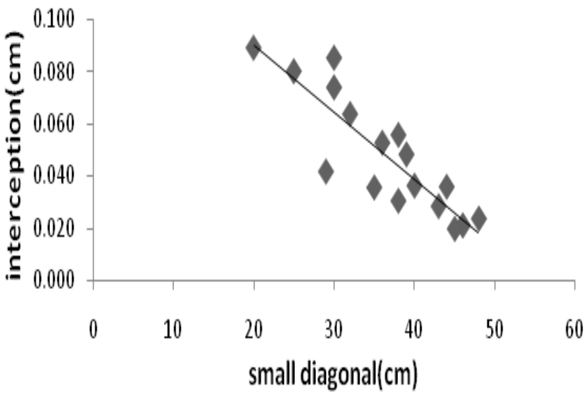

Fig. 6. Relation between interception and small diagonal (group2)

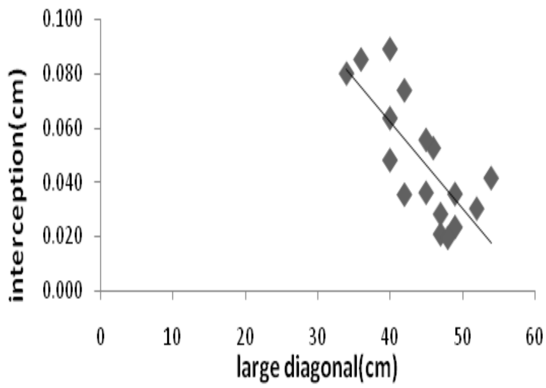

Fig. 7. Relation between interception and larg diagonal (group2)

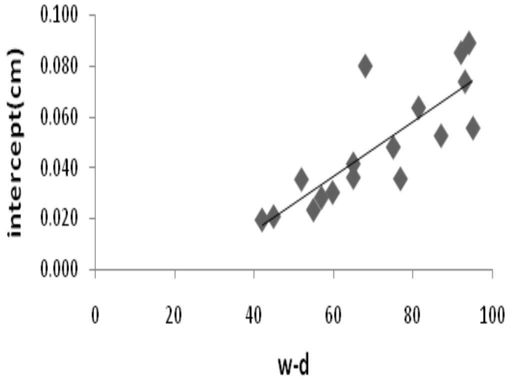

Fig. 8. Relation between interception percentage and interception (gr) (group2)

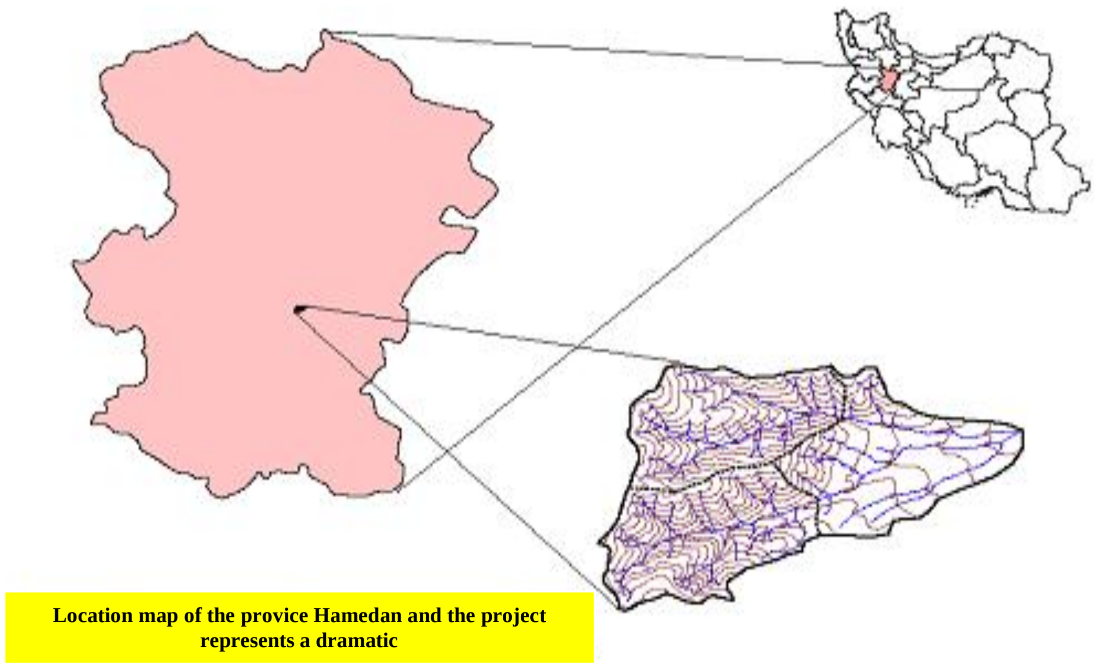

Fig. 9. Location of Gonbad rangelands in Hamadan provience, Iran

Countinued Table 4. Topographical data, plant physiology and interception in *Astragalus parrowianus* (second group)

