

Zoning and Quantitative Evaluation for Safflower

¹Shahryar Dashti, ¹Iraj Alahdadi, ²Seyed Mahmud Reza Behbahani and ²Mohammad Hadi Nazarifar

¹Department of Agronomy and Plant Breeding,

²Department of Irrigation and drainage Engineering, College of Abouraihan, University of Tehran, Iran

Abstract: In this study productivity potential of safflower has surveyed in lands of East Azerbaijan province, Iran. For this reason long term climatic data of 17 climatological and synoptic stations inside the province were used. The most proper planting date was suggested based on the beginning of rainy season in each part of the province, and the different growth stages of dry land safflower were determined. For estimating productivity potential used presented method by FAO. Weighing to agro ecological parameters carried out by Analytical Hierarchy Method (AHP). This procedure has been widely documented in a variety of problem area that has been not used extremely in agricultural decisions in developing countries. Coefficient of determination between predicted and observed yield ($R^2 = 0.51$) showed acceptable estimated data. Results indicated that about 1.6% was highly suitable (S_1) for safflower cultivation, contain Marand and Jolfa region. East of Tabriz and Varzaghan, and Charavimagh about 16.4% of the area, were moderately suitable (S_2), but had limited due to insufficient precipitation. An strip region from north east of province (Kaleibar) to south contain Bostanabad, Bonab, Maragheh and Hashtrud, about 72.3% was found to be marginally suitable (S_3). The lowest productivity potential (9.7%) was related to Sarab in east of province due to topography, and high altitude.

Keywords: AEZ, AHP, GIS, Production potential, Safflower (*Carthamus tinctorius* L.)

INTRODUCTION

The 1998 Revision of the United Nations medium variant population projection indicates an increase of world population to about 8.9 thousand million by the year 2050, with a possible range of 7.3 to 10.7 thousand million. Most experts agree that through full and adequate application of modern agricultural technology, the world's land resources could provide sufficient food, fiber, animal feed, biofuel and timber for such a world population. In practice, however, there will very likely be acute land shortages in some countries, especially in several developing countries (Fischer and Heilig, 1997). Yet, even today About 1.7 billion people are estimated to live in absolute poverty today (FAO, 2011). Already, some 30 developing countries are facing water shortages and by 2050 this number will increase to some 55 countries, the majority in the developing world. This water scarcity, together with degradation of arable land, could become the most serious obstacle to increasing food production (Fischer *et al.*, 2002). About 70% of the world's freshwater use goes to agriculture, (Fischer *et al.*, 2002). The importance of rain fed agriculture varies regionally but produces most food for poor communities in developing countries (Wani *et al.*, 2009).

Agro-ecological Zones (AEZ) method was developed by the Food and Agriculture Organization of the United Nations (FAO) and the International Institute for Applied Systems Analysis (IIASA) (FAO,

1996). This model offers much scope for developing strategies for efficient natural resource management and in this context, recent advances in remote sensing and GIS have made the task of integration and mapping of a wide range of databases much easier. They are traditionally defined as major climate zones with a certain growing period suitable for crops. With its soil, landscape, and climatic characteristics, an agro-ecozone can represent the environmental constraints and potential for new cropping systems, economic viability, and sustainability (Follet, 1996).

In different parts of Iran land suitability evaluation has done for some of this crops by Movahhedi Naeni (1993), Ghasemi Dehkordi (1994), Sarvari and Mahmoudi (2001), Jafarzadeh and Atabakazar (2004), Momtaz *et al.* (2006) and Shahbazi and Jafarzadeh (2004). Several techniques are available for carrying out land suitability analysis. Three methods may be used (de Bie, 2004) for combining land suitability and those are:

