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Ecological and Physiological Study of White Poplar (*Populus alba)* on the Bank of Zayandeh Rood River

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ABSTRACT

Populus alba is a tree species that distributed naturally on the bank of rivers in arid and semi-arid regions. It is geographically extended mainly in Asia and Africa. The acreage of *Populus alba* is about 18500 ha in Iran. The natural presence of this plant in the border of Zayandeh Rood river in Isfahan Province is very important in environmental protection and soil erosion control as a result of river flow. This research was carried out in order to identify its limiting ecological (physical and biophysical) factors. Some of general characteristics of the study area are annual precipitation (210mm), average temperature (17.4°C), maximum and minimum temperature (46.6°C -21.4°C). The climate of the study area, based on Coppen, De Martonne and Ambergeh methods is determined as Steppe, Arid and cold arid respectively. Study area was identified using satellite sites. Factors such as canopy coverage, anthropogenic effects, ground water level and edaphic factor were investigated based on 33 sample plots with the size of 10*10 meters were established systematic-randomly. Soil samples were collected on 19 plots in three depths: 0-35, 35-65, and 65-95 cm. Laboratorial tests were then performed to measure and calculate soil texture, SP, EC, PH, Na, Mg, Cl, $CaCo_3$, and SAR. Results indicate that human effects e.g. cutting of Euphrates as well as periodical change of woodland into croplands had been the major sources of poplar woodland decrease. In view of soil physical factors, the density of Euphrate shows positive correlation with clay presence at the depth lower than 65 cm but shows negative correlation with the proportion of sand on soil texture. Relationship between Euphrate and soil chemical factors is high. Trend of woodland and riverbank variations show that periodical floods had displaces river and eliminated significant portion of Euphrate in the border of river during last decades. Ecological rests (such as Principal Component Analysis, PCA) indicate that among edaphic factors salinity, alkalinity, and toxicity of chloride have destructive effects on the growth of *populus alba*. Acidity and lime are not considered as limiting factors. Soil physical factors such as having light soil texture and absence of clay layer at routable depth naturally prevent expansion of *populus alba* to other sites.

KEYWORDS: *populus alba,* Zayandeh Rood, PCA, environmental protection, soil erosion.

INTRODUCTION

Study of *Populus alba* which has natural growing site in Asian countries is important. In some countries such as China and Kazakhstan many studies has been conducted on this issue. From archaism point of view, *Populus alba* is among the oldest species of populus genus; and according to estimations via fossils of this species, its archaism reaches to 3 to 6 million years ago [1]. This species grows naturally in arid and semi-arid zones such as Tarim region in China, Mongolia, Kazakhstan, Turkmenistan etc. chiefly around the river's terraces. In the light of high level of evaporation and collection of sediments of higher levels of rivers, the rate of minerals is high in soils of these places. Further to the factor of soil salinity other ecological factors of the growing sites of *populus alba* including dry climates, low rate of precipitation, hot summer and cold winter, strong winds, high levels of solar radiations, high evaporation, and a range of flood and dryness of river will impact populus dominated lands. These plant societies play an important role in desert ecosystems [1]. Having diverse climates and rivers with periodical floods, Iran is also numerated as a natural growing zone of populus alba especially in the plain areas that rivers appears in winding forms like Karkheh and Karoon rivers in Khuzestan and Atrak and Zayandeh Rood rivers in Isfahan. Also this species is scattered in the form of planted woodlands in vast areas in arid and semi-arid regions and desserts in Iran. The species of *populus alba* plays a major role in soil erosion control, production of foliage, and coal fuel for villagers of desert areas through creating sustainable ecological societies on the rivers' bank. Meanwhile they can protect villages sand cities against sandstorms further to protection of agricultural products from gales and wind sediments. Therefore, it seems necessary this plant societies to be protected by using correct managerial methods. In this connection, identification of limiting factors of these resources and ecological factors

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would be a proper way; this research has been conducted with the aim of identifying the factors creating *populus alba* woodlands and analyzing its changes trends under the pressure of natural and human factors on the bank of Zayandeh Rood river. Further to limiting factors, some obvious ecological characteristics of *populus alba* will be identified through studying the above items. These characteristics will illustrate importance of this species environmentally in arid and dessert zones and in regard to soil erosion control. Also by this study the proper ways for protecting these natural stands will be presented and it will provide necessary grounds for development of *populus alba* in other regions having similar ecological conditions. Modir Rahmati (1994) stated that *P. alba* can tolerate harsh continental climates [2]. The annual precipitation in its natural stands may range from 75 to 200 mm; and dry seasons may last 7 to 8 months or more. *Populus alba* can grow on sandy loam and clay loam soils and tolerates high PH of soils (8-9.9) as well as high density of soluble salts up to 4.53% (in China). Zhang et al (1996) studied the relation between fire and forest in natural stands of *P. alba* as well as climatological factors on the bank of Tarim river; and proved that there is significant relation between one-year changes in natural stands of *P. alba* and winter precipitation in Tianshan mountains. They also found that seasonal changes in these woodlands relate to relative humidity and it's long-lasting. Statistical studies show the frequency of fires in relation to climatologically factors in the period of 1961-1975; and separately for different months of each year [3]. FAO (1979), studied the bacterial impact on logs of white poplar after cutting down of tree [4]. Kaligari et al (1993) studied the impact of genetic changes in white poplar on the rate of production of biomass and its biochemical properties [5]. Seyedi (2009) studied changes in molecular properties of white poplar which may be arisen as the result of accumulation of bacteria; they also studied changes in pressure of molecular oxide [6]. Zhao et al (1997) studied the mixture of seedlings of *P. alba* and *P. Glandulosa* and analyzed the impact of photo on decay of heartwood and sapwood of P. alba [7].

MATERIALS AND METHODS

Library Search This includes preparation of maps, report and gathering meteorological and hydrological statistics and studying scientific papers on subject matter of our research. These papers were prepared and used via CAB, Internet and journals and publications.

Field Operation:

Riparian woodlands of Zayandeh Rood river were visited before sapling on two stages. Generally three working areas were indicated including the most natural stands of *P. alba*.