Table 2. Topographic data, plant physiology and interception in *Astragalus parrowianus* (first group)

No	Large diagonal (cm)	Small diagonal (cm)	Height (cm)	Volume (cm^3)	Wet (gr)	Dry (gr)	Wet-dry (gr)	Area (cm^2)	Interception (cm)	Interception (%)	Z (M)	Slop (%)	Aspect
1	15	11	13	2288	244	200.0	44	164	0.198	7.388	2190	20.14	9.47
2	31	15	14	6510	275.2	208.7	63	465	0.135	5.055	2256	9.78	158.60
3	38	16	11	6688	159.8	109.0	50.8	608	0.084	3.118	2190	20.14	9.47
4	39	17	11	7293	46.89	300.0	46. 9	663	0.071	2.639	2218	21.51	313.62
5	23	21	17	8211	138	89.0	49	483	0.101	3.785	2244	22.16	125.20
6	32	21	13	8736	154.8	47.8	90	672	0.134	4.997	2306	42.23	346.77
7	35	16	17	9520	201.6	139.1	62.5	560	0.112	4.164	2224	31.01	53.89
8	20	18	18	6480	168.8	68l0	68.8	360	0.191	7.131	2376	13.78	67.10
9	31	24	13	9672	295	200	95	744	0.128	4.764	2303	14.82	120.16
10	33	9	8	2376	322	300	26	297	0.088	3.266	2292	29.32	20.93
11	21	18	15	5670	185	134	51	378	0.135	5.034	2237	25.86	15.78
12	25	15	19	7125	35.76	100	35.7	375	0.095	3.558	2220	23.51	314.62
13	27	25	20	13500	130.4	16:20	68	675	0.101	3.759	2202	16.67	320.90
14	42	25	14	14700	305.6	276.6	74	1050	0.070	2.630	2301	29.43	92.86
15	35	34	13	15470	347.5	194.7	110	1190	0.092	3.449	2214	47.72	148.60
16	39	20	20	15430	223.9	120.4	100	780	0.128	4.784	2226	17.24	98.83
17	34	27	20	18360	327.2	188.9	112	918	0.122	4.552	2204	14.87	322.84
18	39	27	14	14742	269.0	200.0	69	1053	0.066	2.445	2229	17.51	313.62
19	28	27	25	17667	120.0	89.1	114	756	0.151	5.627	2263	14.70	76.49

Table 3. The correlation volume, small diameter, large diameter and height of *Astragalus parrowianus* (plant physiological factors) and altitude, slope, slope (topographic factor) with the interception rate in the first group

Component	Slope	Slope %	Altitude	Interception cm	Interception %	Crown Cover cm^2	Difference in Dry Weight gr	Volume Cm^3	Plant Height	Small Diameter
Slope %	0.02									
Altitude	-0.16	0.01								
Interception %	-0.35	-0.26	0.14							
Interception cm	-0.35	-0.26	0.14	0.99 **						
Crown cover	0.36	0.25	-0.10	-0.48 *	-0.48*					
Difference in dry weight	0.18	0.05	0.08	0.13	0.13	0.71 **				
Plant Size	0.35	-0.03	-0.13	-0.23	-0.23	0.84**	0.83**			
Plant height	0.16	-0.38*	-0.06	0.27	0.27	0.11	0.50**	0.61**		
Small diagonal cm	0.36	0.18	-0.03	-0.23	-0.23	0.88**	0.80**	0.86**	0.37	
Large diagonal cm	0.23	0.20	-0.11	-0.72**	-0.72**	0.71**	0.26	0.46*	-0.24	0.31

Ns at 5 percent is not significant   Significant at 1 percent**   Significant at 5 percent *

Table 4. Topographical data, plant physiology and interception in *Astragalus parrowianus* (second group)