- Subjective combination
- Limiting conditions
- Parametric methods

Subjective combination is based on "expert knowledge". This method will be reliable when the evaluator has a good knowledge of the area and all the LUTs concerned, i.e. if he acquired indigenous. A

hierarchical structure of decision plane is essential and the Analytic Hierarchy Process (AHP) can provide such a platform. The AHP is a multi-criteria decision method that uses hierarchical structures to represent a problem and then develops priorities for alternatives based on the judgment of the user (Abdul Mohit and Mahmud Ali, 2006) on the other hand, Geographic Information System (GIS) provides a spatial framework to land use analysis and it has been recognized as a useful decision support technology. The role of GIS is to generate a set of feasible solutions representing the relative land suitability with respect to any given map layers and to display it (Abdul Mohit and Mahmud Ali, 2006). An AHP-based risk assessment model that can be applied as a stand-alone procedure or integrated with a GIS-based system to determine resource conditions and then the risk proposed by some workers (Weiss and McLaren, 2002) These authors argued that the AHP process allows for consultation with land managers to identify what land values are important to them and to place importance weights on these values (Qureshi and Harrison, 2003).

In 2005, some 13.05 million hectares of land in Iran was under cultivation, of which 50.45% was allocated to irrigated farming and the remaining 49.55% to rain-fed system (Wikipedia, 2012). Safflower (*Carthamus tinctorius* L.) is an annual, broadleaf oilseed crop of the family composite adapted mainly to dry land and irrigated cropping systems is mainly grown for its edible oil for cooking, salad oil and margarine (Omidi and Sharifmogadas, 2010). Research linking health and diet has increased the demand for the oil, which has the highest polyunsaturated/saturated ratios of any oil available. It is nutritionally similar to olive oil, with high levels of oleic acid, but much less costly. Polyunsaturated fats are associated with lowering of blood cholesterol (Weiss, 2000). The safflower, an annual plant, is native to a climate with a long dry season and a limited rainy season. Its defenses are very poor against numerous fungal diseases in rainy conditions, after its seedling stage. This greatly restricts the areas in which it can be grown commercially around the globe (Wikipedia, 2012). It is a minor crop today, with about 600,000 tons being produced commercially in more than sixty countries worldwide. India, United States, and Mexico are the leading producers, with Ethiopia, Kazakhstan, China, Argentina and Australia accounting for most of the remainder (Wikipedia, 2012). India is contributing about 50% of production. In Iran, the safflower cropped area has increased over last few years and reached about 10000 ha during 2008 whereas during 1997 it was 200-300 ha (Omidi *et al.*, 2009). Safflower is an important oilseed crop with 35-40 % oil. It has been used as a source of edible oil and dye since ancient times (Kolsarc *et al.*, 2005). Approximately 250 mm average rainfall in East Azerbaijan and safflower cultivation is 2,000 hectares. In this paper, production potential was estimated, using AHP methods for safflower in East Azerbaijan of Iran.

MATERIALS AND METHODS

The study area is located in west of Iran. Total approximately area is 45481 square kilometers where has located between 36° 45' - 39° 25' northern latitude and 45° 05' - 48° 21' eastern longitude. Figure 1 demonstrates the position of the study area. About 28.2% of lands have capability to rain fed cropping (Table 1). The basic source materials used for spatial analysis of homogeneous zones average date of sowing, germination, and flowering and ripening for each crop region in East Azerbaijan, this data area extrapolated for each culture from literature reported in bibliography (Pasban Eslam, 2004; Pourdad and Beg, 2003; Dadgar *et al.*, 2008; Omidi and Sharifmogadas, 2010). Sowing dates of safflower were based on local crop calendars and ranged from 1 September to 21 October but we when the intended date of planting the first of at least 5 mm of precipitation with probability of 75% (Table 2).

Crop growth steps at physiological maturity as determined by accumulated temperature climatologically indices are calculated from the Iran Meteorological Organization meteorological database. This database contains an historical series (1975-2007) of meteorological observations from 17 synoptic and climatology stations distributed throughout the region and interpolated into a regular grid of 50x50 km. Data included precipitation, mean, maximum and minimum air temperature, vapor pressures, and wind-speed. For collection the values of observed yield in each land unit



Fig. 1: Location of study site, East Azerbaijan, Iran

Table 1: Land capabilities and their area in East Azerbaijan

Land use category	Area in hectares	Percent of total area
Range	2344296.28	51.6
Irrigated Farming	361929.790	8.00
Dry Farming	1281622.80	28.2
Forest	144123.570	3.20
Non Suitable Range	306733.790	6.70
Urban	14892.370	0.30
Wet Lands	32987.410	0.70
Salin Lands	59073.920	1.30

