Comparing Fao Methods to Estimate Wheat Productivity Potential in Damghan Plain of Iran

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Abstract: This investigation was conducted to evaluate the qualitative land suitability for wheat to test accuracy of the applied land suitability evaluation methods. The study area is located in south of Damghan city, Semnan province northeastern Iran. The land suitability class was determined by matching land characteristics with the crop vegetative requirements using Storie method and Square method. The results of physical evaluation revealed that the most important limitations for crop production in the area are the salinity, alkalinity, acidity, high lime and drainage. For determining the accuracy of the applied land suitability evaluation methods, yield potential of irrigated wheat, climatic conditions and topographic situation of the region were first evaluated. In the next step land production potential (predicted performance of wheat) was calculated by using irrigated yield potential and soil limitation factors. Finally the evaluated performance was compared with Farmers performance. The correlation between predicted yields and actual reported yields by local farmers, using Square method suggests a closer resemblance between the simulated production of environment and the situation in which the farmers operate than Storie method.

Key words: Land evaluation • Qualitative suitability • Production potential • Wheat

INTRODUCTION

The ability of the world’s natural resources to provide the needs of its growing population is a fundamental issue for the international community. Limits to the productive capacity of land resources are set by climate, soil and landform conditions and by the use and management applied to the land.

Sustainable management of land resources requires sound policies and planning based on knowledge of these resources, the demands of the use to which the resources are put and the interactions between land and land use. So it is very important for agriculture development planning to take land resources assessment. Different empirical model to predict land productivity for crops under a wide range of weather and soil conditions have been described [1-5]. Most of these models are designed to use available climatic and soil information as statistical averages and generalized crop phenology.

The Food and Agriculture Organization of the United Nations (FAO) developed a methodological framework to assess food production, which widely known as the Agro-ecological zoning (AEZ) methodology [6, 7]. In this study, the land suitability evaluation for wheat was conducted with objective of potential productivity estimation in Damghan plain of Iran.

Study Area: The study area is located in the south of Damghan Plain and in Semnan province of Iran. This study was carried out in an area including 5400 ha between 36° 02’ 31.6” - 36° 08’ 28.5” of the northern latitude and 54° 21’ 56.7” - 54° 27’ 24.1” of the eastern longitude in the form of surveying at a semi-detailed surveying level for determination of soil characteristics and illustration of soil maps.

MATERIALS AND METHODS

To determine the soil characteristics is prepared topographic map by the range 1:50000 and extent of study area in 5400 ha were identified on the map. The 100 profiles as a regular network in the area was drilled and dissected. Soil classification was done based on American soil classification. To investigate the qualitative land
suitability, Storie and Square Root methods were used. Based on these methods, land suitability classes were determined for wheat crop. According to the results of measured land index in parametric method suggested by Sys et al. [8], lands having indexes >75 are in S (very suitable) class. On the basis of this method, land indexes in ranges of 50-75, 25-50 and <25 are classified as S, (moderate suitable), S, (marginal suitable) and N (non-suitable) classes, respectively (Table 1). The Storie and Square Root method [9] are used for calculating the land index (I). Then, using FAO’s growth model were calculated gross biomass production and the net biomass for wheat crop. Potential values were determined using a form of photosynthesis model which calculates crop photosynthesis response to temperature and radiation averaged over a growing season. Anticipated yields were derived from these values by employing yield-reducing factors related to moisture stress, climatic and soil constraints. The anticipated (corrected) yield for each map unit was compared to the maximum potential yield obtainable in the Damghan plain of Iran. The maximum gross biomass production (bgm) were calculated from the following equation:

\[ bgm = f_0 + (1-f_0) \times bc \]

Where bo is the maximum gross biomass in cloudy day
bc: Maximum biomass production in sunny day
f_0: Rate of cloudy days (1-n/N)
(1-f_0): Rate of sunny days (n/N)

Potential net biomass and dry matter yield values were computed using procedures adapted from those described by the FAO. Amount of the Net Biomass (Bn) was obtained from following the equation:

\[ Bn = \frac{0.36 \times bgm \times KLAI}{(1/L)} + 0.25 \times Ct \]

Ct: Respiratory Coefficient
L: Days to Ripening
KLAI: Correction factor for Leaf Area Index
bgm: Maximum Gross biomass

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

\[ Y = Bn \times HI \]

Where Y is 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 which 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) [10].

**RESULTS**

Based on the results obtained from physical and chemical analysis of soil samples, soils were classified as Entisols and Aridisols (Table 2) on the basis of soil taxonomy system 2006. The results of climatic suitability evaluation showed that the climatic characteristics of the region according to climatic and growth data are suitable for wheat cultivation. The wheat growth cycle on Damghan plain of Iran was 1 Nov (Planting) to 21 Jun (Harvest) (Table 1).

