A Research on the Usage of Least Squares Land Grading Design Method in Microsoft Excel

Mustafa ALKAN[1], Tekin ÖZTEKİN[1*]

[1]Tokat Gaziosmanpaşa University, Agricultural Faculty, Department of Biosystem Engineering, Tokat
(orcid.org/0000-0002-7204-7727); (orcid.org/0000-0002-7775-7592)
* e-mail: tekin.oztekin@gop.edu.tr

Abstract: The possibilities of automatic land grading design for the regular shaped (rectangular) fields using the Microsoft Excel 2010 with the least squares technique, have been investigated in this research. When the original level rod and area weighting factor at each grid point of field are entered, the program automatically performs the land grading design for the field in a very short time in contrast to the long calculations required for the conventional method. The cut or fill depths at each grid point, the grading type, the cut-fill volume distribution plan, and three-dimensional perspective views of the field before and after grading were given as the results of the design. The Microsoft Excel program developed with this study can be used for the fields formed with 10 rows by 10 columns with variable grid sizes. The developed program was applied to two different textbook examples, the same results were obtained.

Keywords: Land leveling, Rectangular field, Automatic designing, Excel

En Küçük Kareler Tesviye Projeleme Yönteminin Microsoft Excel Programında Kullanımı Üzerine Bir Araştırma

Öz: Bu çalışmada, matematiksel esaslara dayalı yöntemlerden olan en küçük kareler yöntemi arazi tesviyesi projelemesinin Microsoft Excel 2010'da düzgün şekilli araziler için otomatik olarak programlama olanakları araştırılmıştır. Program, arazi istasyonlarına ait orijinal mira değerleri ve birim alan değerleri girildiğinde, araziye ait tesviye projesini otomatik olarak geleneksel yöntem için gerekli uzun hesaplamaların aksine çok kısa sürede yapar. Projeleme sonuçları olarak, tesviye alanı istasyonlarının kazı-dolgu miktarları, tesviye tipi, kazı-dolgu dağıtım planı, arazinin tesviye öncesi ve tesviye sonrası üç boyutlu persfektif görüntüleri verilir. Bu çalışma ile geliştirilen Microsoft Excel programı, 10 sıralı x 10 kolonlu farklı istasyonlar arası mesafeli parsellere kadar kullanılabilmektedir. Geliştirilen program iki farklı ders kitabı örneğine uygulanmış, aynı sonuçlar elde edilmiştir.

Anahtar Kelimeler: Arazi tesviyesi, düzgün şekilli araziler, otomatik projeleme, excel.

1. Introduction

Land grading is one of the most important factor in surface irrigation method for applying the irrigation equally across the field (Çınar, 1982). In surface irrigation methods, irrigation water is applied from the soil surface with gravity. When irrigation water is applied to the field, the field must have a certain gradient. This desired gradient can only be achieved by land grading (Korukçu, 1981).

Land leveling or land grading for irrigation is the modification of the surface relief of a field to a planned grade to provide a more suitable surface for efficient application of irrigation water (SCS, 1961). In order to achieve an effective and easy surface irrigation, the irrigated field must have a slope that does notchange over the flow length to the extent possible (Güngör ve Yıldırım, 1989; Yıldırım, 2013). Land grading is important not only for the protection of water and land but also for gaining higher yield and quality for crop production. The highest yield and quality is obtained from the lands which are irrigated better (Çınar, 1982). The first systematic procedures for land grading were introduced by Givan (1940) for rectangular fields and by Chugg

1

(1947) for irregularly shaped fields. Both applied least-square technique to define a plane surface that fits the natural ground surface with minimum earthwork (Reddy, 1996). Gebre-Selassie and Willardson (1991) developed a computer program written in FORTRAN and BASIC computer languages to apply least-squares land leveling. The least squares technique is based on the least squares theory in the statistic. The basic principle of this technique is to define a graded plane surface that fits the natural ground surface with minimum earthwork.

Nowadays, there are many computer programs that are used in land leveling or grading in different engineering studies, including topographic maps, volume, cut-fill depths, slope, and many engineering calculations. Some of these programs or softwares are Ezigrade by Foresoft Pty. Ltd. (2018), GradePlane by Carlton (2018), Carlson AgStar by Carlson Software Inc. (2018), OptiSurface by Davco Farming (2018), MultiPlane Land-Farming Design Software by Laserman Inc. (2018), Ditch Assist by Batterill Sales (2018), etc. The use of interfaces or inter-book data, advanced function and graphing features, ease of program access, simplicity of use, and so on reasons in the Microsoft Excel program allowed the Excel to perform the land grading related functions of many of the above-mentioned computer programs in a free of charge. For instance, Vanani et al. (2017) used the Excel Solver to determine the plane equation of land grading, and minimize the earthwork volume based on a desirable cut-fill ratio.

The possibilities of using the least square technique used in the design of land grading projects for rectangular fields were investigated in this study. For this purpose, an Excel spreadsheet template program was developed. The aim of this paper is to introduce the developed Excel program in order to design land grading, and to compare the results of this program to the results of two textbook examples in Turkish.