Table 2: The safflower growth cycle on East Azerbaijan of Iran region

Planting to stability	Ripening	Days to maturity
1 Sep-21 Oct	1 Apr-20 May	200

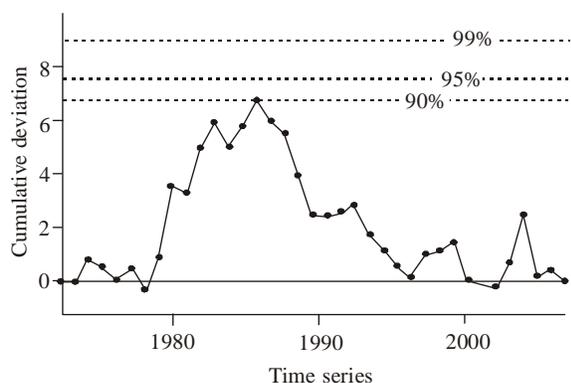


Fig. 2: The homogeneity test of data

was helped by information of region farmers and data of agricultural advancement center in local.

Frequency analysis of data requires that the data be homogeneous and independent. The restriction of homogeneity assures that the observations are from the same population. The tests of homogeneity (Buishand, 1982) carried out based on the cumulative deviations (Fig. 2) from the mean:

$$S_k = \sum_{i=1}^k (X_i - \bar{X}) \quad K = 1, \dots, n \quad (1)$$

where X_i is the records from the series X_1, X_2, \dots, X_n and \bar{X} the mean. The initial value of $S_k = 0$ and last value $S_k = n$ are equal to zero.

Pedological parameters are derived from the digital version of the soil database of Agricultural planning Economic and Rural Development Research Institute, Iran (scale, 1:250,000).

The growing period definition is based on the frost-free period and is considered to be the period (days) during the year when the mean minimum air temperature is equal to or greater than 5°C (Stewart *et al.*, 1984). The potential or "maximum constraint-free yield" attainable by a crop is primarily determined by its genetic characteristics and how well it is adapted to the existing environment. Constraint-free yield is defined as the harvested dry matter yield of a high-producing variety, which can be produced under conditions where water, nutrients, weeds, pests and diseases do not limit crop growth. Under such conditions, the crop yield is limited only by the physiological responses to the amount of radiant energy intercepted by the canopy, the temperature over the course of the growing period and the length of the growing period (Stewart *et al.*, 1984).

Using FAO's growth model were calculated gross biomass production and the net biomass for safflower crop. Potential values were determined using a form of photosynthesis model which calculates crop photo synthesis response to temperature and radiation averaged over a growing season. The maximum gross biomass production (bgm) was calculated from the following equation:

$$Bn = (0.36 \text{ bgm} \cdot KLI) / [(1/L) + 0.25Ct] \quad (1)$$

where,

Ct = Respiratory coefficient

L = Days to ripening

$KLAI$ = Correction factor for Leaf Area Index

bgm = Maximum gross biomass

At the next step with notice to importance of humidity in rain fed condition, water limited production potential (WPP) was calculated:

$$WPP = RPP \cdot [1 - Ky \cdot (1 - (Eta/Etc))] \quad (2)$$

where: wpp, potential yield after water stress (day weight/ha), Eta and Etc : actual and maximum evapotranspiration (mm), Ky : factor of plant response

Anticipated yields were derived from these values by employing yield-reducing factors related to moisture stress, climation and soil constraints. The anticipated (corrected) yield for each map unit was compared to the maximum potential yield obtainable in the East Azerbaijan of Iran.

The next step to determine the production yield was used following equation:

$$Y = bn \cdot HI \quad (3)$$

where, Y = product yield, Bn = rating of total pure biomass, Hi = index of product harvest

The final Land Production Potential (LPP) has been calculated using an equation where the effects of climate, soil, topography and selected land characteristics on crop production have been combined. The LLP obtained by multiplying a land physical index (I) with Potential of product yield (Determination of both indices implies matching of land characteristics with the wheat requirements (Sys *et al.*, 1993).