Region A: This region is known as Pole Marnan (Marnan Bridge) and it is located on the most ending part of Zayandeh Rood river. Its length along the bank of river stands at 6 km and its width ranges from 120 m to 1700 m. this region borders on farmlands on the western side; and a deep canal is located between woodlands and farmlands in this part.

Region B: This region is located near the bank of Zayandeh Rood river in Shamsabad village about 45 km far from southern side of Isfahan city. This region includes separated parcels of Tamarix and mixture stands of Tamarix and *P. alba*. Length of this region along the river is about 7 km and its width in some point is very low and in the widest point reached to about 1250m. This region is also limited to road and water supply canal. Furthermore, along this direction height of the region goes high; and there are some farmlands within these woodlands.

Region C: This a small parcel having a distance more than 1650m from region A. in the last 15 years it has been used as a shrimp farming pool; and it is converted to natural stands of P. alba in the recent decade.

Measurement of Plant Coverage and Environmental Factors

We used random systematic sampling system for assessing plant coverage and environmental factors. Our sampling grid's dimensions were: 500m along river and 150m vertically to river (distance of plots). Dimensions of plots were 10*10m and their numbers were 33 plots (Tables 1 and 2).

Plant coverage factor were: number of trees, height of trees, dbh, diameter of canopy, percentage of total number of white poplars in stands, and number of regenerations; and such factors for Tamarix trees. Also plants in sub-canopy including weeds and shrubs and finally total number of plants in each plot were measured.

Water Resources Factors

These factors in each plot include: elevation from river basin, distance from water canal located between woodland sand farmlands, depth of underground water table, distance from old basin of river, and distance from current basin of river.

Human-Relating Factors

Including cut poplars in each plot, the status of exploitation (grazing and enclosure), and firing in sampling area.

Table 1- List of Factors Measured in Each Plot

Item	Abbreviation Code	Description
1	NO-TRANS	Ref. of transect
2	NO-PLOT	Ref. of plot
3	NO-P	Number of Poplar trees
4	D-P	dbd of *Populus alba* (cm)
5	H-P	Height of *Populus alba* (m)
6	D-C-P	Diameter of canopy of *Populus alba* (m)
7	NO-SA-P	Number of regenerations of *Populus alba*
8	H-SA-P	Heights of seedlings of *Populus alba*
9	%C-P	*Populus alba* coverage percentage
10	NO-T	Number of Tamarix shrubs
11	H-T	Average height of Tamarix (m)
12	D-C-T	Diameter of canopy of Tamarix (m)
13	NO-SA-T	Number of regenerations of Tamarix
14	H-SA-T	Heights of seedlings of Tamarix (m)
15	%C-T	Tamarix coverage percentage
16	NO-HERB	Number of bush species
17	%C-ETC	Number of weed species
18	%TOTAL-C	Percentage of coverage of accompanies plants of P. alba – Tamarix
21	%TOTAL-C	Total coverage percentage in each plot
22	NO-CUT-P	Number of Poplars cut
23	FIRE	Fire percentage
24	MGT	Management status (enclosure or open)
25	D-OLD-R	Distance of plot from old basin of river (m)
26	D-NEW-R	Distance of plot from current basin of river (m)
27	D-CHANEL	Distance of plot from water supply canal (m)
28	H-R	Elevation of plot from river's basin (m)
29	WATER-L	Depth of underground water table (m)

Table 2- Quantity measures in sampling units in different regions

The factors examined															
Name of Marl	NO-TRANS	NO-PLOT	NO-P	D-P	H-P	D-C-P	NO-SA-P	H-SA-P	%C-P	NO-T	H-T	D-C-T	NO-SA-T	H-SA-T	**%C-T**
(A) Marhan Bridge	1	1	12	3	4	1	200	1	80	10	1	1	0	0	**1**
	1	2	8	11	7.18	3	40	0.4	50	80	3	1.2	85	0.6	**70**
	1	3	5	9.75	6.87	3	61	0.5	35	19	4	1.5	26	0.7	**50**
	1	4	3	35	8	3	20	0.3	70	18	3	2	20	0.25	**25**
	1	5	2	12.5	11	3	35	0.5	20	50	3	1.1	65	0.5	**80**
	1	6	2	22.5	7.5	3.75	48	0.5	25	15	2.75	2	18	0.6	**45**
	2	7	5	2.5	2	1.2	12	0.4	20	150	1	0.25	65	0.4	**50**
	2	8	0	0	0	0	0	0	0	16	1.5	1.5	0	0	**20**
	2	9	10	10.1	8.2	3	6	0.8	70	12	3	0.75	0	0	**5**
	2	10	0	0	0	0	0	0	0	80	1	0.8	0	0	**40**
	2	11	13	9.5	4.8	2.7	0	0	70	10	2.5	0.75	12	0.5	**15**
	2	12	0	0	0	0	0	0	0	20	3	2.5	20	0.5	**70**
	3	13	0	0	0	0	0	0	0	80	3	1.2	0	0	**80**
	4	14	0	0	0	0.5	10	0.75	2	100	2	0.8	50	0.4	**75**
	4	15	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	5	16	0	0	0	0	0	0	0	100	3.5	1.5	0	0	**100**
	5	17	2	26.5	8.5	4.25	7	0.5	35	40	3.5	1	0	0	**35**
(B) Shams Abad Bridge	1	18	0	0	0	0	0	0	0	120	1.5	0.9	0	0	**80**
	2	19	1	25	16	7	3	0.6	50	27	1.5	1	0	0	**80**
	2	20	6	13.5	5.8	3.4	16	0.8	50	10	2	1.2	0	0	**10**
	2	21	4	14.25	5.1	3.2	3	0.5	35	110	2	0.8	0	0	**55**
	3	22	0	0	0	0	0	0	0	100	3	1.2	0	0	**95**
	4	23	1	35	14	5	3	0.4	25	100	3	1.15	0	0	**95**
	5	24	0	0	0	0	0	0	0	110	0.8	0.75	80	0.4	**75**
	5	25	2	25	8	4	0	0	35	103	2	0.6	0	0	**25**