No	Large Diagonal (cm)	Small Diagonal (cm)	Height (cm)	Volume (cm^3)	Wet (gr)	Dry (gr)	Wet-dry (gr)	Area (cm^2)	Interception (cm)	Interception %	Z (M)	Slop (%)	Aspect
1	40	20	25	20500	294.0	200	94	800	0.089	3.321	2206	19.511	313.62
2	34	25	28	23800	168.0	100	68	850	0.080	2.985	2235	22.511	312.62
3	40	32	20	25600	281.4	200	81.3	1280	0.064	2.372	2255	23.511	313.62
4	36	30	27	29160	192.0	100	92	1080	0.085	3.179	2277	22.882	70.451
5	54	29	20	31320	365.0	300	65	1566	0.042	1.549	2336	19.903	140.84
6	46	36	22	36432	287.0	200	87	1656	0.053	1.960	2232	34.872	58.133
7	45	38	21	35910	363.9	67.5	95	1710	0.056	2.073	2304	54.579	350.26

Countinued Table 4. Topographical data, plant physiology and interception in *Astragalus parrowianus* (second group)

8	45	40	20	36000	365.0	300	65	1800	0.036	1.347	2268	35.088	39.346
9	40	39	24	37440	175.0	100	75	1560	0.048	1.794	2259	27.234	206.61
10	49	44	21	45276	276.8	200	76.8	2156	0.036	1.329	2196	24.30	46.80
11	52	38	22	43472	159.8	100	59.8	1976	0.030	1.129	2215	21.511	313.62
12	42	35	40	58800	252.0	200	52	1470	0.035	1.320	2219	25.511	313.62
13	49	48	26	61152	176.3	29.4	55	2352	0.023	0.873	2191	13.217	184.65
14	47	46	34	73508	145.0	100	45	2162	0.021	0.777	2250	16.511	310.62
15	47	43	38	76798	357.0	300	57	2021	0.028	1.052	2265	23.518	314.62
16	48	45	40	86400	342.1	300	42.1	2160	0.019	0.727	2254	19.52	313.62
17	42	30	16	20160	293.0	200	93	1260	0.074	2.754	2233	16.761	315.62

Table 5. The correlation volume, small diameter, large diameter and height of *Astragalus parrowianus* (plant physiological factors) and altitude, slope, slope (topographic factor) with the interception rate in the second group

Component	Slope	Slope %	Altitude m	Interception %	Interception cm	Crown Cover Cm^2	Difference in Dry Weight gr	Plant Size Cm^3	Plant height cm	Small Diagonal
Slope %	-0.09									
Altitude	-0.04	0.40 *								
Interception %	0.06	0.04	-0.02							
Interception cm	0.06	0.05	-0.02	0.99**						
Crown cover	-0.13	-0.03	-0.11	-0.91**	-0.91**					
Difference in dry weight	-0.17	0.40*	0.09	0.79**	0.79**	-0.62**				
Plant Size	0.19	-0.20	-0.09	-0.79**	-0.79**	0.77**	-0.81**			
Plant height	0.35	-0.23	-0.09	-0.36	-0.37	0.24	-0.68**	0.79**		
Small diagonal	-0.13	0.02	-0.13	-0.88**	-0.88**	0.95**	-0.59**	0.79**	0.32	
Large diagonal	-0.13	-0.07	0.07	-0.68**	-0.68**	0.76**	-0.43*	0.45*	-0.03	0.53*

*, **= Significant at %5 and %1, respectively

Table 6. Average of plant physiographic characteristics in plots of rainfall simulator

Group Number	Canopy Cover %	Litter %	Stones and pebbles %	Soil %	Interception Percent	LAI	Large Diagonal cm	Small Diagonal cm	Height cm	Crown cover	Wet weight	Dry weight
1	90.26	1.93	4.73	3.067	4.421	0.516	30.94	20.31	15.52	642	229	56
2	94	1.44	2.55	2	1.85	0.477	44.52	36.35	26.11	1640	264	206

Table 7. Best simple linear regression models in measuring the interception in *Astragalus parrowianus* (group I and group II)

No.	Equation	R^2	r	P-Value	X	Group	Volume Range
1	y =-7E-05x + 0.1595	0.2571	-0.507 *	0.035	Area (cm2)	1	0.002-0.02 m^3
2	y =-0.0036x + 0.2278	0.532	-0.729 **	0.000	large diagonal	1	0.002-0.02 m^3
3	y =-9E-07x + 0.0887	0.6892	-0.83 **	0.000	volume	2	0.02-0.087 m^3
4	y = 0.0011x - 0.0271	0.6674	0.816 **	0.000	wet-dry weight	2	0.02-0.087 m^3
5	y =-5E-05x + 0.1222	0.8633	-0.929 **	0.000	Area (cm2)	2	0.02-0.087 m^3
6	y =-0.0032x + 0.1913	0.5777	-0.76 **	0.002	large diagonal	2	0.02-0.087 m^3
7	y =-0.0026x + 0.1413	0.7654	-0.874 **	0.000	small diagonal (cm)	2	0.02-0.087 m^3