Weighing to agro ecological parameters carried out by analytical hierarchy method (AHP). This procedure has been widely documented in a variety of problem area that has been not used extremely in agricultural decisions in developing countries. The presence of significant relationship between observed yield and predicted yield prove the accuracy of selected land evaluation manner. After fixing qualitative and quantitative land suitability classes, output results as georeferenced suitability maps using Geography Information system (GIS) utility were presented (Zali Vargahan *et al.*, 2011)

In order to assess the results of this study, the actual yield statistics have been recorded in areas of the province were used. Location areas were determined using GPS. Similar in location, predicted statistics extracted, and were fitted to determine the accuracy of results. In order to assessment model, testing and selecting the optimal model of regional GIS analysis

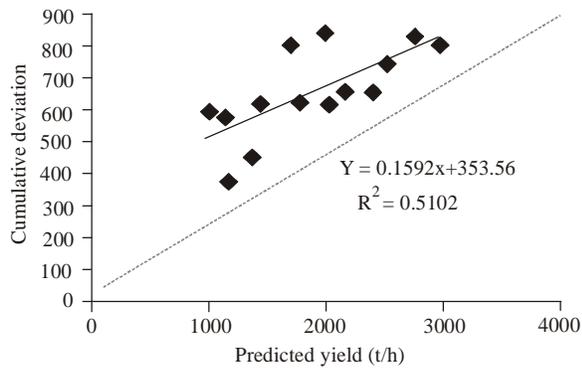


Fig. 3: The regression of observed yield and predicted for safflower, using AHP method

functions were used. It can function with a variety of statistical properties of effective layers of in the final mapping tables and histograms can evaluate.

RESULTS AND DISCUSSION

The results showed that the AHP model is a sufficiently appropriate approach for the evaluating of suitable lands for safflower growth and development throughout East Azerbaijan geographic extent (Fig. 3). Capabilities for regions that are able to dry farming have area about 28.2% of total lands of East Azerbaijan, presented in Table 1.

In order to determine the relative weight of the main parameters, the geometric mean for each of the matrix was formed. Calculate the relative weight of each of them and then to determine the relative weight was criteria, sub criteria and alternatives. The final weight of each of the alternatives was determined (Table 3).

Regarding to FAO model, the estimated temperature and radiation potential of safflower yield was about 1560 kg/ha. The estimated LPP values for the study area varied between 1200 and 2600 kg/ha (Fig. 4). The lowest values were found in the map where soil conditions were unfavorable due to high salinity and alkalinity and high altitude. This unit is located in the east part of the study area. The higher estimated LPP values are located west north side of the study area.

Interpolation among data showed, about 0.2% was highly suitable (S₁) for safflower cultivation, contain Marand and Jolfa region (Table 4). East of Tabriz and Varzaghan, and Charavimagh about 2.0% of the area, were moderately suitable (S₂), but had limited due to insufficient precipitation. An strip region from north east of province (Kaleibar) to south contain Bostanabad, Bonab, Maragheh and Hashtroud, about 14.1% was found to be marginally suitable (S₃).

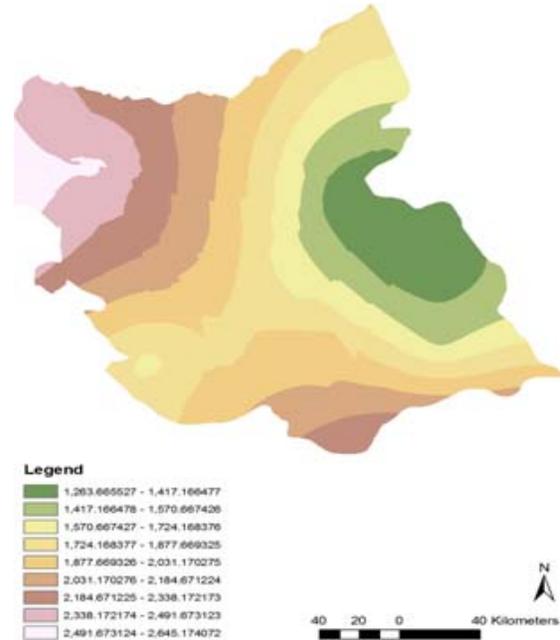


Fig. 4: Raster map of potential productivity (kg.ha⁻¹)