	5	26	2	12	3.5	3	0	0	15	42	2	1.1	0	0	**40**
(C) Shrimp pond area	1	27	2	13.5	4.5	3.6	0	0	15	4	2	1.2	0	0	**5**
	1	28	3	10.6	3.6	3	0	0	25	7	1.6	1.2	0	0	**10**
	1	29	5	10	3	3.2	35	1	50	0	0	0	0	0	**0**
	1	35	0	0	0	0	0	0	0	95	1.5	1.1	0	0	**85**
	2	31	2	18	6	5	10	0.5	35	20	1.7	1.5	0	0	**35**
	2	32	12	14	12	3	8	0.4	80	20	1.5	1.5	0	0	**10**
	2	**33**	**1**	**9**	**3.5**	**3.4**	**0**	**0**	**10**	**26**	**1.5**	**1.5**	**0**	**0**	**40**

Soil Sampling:

Whereas these lands are alluvial lands in which sedimentation have occurred in different stages and in different years, and whereas they show much diversity in such an extent that it is probable sedimentary layers with near ages being different, we took sample with auger in three depths (0-35, 35-65, and 65-95).

Laboratorial Operations

Considering high volume of soil samples and limitation of laboratorial facilities at this stage we tried to measure those factors limiting quality of soil which may cause decrease in growth of plants. Hereinbelow we describe methods of measurement as well as the said factors.

Soil Texture Measurement

For setting out ratio of solid particles (gravel, slit and clay) in soil samples, we used mechanical analysis. At the said method called Bouyoucos, different soil particles were classified in accordance with their deposition rates.

Measurement of Saturation Percentage (SP)

For measuring SP we prepared a saturated mud from soil samples and put it in an already weighted capped vessel and then weighted the vessel. After then we put the saturated mud in an oven with 110°C during a period of 24 hours and calculated SP of soil sample by the following formula:

SP= [(weight of saturated mud – weight of dried soil)/(weight of dried soil)] * 100

PH Measurement

Reaction of soil and water or PH is one of the most important chemical characteristics which is a function of concentration of ions of solution. This factor may be calculated by many ways. At this research we measured PH by a digital PH meter because of a higher speed and precision in comparison with other methods.

EC Measurement

For measuring EC of water samples of saturated mud we used EC meter. Therefore, after setting up the device we at first set out EC of standard solution (0.1 Kcl normal) and recorded its temperature. Then having used the relevant conversion table, we calculated Electrode Correction Coefficient (K) by this formula: K= C/CR

Calcium and Magnesium Measurement ($Mg^{2+} + Ca^{2+}$)

Ca and Mg were measured via complexometry method with versin solution (EDTA). In the said method, total amount of Ca and Mg ions were calculated on the basis meq/l by the following and considering the volume of the used Versin solution:

($Mg^{2+} + Ca^{2+}$) = [(normality of versin*volume of versin)/volume of tested extract]*1000

Then the amount of Ca ion (according to me/l) was calculated separately through calibration with versin and the amount of Mg ion was calculated through finding the difference of ions of Ca and Mg.

Measurement of Na^{+}

Na of samples was determined through flame photometry by flame-photometer. In the light of privileges this method has in terms of precision, speed, and no need to reagent and any special chemical solutions, it has priority for measurement of Na.

Measurement of Cl

The rate of Chlorine was measured via calibration silver nitrate $AgNO_3$ in the presence of potassium nitrate as reagent

Measurement of $CaCo_3$

The amount of lime of soil samples was determined by calibration with 15% sodium hydroxide.

Calculation of Sodium Absorption Rate (SAR)

SAR was calculated by the following formula. In this formula, Na, Ca, Mg. are solute cations according to eg/l.

$$SAR = \frac{NA^{=}}{\sqrt{(CA^{2-} + Mg^{2-})}}$$

Table 4. The sampling results of the measured factors

Name of	Sp%			Ph			EC(mm ho/cm)		
A1-S1	62.46	69.31	-	7.97	7.3	7.9	13.8	10.37	-
A1-S2	52.08	44.23	37.52	7.69	7.57	7.55	3.85	5.41	**7.41**
A1-S3	39.5	35.51	-	7.48	7.58	-	5.42	3.61	-
A2-S1	35.77	33.54	62.59	7.84	8.05	7.41	0.58	0.47	**2.31**
A2-S2	57.6	62.95	59.4	7.48	7.6	7.4	4	6.07	**6.48**
A2-S3	40.37	-	-	7.72	-	-	5.19	-	-
A4-S1	24.5	35.76	34.83	7.84	7.96	8.11	1.68	0.66	**7.39**
A5-S1	49.57	35.91	28.08	7.83	7.73	7.88	25.67	7.59	**6.18**
B1	38.52	46.42	36.91	7.57	7.71	8.42	2.14	7.59	**7.38**
B2-S2	38.88	44.12	37.86	7.32	7.8	8.07	5.19	10.16	**8.34**
B2-S3	42.97	40.82	40.7	8.01	8.01	8.05	45.99	41.71	**25.16**
B2-S4	42.97	40.82	40.7	8.01	8.01	8.05	45.99	2.97	**12.64**
B3-S1	33.08	24.76	34.32	7.93	8.19	7.82	1.71	2.97	**12.64**
B4-S1	65.72	54.73	58.31	7.89	8.22	8.23	14.07	14.68	**15.29**
B5-S1	34.8	35.6	-	7.97	8.15	-	17.11	21.39	-
B5-S2	40.15	34.95	34.27	8.1	8.05	7.94	13.05	5.56	**7.81**
C	**46.63**	**41.84**	**79.56**	**7.57**	**7.73**	**7.85**	**1.09**	**3.69**	**1.6**

Table 5- The chemical and physical sampling results of soil samples (in three depths) in natural stands of *P. alba* and Tamarix

Name of Soli	SAND	SILT	CLAY
	0-35	35-65	**65-95**
A1-S1	Silt clay	Silt clay	-
A1-S2	Loam	Silt loam	**Silt loam**
A1-S3	Silt loam	Silt loam	**Silt loam**
A2-S1	**Silt loam**	**Silt loam**	

Assessment of Declines in Surface of Natural Stands of *P. alba*

For studying this factor we prepared maps of these stands in different years. So, boundaries of woodlands of *P. alba* and the river were indicted in accordance with a 1:50000 map. Then boundaries of woodlands of *P. alba* and Tamarix as well as boundaries of the river were indicated by aerial (satellite) photos taken in 1989 with the scale of 1:50000. The third map was drawn in accordance with the data registered in this region and measurement of width of parcels during field operation.