*, **= Significant at %5 and %1, respectively

Conclusion

For modeling the water balance of rangelands, all components of water cycle should be quantified. One of these components is the interception (Wood *et al*., 1998). 85-95% of annual rainfall in arid and semi arid regions of the world are evaporated or spent in plant metabolic activity and only 5- 15% of precipitation will remain to feed the stream flow or groundwater. Usually, in dry and semi-arid rangeland areas with lower density of canopy cover, the interception rate is lower as compared with the temperate forests and wet areas. However, in such areas, even small amounts of water loss can be important (Brooks *et al*., 1997). Based on the regression models obtained in this study, the interception rate in *Astragalus parrowianus* can be measurable so that if the height of rainfall is 2.87 cm in the region and *Astragalus parrowianus* has a volume of 0.002 to 0.02 m^3 and average crown cover of 0.0642 m^2, 4.422% of total precipitation can be absorbed and if *Astragalus parrowianus* has a volume of 0.02 to 0.087 m^3 and average crown cover of 0.1640 $m^{2,}$,1.85% of total precipitation will be absorbed. On the other hand, LAI is 0.516 and 0.477 in first and second groups, respectively (Table 6). The results indicate that structural factors such as plant diagonal, plant canopy cover and plant size have direct impacts and physiographic factors of areas have indirect impacts on *Astragalus parrowianus*'s interception. Therefore, slope and different heights showed no significant effects on the interception rate (Tables 2 to 5) but physiographic factors affect the species composition and vegetation percentage. As in the southern slopes, vegetation cover and density are less than Northern directions. Apparent structure of plant, irregular spaces and low index of leaf area are factors that decrease the interception with increasing the size and volume of *Astragalus parrowianus*. So, the plant structural factors have a high and inverse correlation with the interception (Figs. 1 and 2 in first group) and (Figs. 4 to 7 in the second group). Leaf area index is also decreased with increasing the volume and diversity leading to the reduced transpiration in plants because of water conservation. Study conducted by Xiao *et al*. (1998) in Sacramento, California represents the inverse relationship between canopy cover and leaf area index with the interception rate. So, the interception rate in the needle leaf trees in summer with large leaf area index of 5.1 was %36 and in medium-sized needle-leaf trees with LAI of 3.7 was 18.1%. Wang *et al*. (2005) in Shabotu desert region of China showed that the linear model is positively related to the interception and amount of crown cover in sagebrush plant community and Karagana community. As in the community with 30% sagebrush cover and 0.8 m^2 canopy cover in the growing season, the average was 5.9% , the community with 46% Karagana cover and 3.8 m^2 crown cover had the average of 11.7%. However, this study compared two plants in a different society and some comparisons have been done within the group. Based on graph 3, a high positive correlation is seen between dry and wet weights (r =84%) and also between fresh weight and interception (r=36%) in the first group. In the study conducted by Wood *et al*. (1998) in Chihuhan area in China, in hardwood plants(forbs and shrubs), there is a high correlation between dry and wet weights with the interception rate. Biomass plants determine the plant weight and have a direct relationship with the interception so the interception rate will increase as the plant weight increases and vice versa. The study conducted by researchers in Regina University on grasses and hardwood indicated that the interception rate has declined as the aerial biomass was reduced in annual and perennial plants while being harvested and grazed by livestock. So, in the individual events based on off-season precipitation, the impact of plant structural parameters and leaf area index is significant on the interception rate and is reduced when the aerial biomass is lower. Results obtained from the studies conducted in Gonbad Rangeland of Hamedan province show the rate of interception in yellow milk-vetch (*Astragalus parrowianus*). This plant is one of the most important plants in semi arid rangelands and various regression models have made the estimated interception rate of this plant clear using other elements (environmental elements and morphology). Based on this set of three overall results obtained from this study, similar principles of rangeland management and ecohydrology conditions, we can conclude that:

1- With rangelands that are closed to watershed upstream, the possibility of increasing the volume of an *Astragalus parrowianus* leads to the increased effective precipitation and reduced interception.