Table 3: Weighting parameters in safflower based hierarchical model

Parametre	Classes	AHP	
		2end level	3rd level
Precipitation of the 1st month (mm)	S1	0.46	0.59
	S2		0.25
	S3		0.12
Precipitation of the 2nd month (mm)	N1	0.21	0.04
	S1		0.58
	S2		0.35
Precipitation of the 3rd month (mm)	S3	0.15	0.06
	N1		0.01
	S1		0.56
Precipitation of the 4th month (mm)	S2	0.09	0.31
	S3		0.27
	N1		0.19
Mean temp. of the 1st month (°C)	S1	0.06	0.12
	S2		0.54
	S3		0.31
Meantemp.of the 2ndand3rd month (°C)	N1	0.03	0.10
	S1		0.05
	S2		0.51
	S3		0.26
	N1		0.15
			0.08

Table 4: Land suitability of safflower cultivation in East Azarbaijan

Group	Capability	Percent to area	Area in Km ²
S1	Highly suitable	0.20	114.600
S2	Moderatly suitable	2.00	904.400
S3	Marginally suitable	14.1	6379.30
N1	Not siutable	83.6	37779.4

The lowest productivity potential (about 83.6%) was related to Sarab in east of province due to topography, and high altitude.

The good conformity between predicted yield potential and observed yield (R² = 0.5102) emphasize that predicted yield by FAO model is entirely acceptable (Fig. 3). Observed yield was lower than

estimated yield that can be caused mainly by low management and other factors which are effects on the safflower production. The considerable variability of soil characteristics over short distances will undoubtedly also lead to important local differences in safflower productivity.

CONCLUSION

If the chemicals and physical soil conditions are not improved by adapted management, safflower yield will be seriously affected. Results of the production model estimates, suggest the upper limit of the production capability of the available soil and climatic resources for this region. Given that much of the lands in province have been devoted to wheat cultivation therefore, the farmers have inclination for wheat-fallow cropping pattern. So introduction regions with high production potential by safflower, will improve cropping pattern, and change it to wheat-safflower. Thereby soil will protect against erosion, increase revenue and reduce risk of products loss in the rain fed cultivations.

ACKNOWLEDGMENT

I am highly indebted to Agricultural planning Economic and Rural Development Research Institute, and Iran Meteorological Organization for providing necessary information regarding the project.