Conclusion

Analysis of Data

At this stage, all data gathered in library studies, field studies and laboratorial operations were entered into computer via Excel and the necessary graphs and charts were prepared with this software.

Some results were presented in descriptive form; but for statistical analysis of data we used Statistical software. We used correlation analysis, t test, different ways of classifications, PCA analysis method for better understanding of relations of environmental and biological factors.

1- Effective Factor on Formation of *P. alba* Woodlands in the Region:

Generally, natural dispersion of *P. alba* is closely related to humidity resources such as riverine flows, underground water table, and annual floods. These conditions are visible along riparian areas of Zayandeh Rood river. In accordance with the conducted studies and land classification maps (Yousefi, 2004) woodlands of *P. alba* are dispersed is regions having 3 to 4 floods per year [8]. Also it is believed that the flooding plain had less elevation difference with riverine basin in the past; and in flooding times the plain would be faced with outburst of water flow. Furthermore, twisting shape of Zayandeh Rood river in the areas of establishment of woodlands of *P. alba* is another factor creating these woodlands, because such conditions create a natural impediment along river and cause outburst of floods to the riparian areas and then calming riverine water flow; finally leading to more influence of water into these areas. Another factor causing existence of these woodlands especially in dry years is underground water table which is high in these areas. Trees near the area). This area is far from river and it is less dependent to riverine water flows.

2- Modality of Dispersion of *P. alba* in the Region:

In general *P. alba* is dispersed on the bank of Zayandeh Rood river in flooding plain and in the areas with high underground water table; and it is dispersed in compact stands and sometime in mixture with Tamarix trees. Of course, in young stands number of *P. alba* is more than Tamarix trees and at the stand ages number of density of P. alba will decrease and will reach to one per 100 m² or more and the spaces between will be occupied by Tamarix trees.

3- Regeneration of *Populus alba* in the Region:

According to the studies it seems that in all areas of our research i.e. Marnan Bridge area (A), Shams Abad village (B), and Water Reservoir Pool (C), natural stands of P. alba have regenerated by seed germination, but currently these young, matured, and aged stands are regenerating through root sprouts. Should Poplar trees be in danger for any reason by physical factors (cutting, firing etc.) or by wild animals such as pigs, they rapidly increase root sprouts. In Marnan bridge area where fire occurred in natural stands of *P. alba* root sprouts increased rapidly so that we could see 10 to 20 sprouts with the distance of 6 to 7 meters in each tree. This fact shows expand surface root development in this tree.

4- Growth of *P. alba* in Isfahan Region:

Growing sites of P. alba in Isfahan region exist in two natural and cultivated forms; natural stands of P. alba exist on the bank of Zayandeh Rood river accompanied by Tamarix woodlands, the growth status of which has been presented in Table 6, representing the data resulted from measurements of sample plots. In general, there is significant positive correlation between dbh, diameter of canopy and height of Poplar trees, standing at 84% and 81% respectively (image 5-3).

Table 6- Growth Status of P. alba in the measured plots

Factors Measured	Maximum	Average
Number of P. alba trees	13	4
Height (m)	15	7
Diameter at breast height (cm)	35	15.4
Diameter of Canopy (m)	7	3.4

The biggest P. alba tree measured in nature had the dbh of 45 cm, the height of 15 m and the canopy diameter of 7 m. seedlings on the bank of river were dried as the result of riverine drought and light soil texture while growth of young seedlings of tamarix were proper. Dryness of river have had impact on riparian pure young stands of *Populus alba* so that their lower branches may be dried out and fallen and compactness of them may decrease. Trunk of old trees may decay and become hollow inside and their branches may be fallen as the result of wind or activity of termites leading to decrease of canopy. In general, young seedlings have good growth in loamy soils with high percentage of clay and have mere good stability because of high humidity of soil and soil's maintenance capacity.

5- Accompanied Flora of Natural Stands of *P. alba* – Tamarix

According to Chen (1983), plant types in different woodlands of *P. alba* are similar i.e. they are composed of some distinct species and therefore they have a simple ecological structure. These plants are chiefly xenophile and homophile [9].

According to the mensuration carried out in woodlands of *P. alba* in Isfahan, these ecosystems have few biodiversity and are formed by few plants. The upper story is mainly dominated by *P. alba* and Tamarix tees and other companion plants are some species of shrubs and bushes and finally the lower story is dominated by grasses and annual halophytes.

6- Inter-Species Correlation Estimation

Two species show correlation between them when 1) both select and/or avoid a same habitat. 2) both have the same biotic and/or abiotic needs. 2) One or both show correlation with other species or avoid from other species [10]. Therefore, in the light of the fact that the dominant flora is comprised by Tamarix and Poplar trees which are found in mixed form or separately, we used the method of "presence, absence" for estimating correlation between them.

7- Changes in Surface of the Studied Stands

The areas (surfaces) of woodlands of *P. alba* and Tamarix trees within the studied areas have been presented in table 7- in accordance with the maps of 1955, satellite photos of 1989 and the estimation performed in 1999:

Table 7- Total area of stands studied in Marnan Bridge area and Shamsabad village in different years (area in hectare)

Shams abad village	Marnan Bridge	Year
216	495	1334
259	395	1378
123	297	1388

These areas include plant coverage with typical flora of *P. alba*, and mixed flora of P. alba and Tamarix trees which were typically classified by satellite photos in 1989 and by field operation in 1999; in table 8 changes in typical woodland of *P. alba* – Tamrix has been indicated.

Table 8- Surface of typical woodlands of *P. alba* – Tamrix in Marnan bridge area and Shams Abad village in hectares

Shams abad village (Hector)	Maran Bridge (Hector)	Year (Hector)
117	88	1378
88	68	1388
%25	%23	Discount percent

Anyway, the rate of decrease in surface of woodlands, especially typical woodlands of P. alba – Tamarix, during the period of 1955 to 1999 was remarkable.