2- In the range of erosion-sensitive sheet, slide, creep and flow solifloction, planting and developing the plants with high interception levels is effective to increase the resistance range. According to the study, other species of *Astragalus* with smaller size, larger crown cover and leaf area index can be used.

3-To increase the rangeland watershed discharge, converting the vegetation species with deep roots to species with the surface root, converting the vegetation species with high interception capacities to less capacities and converting the vegetation with high annul evapotranspiration to less evapotranspiration are suggested (Brooks *et al*., 1997).

Acknowledgment

The work was carried out as part of the ecohydrology project funded by Committee regional water Hamadan stock company (under the Ministry of Energy). We thank president of Research and Management Company Dr. Hoshang Vafaii for his great contributions in studies and Dr. Zahra Kolahchi for data analysis and Mr. Aghamohamadi for assistance in field and eng falah for helpful guidance.

References

Assadian, Gh. Kolahchi, N. Sadeghi Manesh, M. 2009. Investigation of effect and type of construct in different times on amount of gum tracaganth in yellow milk vetch *(Astragalus parrowianus), Pajouhesh & Sazandegi* **21:** 170-175. (In Persian).

Brooks, Kenneth N., Ffolliot, Peter F., Gregersen, Hans M., Debano, Leonard F. 1997. Hydrology and the Management of Watersheds, Second Edition, Iowa State Press, Blackwell Publishing Company.

Corbett, Edward S; Crouse, Robert P. 1968. Rainfall interception by annual grass and chaparral losses compared. Res. Paper PSW-RP-48. Berkeley, CA: Pacific Southwest Forest & Range Experiment Station, Forest Service, U.S. Department of Agriculture; 12 p.

David, J. S., Valente, F. and Gash, J. H. C., 2005. Evaporation of intercepted rainfall, Ch 43, Encyclopedia of Hydrological Sciences, (Ed: MG Anderson), John Wiley, Chichester: 627-634.

Gash, J. H. C., 1979. An analytical model of rainfall interception by forests. Quarterly *Jour. Royal Meteorological Society,* **105:** 43-55.

Hoppe, E. 1896. Precipitation measurements under tree crowns. 50 pp. (Translated from German by A. H. Krappe, Division of Silvics, U. S.Forest

Serv., 1935, Trans. No. 291).

Horton, R. E. 1919. Rainfall interception. Monthly Weather Rev. U **7:** 603-623.

Newman Brent D, Wilcox, Bradford P., Steve Archer, David D. Breshears, Clifford N. Dahm, Christopher J. Duffy. Nathan G. McDowell, Fred M. Philips, Bridget R. Scanlon, Enrique R.Vivoni, 2002. The ecohydrology of Arid and semiarid Environments: A scientific vision.

Pidwirny, M. 2006. "Interception, Stemflow, Canopy Drip, and Throughfall". Fundamentals of Physical Geography, 2nd Edition. Date Viewed. http://www.physicalgeography. net/fundamentals/8k.html.

Pumo, D. Viola, F and L. V. Noto. 2007. Ecohydrology in Mediterranean areas: a numerical model to describe growing seasons out of phase with precipitations. Palermo, Italy 2007.

Ramak Masumi. A. 2007. Iran, *Astragalus*. vol. 5, published by research institute of forest and rangelands, Tehran, Iran (In Persian).

Rothacher, J. 1963. Net precipitation under a Douglas- fir forest. For. Sci. **9:** 423-429.

Wang, Xin-Ping. Xin-Rong Li; Jing-Guang Zhang; Zhi-Shan Zhang; Ronny Berndtsson. 2005. Measurement of rainfall interception by xerophytic shrubs in re-vegetated sand dunes / Mesure de l'interception de la pluie par des arbustes xerophiles sur des dunes de sable replantees *Hydrological Sciences Jour,* **50:** 1–910.

Wood, M. K. Jones, T. L. Vera-Cruz, M.T. 1998. Rainfall interception by selected plants in the Chihuahuan Desert. *Jour. Range management* **51:** 91-96.

Xiao, Qingfu. Mcpherson, Gregory. Simpson, James R. Ustin, Susan l. 1998. rainfall interception by Sacramento's urban forest. *Jour. Arboriculture* **24(4):** 235.

Zinke, P. J. 1967. Forest interception studies in the United States, pp. 137-161. In W. E. Sopper and H. W. Lull, International Symposium on Forest Hydrology. New York, USA.