REFERENCES

- Abdul Mohit, M. and M. Mahmud Ali, 2006. Integrating GIS and AHP for Land Suitability Analysis for Urban Development in a Secondary City of Bangladesh. *J. Alam Bina*, 8(1): 1-19.
- Dadgar, M., Sh. Mahmoodi, M.H. Masihabadi and A.M. Shahsavari, 2008. Quality assessment of land suitability for safflower and soybean cultivation in Faryab Damavand culture method. *Plan Ecosyst.*, 18: 90-101.
- De Bie, C.A.J.M., 2004. Land evaluation. Lecture notes for the land evaluation/SA. Agro-Ecological Zoning (AEZ), Land Evaluation (LE) and Crop growth modeling Module. ITC, Enschede.
- FAO (Food and Agriculture Organization of the United Nations), 2011. FAO. Retrieved from: <http://www.fao.org/hunger/en>.
- FAO (Food and Agriculture Organization of the United Nations), 1996. Agro-ecological Zoning Guidelines. FAO Soil Bulletin No. 76. FAO, Rome.
- Fischer, G. and G.K. Heilig, 1997. Population momentum and the demand on land and water resources. *Phil. Trans. R. Soc. Land. B*, 352: 869-889.
- Fischer, G., H.T.V. Velthuisen, M. Shah and F. Nachtergaele, 2002. Global Agro-ecological Assessment for Agriculture in the 21st Century: Methodology and Results. IIASA, FAO.
- Follet, R., 1996. Determination of agroecozones in the continental United States. Unpublished ARS Report. Colorado State University, Fort Collins, CO.
- Ghasemi Dehkordi, V.R., 1994. Soil study and land suitability evaluation Barkhar region of Isfahan. M.Sc. Thesis, Faculty of Agriculture, Soil Science Department, Tehran University.
- Jafarzadeh, A.A. and M.R. Atabakazar, 2004. Land suitability evaluation of Shakaryazi region for wheat, barley, alfalfa, sugar beet and safflower. Proceeding of the International Conference of CIGR. Beijing, China, Session IV, part 5, 7: 1-5.
- Kolsarc, O., S. Alluo and M.D. Kaya, 2005. The effects of tillage and nitrogen doses on water use efficiency soil moisture and seed characters of safflower (*carthamus tinctorius* L.) in wheat-safflower rotation system. Proceeding of the 6th International Safflower Conference. Istanbul, pp: 126-131.
- Momtaz, H., A.A. Jafarzadeh and H.R. Neyshaboori, 2006. Qualitative evaluation of land suitability for crops commonly grown in Ahar city Yakhfuzan region. *Agric. Knowl.*, 16(3): 67-81.
- Movahhedi Naeni, S.A.R., 1993. Land suitability evaluation of Gorgan area for main agricultural crops. M.Sc. Thesis, Faculty of Agriculture, Soil Science Department, Tarbiat Modarres University.
- Omidi, A.H. and M.R. Sharifmoghadas, 2010. Evaluation of Iranian safflower cultivars reaction to different sowing dates and plant densities. *Appl. Sci.*, 8(8): 953-958.
- Omidi, A.H., H. Khazaei and S. Hongbo, 2009. Variation for some important agronomic traits in 100 spring safflower (*Carthamus tinctorius* L.) genotypes. *American-Eurasian J. Agric. Environ. Sci.*, 5(6): 791-795.
- Pasban Eslam, B., 2004. An evaluation of yield components in new spineless genotypes of safflower (*Carthamus tinctorius* L.) Iranian J. Agric. Sci., 35(4).
- Pourdard, S.S. and A. Beg, 2003. Safflower: A suitable oilseed crop for dry-land areas of Iran. Proceeding of the 7th International Conference on Development of dry lands. Tehran, Iran, pp: 158.
- Qureshi, M.E. and S.R. Harrison, 2003. Application of the analytic hierarchy process to riparian revegetation policy options, small-scale forest economics. *Manag. Policy*, 23: 441-458.
- Sarvari, S.A. and S.H. Mahmoudi, 2001. Qualitative land suitability evaluation for irrigated sugar beet in Ghazvin region. Iran. *J. Soil Water*, Special issue on soil survey and land evaluation, pp: 66-75.
- Shahbazi, F. and A.A. Jafarzadeh, 2004. Qualitative evaluation of land suitability in Khushe Mehr region of Bonab for wheat, barley, alfalfa, onion, sugar beet and maize. *J. Agric. Sci. Univ. Tabriz*, 14(4): 69-86.

- Stewart, R.B., J. Dumanski and D.F. Acton, 1984. Production potential for spring wheat in the Canadian Prairie Provinces. *Agric. Ecosyst. Environ.*, 11(1): 1-14.
- Sys, C., E. Vanranst and D. Beernaerft, 1993. Land evaluation. Part III: Crop requirements. Agricultural Publications 7, General Administration for Development Cooperation, Brussels, Belgium, pp: 191.
- Wani, S.P., J. Rockstrom and T. Oweis, 2009. Rain fed Agriculture. *Water*, 10: 115.
- Weiss, E.A., 2000. Oilseed Crops. Blackwell. Sci. Ltd., Oxford, UK, pp: 364.
- Weiss, J. and D. McLaren, 2002. Victoria's pest plant prioritization processes. Proceedings of the 13th Australian Weeds Conference.
- Wikipedia, 2012. Agriculture in Iran. Retrieved from: http://en.wikipedia.org/wiki/Agriculture_in_Iran#cite_note-atiehbahar.com-3.
- Zali Vargahan, B., F. Shahbazi and M. Hajrasouli, 2001. Quantitative and qualitative land suitability evaluation. For maize cultivation in Ghobadlou region, Iran. *Ozean J. Appl. Sci.*, 4(1): 91-104.