8- Changes of River within the Area

In the light of flooding regimes in different years, riparian erosions increase width of river so that its width has been reached to 370 to 420 m in some areas. During the years in which river is calm within the riparian terraces tamarix and poplar trees regenerate and during flooding years they will be devastated and new places will be prepared for regeneration. In the years 1991-92 a flood with a maximum discharge of 950 m^3/s occurred in Marnan Bridge area that caused drastic changes in the river's route.

Table 9- Surface area of river in the regions subject matter of our research during different years

1378	1368	1342	Area name
219	85	98	Maran Bridage (Hector)
358	276	122	shamsAbad Village (Hector)

For better analysis of displacement of river's basin, we analyzed it by t-test through comparison of the status in 1989 and the status quo (Table 10). The results show that this displacement is meaningful significantly on 5% level.

Table 10- Statistical analysis of displacements of basin of Zayandeh Rood river in the regions subject matter of the research

Significant level	Freedom degree	T	Standard deviation	Difference	Number of samples	Standard deviation	Average	Old and new river's basins
OLD-R	552.879	775.543	775.543	-				
NEW-R	695.455	726.615	726.615	142.576	261.761	-3.129	32.000	0.004

9- Analysis of Riparian Underground Water Table

Underground water table near Zayandeh Rood river from Marnan Bridge area to Shams Abad village was studied via data of piezometer wells, released by Water Supply Organization, the result of which is as follows (Table 11):

Table 11- Changes in Underground Water Table near Zayandeh Rood river

Name of Well	Number of Statistical Years	Average of water table	Standard deviation	Percentage of changes
Isfahan	4	11.97	1.45	12.1
Ghoush Sarizi	5	14.9	48%	3.2

As it is clear, the minimum depths of underground water is in Marnan Bridge area and Shams Abad village; of course, there is some distance from wells up to the borders of woodlands, however, considering altitudinal gradient, underground water table is higher in woodlands. Therefore, one of the main reasons of creation and existence of woodlands of P. alba is underground water table; and as we see P. alba faces with restriction in growth in distance between Marnan Bridge area and woodlands around Shamsabad (Norouz Abad) village where underground water table goes down.

10- Relation of *P. alba* and Water-Related Factors

In this connection, we analyzed correlations of such factors as depth of underground water, height from river's basin, distance from water supply canal, and distance from old and new river's basins with percentage of plant coverage, and number of regenerations [2]. In this basis, factors relating to *P. alba* show negative correlation with distance from old river's basin; and positive correlation with distance from new river's basin. Therefore, as distance of new river's basin decreases with woodlands of P. alba, the surface area of such woodlands decreases; but when the distance of old river's basin with woodlands of P. alba decrease the surface of woodlands increases. This fact clears that woodlands of *P. alba* have been created under effect of old river's basin, but they would be devastated by floods of new river. Correlation of *P. alba* and water supply canal was also positive; as distance with this canal increases, woodlands of P. alba increase because of closeness to river. Furthermore, this canal is created by man and its route has had impact on woodlands of *P. alba*. Such canals may play a major role for supplying water for these woodlands at the time the river dries up. Depth of underground water and latitudinal difference of woodlands and river's basin show negative correlations especially in terms of regeneration of P. alba so that as this depth decrease natural regeneration increases.

Table 12- The rate of correlation of number, coverage percentage, and regeneration of P. alba with water-related factors

	distance form old river's basin	distance from new river's basin	distance from water supply canal	height from river's basin	underground water table
NO-P	0.344	0.220	0.342	-0.016	-0.148
%C-P	-0.263	0.233	0.254	-0.063	-0.095
NO-SA-P	-0.069	0.195	0.416	-0.158	-0.195

11- Human Factors effective on Woodlands of *P. alba*

Wang Shiji (1970) has introduced such factors as cutting poplar trees for using as fuel, using this tree for feeding livestock, and conversion of woodlands into farmlands as the effective human factors on devastation of woodlands of P. alba. We also will introduce some importance factors after assessment of factors in Isfahan region.

12- Agricultural Activities:

In the light of existence of underground water and capable farmlands in Isfahan alluvial plain and existence of Zayandeh Rood river as another water supplying resource, agricultural activities face with prosperity along the bank of river; and it shall be numerated among limiting factors of woodlands of *P. alba*. Region C is completely surrounded by farmlands. Region A borders on the river on one side and on farmlands on the other side; and Parcels B is limited to the river on one side and to the road on the other side; and farmlands have been located between parcels of woodlands of *P. alba* and Tamarix trees and separated them from each other.

13- Exploitation through Cattle Grazing

Considering that leaves of *P. alba* and its seedlings are very tasty for livestock, grazing would impact regeneration of this trees, both seedlings and sprouts and would prevent development and regeneration of these woodlands. In Isfahan two regions of A and C are surrounded by National Resources Agency as protected areas; but region C is free for grazing.

14- Cutting of Poplar Trees

Whereas rural areas and human centers are close and/or adjacent to natural stands of *P. alba*, villagers and livestock breeders cut trees illegally for preparing fuel and shelters both for themselves and for their livestock.

Table 13- Percentage of Cut Trees by Man in the Regions under Study

Name of Region	Marnan Bridge Area (A)	Shams Abad Village (B)	Shrimp pond area -Region (C)
Percentage of Cut Trees	13.80	23.80	65.30

15- Fire

According to local information, in some parts of region fire has taken place in the past years. In the year of this research (2010) many parts of rangelands and woodlands of *P. alba* in Marnan Bridge area faced with fire and many strong trees of P. alba and Tamarix devastated; furthermore we reached to the following facts:

White poplar is more resistant to fire than Tamarix trees in such an extent that we could see in the areas that Tamarix trees were burnt and devastated, poplar threes could exist whether their trunk faced with damage. In these areas canopy of poplars were remained sound and healthy.

16- Saturation Percentage

This factor is affected by soil texture; and it shows more standard deviation in the depth of 65-95 cm than other layers, meanwhile SP in this layer is more than other layers. SP in the depth of 65-95 shows a positive correlation with number of percentage of *P. alba*; but it shows negative correlation with number of tamarisk trees. This correlation is significant on 5% level.