The results of land suitability evaluation for wheat cultivation are shown in Table 2. The changes range amongst different classes in land units based on the Storie method and Square Root method were S_2, N_2, N_3, S_3, N_3, S_3, N_2, N_2, N_2.
Table 3: The estimation of wheat production potential on Darrughan plain

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum leaf photosynthesis (kg/ha)</td>
<td>20</td>
</tr>
<tr>
<td>Maximum biomass production in sunny day (kgC/ha/day)</td>
<td>352.2</td>
</tr>
<tr>
<td>Maximum biomass production in cloudy day (kgC/ha/day)</td>
<td>181.5</td>
</tr>
<tr>
<td>Rate of cloudy days (1 - r/N)</td>
<td>0.36</td>
</tr>
<tr>
<td>Rate of sunny days (r/N)</td>
<td>0.64</td>
</tr>
<tr>
<td>Maximum biomass production bgm = (kgC/ha/day)</td>
<td>229.50</td>
</tr>
</tbody>
</table>

Table 4: Results of the observed and estimated yield for wheat, using Square Root, Storie methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Square Root Storie</th>
</tr>
</thead>
<tbody>
<tr>
<td>Map units</td>
<td>Area (km²)</td>
</tr>
<tr>
<td>1.1</td>
<td>898.32</td>
</tr>
<tr>
<td>1.2</td>
<td>316.44</td>
</tr>
<tr>
<td>1.3</td>
<td>507.60</td>
</tr>
<tr>
<td>2.1</td>
<td>986.04</td>
</tr>
<tr>
<td>2.2</td>
<td>457.38</td>
</tr>
<tr>
<td>2.3</td>
<td>369.90</td>
</tr>
<tr>
<td>3.1</td>
<td>844.02</td>
</tr>
<tr>
<td>3.2</td>
<td>738.18</td>
</tr>
<tr>
<td>3.3</td>
<td>312.12</td>
</tr>
</tbody>
</table>

Table 5: The statistics analysis: Observed yield with land index and estimated yield for wheat, using Square Root, Storie methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Regression</th>
<th>R²</th>
<th>Regression</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Square Root</td>
<td>Observed yield and estimated yield</td>
<td>0.9974</td>
<td>Observed yield land index</td>
<td>0.9974</td>
</tr>
<tr>
<td>Storie</td>
<td>Observed yield and estimated yield</td>
<td>0.9896</td>
<td>Observed yield land index</td>
<td>0.9896</td>
</tr>
</tbody>
</table>

and S₁, S₂, N1-N₂ respectively. The maps was classified into two to four suitability classes in different methods. Fig. 1, 2 shows the maps of land suitability classes in the region by means of different methods. Regarding to FAO model the estimated temperature and radiation potential of wheat yield was about 8855.8 kg/ha⁻¹ (Table 3). The estimated LPP values for the study area by Square Root and Storie methods varied between 209.88 to 5570.29 kg/ha⁻¹ and 38.96 to 4064.81 respectively (Table 4). The lowest values by Square Root was found in the map unit 3.1 where soil conditions were unfavourable due to high salinity and alkalinity. This unit is located the southern part of the study area. The highest estimated LPP values by same method is located side of the northern of the study area and range of its LPP values was around 5.6 th ha⁻¹. Table 4 and Fig. 1 to 4 shows correlation between estimated yield, observed yield and land index in different methods. Also are shown, correlation coefficient between the mentioned parameters in Square method (R=0.9974) were higher than Store method (R=0.9896).
Fig. 1: The Regression of observed yield estimated yield for wheat, using Square Root method

Fig. 2: The Regression of observed yield and land index for wheat, using Square Root method

Fig. 3: The Regression of observed yield and estimated yield for wheat, using Storie method

Fig. 4: The Regression of observed yield and land index for wheat, using Storie method
DISCUSSION

Regarding FAO model [8], wheat production potential under favorable soil and climatic conditions was estimated about 8855.8 kg ha\(^{-1}\). The good accordance between estimated yield potential and observed yield potential in Square method approve that Square method has more accuracy and efficiency than another one. The estimated statistic correlation between estimated yield and observed yield in Square method approve this subject (\(R^2 = 0.9974\)).

Also the land index has a strong impact on the estimated land production potential. The higher values of land index by Square method were calculated for northern and central soils on the Damghan plain than the southern soils. The higher correlation between observed yield and land index suggest that results of Square Root method is closer to reality than another one.

Ashraf et al. [11], Jafarzadeh et al. [12], Shahbazi and Jafarzadeh, [13] and Behzad, et al. [14] emphasized on Square Root method (SR) and suggests that the use of Square Root is more appropriate for evaluation of the qualitative land suitability than others.

The more than 60% of the study area (Map units 3.1, 3.2, 3.3, 2.1and 1.1) had an estimated production potential below 2.0 t ha\(^{-1}\), which was much less than wheat production potential under favorable soil and climatic conditions. The considerable variability of soil characteristics over short distances will undoubtedly also lead to important local differences in wheat productivity. The land physical evaluation by Square method emphasized that northern and central parts (Map units 1.1, 1.2, 2.2 and 2.3) were markedly better than southern (Map units 3.1, 3.2, 3.3, 2.1 and 1.1). This is expressed by the reduction of the LPP of 5570.29 kg ha\(^{-1}\) to 209.88 ha\(^{-1}\). In these area high pH, basic cations, lime, alkalinity and salinity were upper than the required level for optimal wheat grow. If the chemicals and physical soil conditions are not improved by adapted management, wheat 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.

REFERENCES