17- Soil PH

Soil PH is high in this region and stands at an average amount of 7.7. This factor shows low standard deviation; the maximum PH stands at 8.42 and the minimum one stands at 7.3. There is not statistical correlation between number and percentage of poplar and tamarisk trees with soil PH.

18- Electrical Conductivity (EC)

Javanshir (1997) believes that tolerance range of *P. alba* against EC and Na is expand [11]. The results show that the range of changes of EC in woodlands of *P. alba* in Isfahan region is approximately high i.e. from 0.5 to 46 mμ; and its average stands at 8.9. From the statistical point of view correlation of number and percentage of coverage of *P. alba* with EC is weak and negative; but it is positive with number and percentage of coverage of tamarisk trees on significant level of 5%.

19- SAR

This factor is achieved through calculation and measurement of Na, Mg, and Ca. The average of SAR=14.84 in the region is high especially in the depth of root development of P. alba i.e. 65-95 cm; and its maximum rate is in surface layer that stands at 45.20 representing sodium-rich soils. From statistical point of view correlation of SAR with percentage of *P. alba* is negative but it is not significant on 5% level. However, this correlation is positive and significant on 5% level for tamarisk shrubs.

20- Cations Measured in Soil

Ca, Mg, and Na, are the main cations of soil which were measured here. Their range of changes shows that this region has a broad range of such changes, especially in regard to Na. their high rate shows salinity and alkalinity of the region. Coverage percentage and number of *P. alba* trees correlate negatively with sodium (Na) and calcium (Ca), not significant on 5% level. But these elements correlate positively with coverage percentage and number of tamarisk shrubs and it is significant on the said level. However this correlation is positive with Mg but it is weak.

21- Lime ($CaCO_3$)

On the strength of the research conducted in the natural sites of *P. alba*, accumulation of lime in the layer of root expansion of this tree increases because of an increase in water absorption [1]. In general, the range of changes of lime in sampling areas is low and stands at a maximum ratio of 3.4%. According to statistical analysis, the quantity of lime in depth of 0.35 has positive correlation with number and coverage percentage of *P. alba* on significant level of 5%.

22- Chlorine (Cl)

This factor has significant impact on soil quality especially that it may cause toxicity in soil. Therefore, those species tolerant to a broad range of changes in Cl shall be importance in desert areas. Cl in the region subject matter of our research fluctuates in a broad range with a high standard deviation rate. Its standard deviation in surface layer stands at 101, the maximum rate of Cl stands at 422 meq/l, its minimum stands at 3meq/l and its total

23- Soil Texture:

In general, soil texture of the region is Silt Loam, in such an extent that the maximum percentage of soil particles in three depths of soil is silt, and gravel and clay stands at the next ranks. This fact shows light texture of soil. However, changes in the region and in all depths of samplings range broadly. Statistically, percent of gravel in the depth of 65.95 and percent of silt in the depth of 0.35 negatively correlate with number of percentage of coverage and were significant on 5% level; and percent of clay in the depth of 65-95 cm positively correlates with the said parameter, significant on 5% level. But tamarisk shrubs negatively and significantly correlate with percent of clay in the depth of 65-95 cm and positively with percent of gravel in the same depth. Therefore, whereas this depth (65-95 cm) I the main layers of root expansion of P. alba, clay layers in this depth shall be importance of this tree because of its high capacity of water keeping and it may bring sustainability for natural stands of *P. alba*.

24- According to Biophysical Parameters

These parameters include all factors relating to flora in sample plots. We used Clustering Analysis as an ecological method and numbers of classes were indicated according to flora factors. At this method, we classified biophysical factors via unsimilarity index of Euclidean Distance and combining of classes through weighted averages (graph 5-2). The results show that a major part of plots with few differences have been put in two separated classes; and few of them depend to not class. Therefore, plots with dominant flora of tamarisk were classified in one category and those dominated by *P. alba* were classified in another one. Plots numbers 1, 23, 7, and 25 having special presence of *P. alba* (dominant species) with companion plants were classified separately.

25- Classification in accordance with Physical and Chemical Factors of Soil

These factors are all physical and chemical features resulted from analysis of soil samples in three depths of 0-35, 35-65, and 65.95 cm. using clustering method via Euclidean Distance and mixing classes via weighted averages, we found that the sampling units have not been separated from each other by a special pattern. However, some differences were clear among plots

26- Classification of Region According to Hydrological Factors

Factors used in this part, include distance of sample plots with old and new basins of the river, altitudinal difference of region and river's basin, and underground water table. For this purpose, we used clustering method and reached to two lasses. Plots 27 to 33 were categorized in one class. These plots are in Region C at the most distance from river. Second class indicates Marnan Bridge area (A) and Shams Abad village (B). In this class four groups of plots are identifiable based on Euclidean Distance; plots of Marnan area (8 to 26) were categorized in one group.

27- Determining the main factors in natural sites of *P. alba*

We used Principal Component Analysis (PCA) for determining main biological and environmental factors of natural sites of *P. alba* which were measured in all plots. For the first time Ziaei and Fakhreddin (1992) used PCA method for analysis of data in ecology [12]; but this method was innovated by Framine and Hughes (1995) [13]. PCA is a multivariable technique which is consistent with internal structure of matrixes and it is usable in computers.

Pak Parvar (2010) analyzed characteristics of 14 natural sites of *P. alba* and 32 environmental factors in 40 plots via PCA technique [14].

28- Determining Main Biophysical Factors (Flora)

Upon using PCA technique we could identify five main biophysical factors (table 14). According to data, 5 main parameters were the main cause of 77% of changes out of which 26% was related to the first parameter; 17% to the second one, and the remaining part to three other parameters.

Table 14- Special quantities of main parameters by using biophysical data

Main parameter	Special quantity	Percent of total variance	Special cumulative quantity	Percent of cumulative variance
1	4.37	25.94	4.67	25.94
2	3.36	18.68	8.03	44.63
3	2.27	12.59	10.35	57.22
4	1.96	10.88	12.26	68.10
5	1.64	9.14	13.95	77.24

The result of PCA shows that there is no effective biophysical factor and we may not indicate one or more factor(s) for separating *P. alba* societies. But on the strength of Eigenvector matrix and correlation of biophysical factors with the first to fifth parameters, the following factors show the maximum correlation with the first parameter respectively: percentage of coverage of *P. alba*, diameter of canopy of P. alba, and height of P. alba. Meanwhile, height of seedlings and shrubs of tamarisk had the most correlation with the second parameter; and the third to fifth parameters had no considerable correlation with biophysical factors .Therefore, it was revealed that the studied natural sites were under impact of the first parameter whereas they were homogenous. Therefore, regional factors relating to *P. alba* had special importance and were under impact of changes.

29- Determining Main Factors Relating To Soil (Chemical and Physical)

We used PCA method for determining main and decisive factors out of 13 chemical and physical factors of soil which were measured in three depths of soil. At this analysis 7 main parameter were indicated which would describe 87.8% of all changes. Share of the first parameter is 40.5%. Therefore, the major effects arise by those factors that have significant correlation with the first parameter. The second parameter had 17% impact. Other parameters had lesser impacts.

We used Eigenvector matrix for determining main factors having a good correlation with the first and second parameter. On this basis EC, Cl, Na, Mag, and SAR factors had a high correlation of 70% with the first parameter; representing that major changes of natural sites of P. alba are under effects of these factors. Also physical factors of soils such as soil textures including gravel, silt, and clay as well as soil SP, which is also under the effect of soil texture itself, had a high correlation of 70% with the second parameters especially in the depth of 0.65 cm of soil. These factors cause the most changes in natural sites of *P. alba* after the factors of the first parameter.

30- Determining Main Hydrological Factors

We used 5 hydrological factors in this regard: distance from the new and old basins of the river, distance from water supply canal, and height from basin of the river, and underground water table. Using PCA method, two main parameters were jointly determined that would describe 71% of changes of total data. Share of the first parameter was 50% and that of the second parameter 21% (table 15). Therefore, those factors having significant correlation with the first parameter could have impact on changes of natural sites of *P. alba*. Therefore, we determined the correlation rate of factors with main parameters via matrix of eigenvectors (table 16). Results show that underground water table and height from basin of the river have the most correlation with the first parameter and therefore they are introduced as decisive factors out of the said factors.

Table 15- Main parameters and their special quantities according to hydrological factors

Main Parameter	Special Quantity	Percent of Total Variance	Special Cumulative Quantity	Percent of Cumulative Variance
1	3.49	49.84	3.49	49.84
2	1.47	21.07	4.96	70.91

Table 16- Matrix of Eigenvectors and correlation of hydrological factors with main parameters
(Factors having more than 0.7 correlations with main parameters have been marked here)

	Index I	Index II
D_OLD_R	0.662	-0.366
D_NEW_R	0.661	0.465
D_CHANEL	-0.435	0.775*
H_R	0.897*	-0.096
WATER	0.868*	-0.295
Exp.var	3.489	1.475
Prp.Totl	**0.498**	**0.211**

31- Determining of Final Main Factors in accordance with Environmental Factors

In this connection, we selected those factors which had the most correlation with the first and second parameters out of physical and chemical factors of soil and hydrological factors; and again we tested them via PCA method (table 17). In total, 5 main parameters were achieved that describes 87.2% of total changes. Shares of the first and second parameters were 50% and 17% respectively. Therefore, main changes are under effects of these two parameters especially the first parameter.

Table 17- main parameters and special quantities in accordance with main environmental factors

Main Parameter	Special Quantity	Percent of Total Variance	Special Cumulative Quantity	Percent of Cumulative Variance
1	13.98	49.93	13.98	49.93
2	4.794	17.122	18.776	67.056
3	2.255	8.053	21.035	75.0109
4	2.017	7.204	23.048	82.313
5	1.386	4.494	24.433	87.262

Then, the rate of correlation of the analyzed factors with main parameters was calculated in accordance with Eigenvector matrix (table 5-18). On the strength of this analysis, the first parameters had the most correlation (more than 70%) with chemical factors of soil such as EC, Cl, Na, Mg and SAR. The second parameter had a good correlation with physical factors such as SP, and percentage of gravel, clay and silt; and the third parameter had no significant correlation with nay factor.

RESULTS

However, the fourth parameter had a good correlation with such factors as underground water table and elevation from basin of the river; and the fifth parameter had no correlation with any factor. Therefore, we can consider the above factors respectively as the most important factors having impact on natural sites of *P. alba*. Considering that among biophysical factors, Poplar-related factors had a high correlation with the first parameter as indicted by PCA method, the above environmental factors shall have the most effects on the poplar-related factors. By virtue of correlations tests, these environmental factors mainly had negative relation with number of percentage of *P. alba*; therefore, they will finally limit the growth of P. alba in this region.

Considering climatologically conditions of Isfahan region which is adjacent to desert and dominant wind directions which is mainly northerly and northeasterly and in some months it may bring sandstorms and dust to Isfahan city and its farmlands from the south, this fast-growing species which is properly adapted to the conditions of this region would control the negative impact of strong winds and storms. As it is measured in Region C with the age of 15 years, some poplar trees exist with the height of 12 m, canopy diameter of 5 meter and dbh of 18 cm, showing its fast growth. As it is mentioned in conclusion section, such human factors as agricultural activities, cutting of polar trees, livestock grazing and fire would impact these woodlands. In region A (Marnan Bridge area) during the years 1955 to 1989 i.e. a period of 35 years 100 hectares of woodlands have been converted into farmlands; but the region C is limited to farmlands on one side and ongoing agricultural activities would prohibit development and expansion of woodlands of P. alba. Cutting of poplar trees is under the effect of human activities such as preparing shelters for either man or livestock and providing fuel. Region C is surrounded by farmlands for this purpose and it faced with the most cutting percentage. Region B stands at the second rank because of adjacency to some villages; and finally Region A faced with the fewer cuttings because it is located far from human centers and it is surrounded as a protection area.

The role of protection of woodlands of *P. alba* for development of these areas is not tangible because in practice the protected areas may also be used for grazing illegally. This fire stimulated root sprouts and whereas rooting system of this tree is spread on surface of soil, they rapidly would give sprout. Considering huge quantities of these sprouts around each tree, we would expect to see more dense poplar trees in the future.

Hydrological factors such as the existence of river and underground water table hall have important role in creation of woodlands of *P. alba*; and again any changes in these factors shall have a major role in limitation and/or development of such woodlands. Woodlands of P. alba were on the bank of the river in those areas which might be faced with floods once per each two or three years in accordance with the report of Department of Penology and Land Classification; and the researchers conducted by some researchers (study of references and generalities of P. alba) have proved that one of main factors for development of natural woodlands of P. alba is dispersion of seeds by floods. Furthermore, high underground water table would play a major role in development and existence of these woodlands. In Isfahan region there is no much change in underground water table but erosion of the river's basin has be resulted in increase of the altitudinal difference between woodlands of P. alba and basin of the river so that floods would not be reached to these woodlands and this may impede development of woodlands and establishment of new woodlands of P. alba and promotion of growth of this tree.

On the other hand, dislocation of river's basin may have much impact on woodlands of *P. alba*. During the years 1989 to 1999 the most changes have been occurred in the route of river, especially in the areas that the said woodlands exist. In such areas the slope of river decreases and it may be twisted and its route would be changed under the effect of floods. Such change has been occurred by a huge flood in the years 1991-92, and resulted in the erosion of side riparian terraces as well as erosion of basin of the river. About 35% of riparian woodlands were devastated by this flood. Displacement of basin of the river was significant and indicated by a t-test. Of course, in case river faces with a peace for a long time and there is a reliable humidity for woodlands, the new ones may be formed along the bank of the river.

Although water supply canal near woodlands of *P. alba* is a resource of humidity for them, but near this canal density of such tree decreases because of cutting by man. In the recent years, reduction of precipitation, especially snow, has been resulted in a decrease in riverine water flow. In general, sampling units shall be divided into two groups: 1. with dominant flora of tamarisk trees and 2- with domination of mixed woodlands of P. alba and tamarisk; because pure stands of P. alba is very low and they are mainly mixed by tamarisks; and parcels with pure tamarisks are situated between typical stands of P. alba.

Sampling units in the studied area have not been situated in completely separated classes in term of soil factors. This fact shows diversity of soil in depths and different points of sampling area; and range of changes of some physical and chemical factors is very broad and the region is under effect of them. Among these factors we may name Na, Mg, Cl, and EC. Generally, soils of this region are saline soils; and in some areas they may tend to alkaline soils as we measured their SAR. Such range of changes shows that *P. alba* is very tolerant to the range of changes of the said factors. In some region with high rates of salinity, sodium and toxicity of chlorine, number of poplar trees may decrease and their growth will weaken (tending the leaves to yellow and premature fall) but they have not been eliminated completely because there is sufficient humidity accessible for them as it is cleared by our research. This humidity reached to them through water supply canal so that the soil even in deep profiles is wet and humid. High humidity in soil increases tolerance of poplar trees; furthermore, this matter caused accumulation of materials i.e. existence of humidity in deep layers of soil and evaporation of such humidity will lead to accumulation of materials and minerals in on-meter depth profile. Whereas this region has not been faced with flooding, the materials and salts have not been washed out. In general, correlation of biologic factors of *P. alba* with the said elements in different depths is negative while they have positive correlation with tamarisks. Therefore, tamarisk trees have been developed in this region vastly.

The results of field observation and statistical tests show that *P. alba* would have a good germination in different soil textures in terms of physical factors of soil; but in silt loam, silt clay soils it may be established better with successful germination of seedlings; while in light-texture soil, seedlings would intend to dry after termination and growth. This is because of the fact that *P. alba* is more sensitive to humidity than other factors and it would develop surface root system. Therefore, those types of soils that have a heavy texture in rooting depth of P. alba, is more proper than light soils because they would main high amount of water and humidity. But tamarisk shrubs with their deep roots would grow on different soil textures and even can grow more successfully in light soils.

X^2 test between two species of *P. alba* and Tamarix spp. showed that they are not related to each other in terms of presence or absence in stands. Therefore, they would grow in the same ecosystems. However, ecological range of Tamarix spp. is broader than ecological range of P. alba i.e. Tamarix species would live in a range of ecosystems with different environmental factors; therefore we would see tamarisks shrubs in natural stands of P. alba but in those areas which P. alba may be eliminated because of environmental conditions, tamarisks would occupy the region thanks to their tolerance to different environmental factors. In physical terms of view in the recent decade the huge floods causing side riparian erosions were the most important factor that decreased natural stands of *P. alba* in Marnan Bridge area (A). By erosion of basin of river, water would contract directly with the loose lower layers and would erode them simply; then riverine terraces on which poplar and tamarisk trees grow may be fallen down into river resulting drastic side erosion of the river.

In statistical point of view, (analysis via PCA method) the chemical factors of soil such as Cl, Mg. Na, and EC are the main effective factors on woodlands of P. alba; after then physical factors of soils are the most important one and at the third rank hydrological factor and change of route of river stand. On the other hand, in accordance with PCA statistical analysis of biological factors in sample plots, these factors were indicated as main factors impacting existence of Poplar trees; therefore, change in environmental conditions would impact growth of *P. alba*. Of course, changes in soil texture would limit establishment of *P. alba* but it may not change in short distances and therefore it has not vast impact on these woodlands. But chemical factors of soil such as salinity, alkalinity and toxicity of chlorine would impact such trees vastly and would decrease growth of poplar trees; and whereas tamarisk shrubs are more tolerant to such factors (as indicated by statistical tests, they have positive correlation with the said factors despite *P. alba*) and would simply substitute P. alba. Currently, some factors as decrease in river's water flow and altitudinal difference of woodlands and river's basin, change in river's route which is itself the result of side erosion of river's basin, would lead to drastic evaporation, drought of lands because of remaining far from floods, insufficient feeding of underground waters by fresh water of the river, and accumulation of salts and minerals in surface layers of soils. Furthermore, poplar and tamarisk trees expel these materials via their aerial parts as a resistance mechanism which exacerbates the situation.

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