2. Materials and Methods

In order to evaluate the performance of the developed Excel spreadsheet program for land grading design; the result values for two rectangular shaped field plots as the first one formed 6 rows by 4 columns (24 stations) from Güngör and Yıldırım (1989) with dimensions of 117x186 m, and as the second one formed 6 rows by 5 columns (30 stations) with the size of 26.7 da from Yıldırım (2013) were compared to the results of the program. After performing the topographic surveying of the fields, level rod values (elevations in meter) and area weighting factors for the grids were given in the reference books, and then the fields were divided into grid squares of d = 30 m in length. These values of the grids as input were entered into the cells of Microsoft Excel spreadsheet program. This data is used in a multi-sheet spreadsheet template (Figure 1) in the Microsoft Excel 2010 environment in order to be able to perform calculations related to the land grading design. In other words, the project calculations are performed only when the user enters the area weighting factor (Excel cells in yellow) and the elevation (Excel cells in blue) at each grid point with the general soil structure (Excel cell of C1) of the field (Light, Medium, Medium-Heavy or Heavy) to the appropriate cells on the template of the Excel. The program automatically performs the planned land grading design in 10 phases and presents the outputs to the user. The phases of performed land grading design are determining coordinates of origin of field (X_c, Y_c); elevation of origin of field (H_c); slopes of grading plane in the X and Y directions (M_x, M_y); elevation of grading plane at origin of field (H_o); elevations of grading plane at each grid point (H_{ij}, where i = grid point location along the Y-axis, and j = grid point location along the X-axis); cut or fill depths at each grid point; total volume of earth in cut and fill for field; cut-to-fill ratio and if this ratio is insufficient, adjust cut-to-fill ratio; total volume of earth in cut per unit area; the grading type; the volume distribution plan of the field showing cut, fill, or naturel surfaces at each grid point; and three dimensional images of field before and after grading.

2
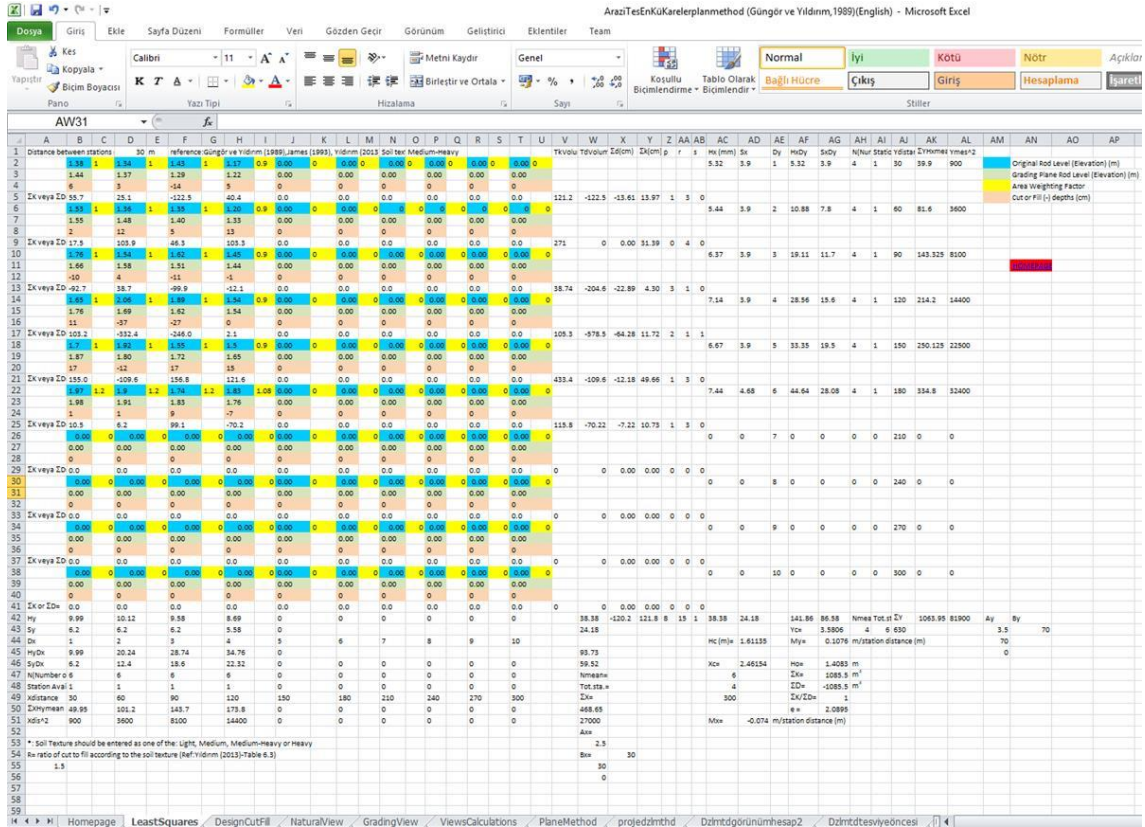
Figure 1. One of the Microsoft Excel template showing a part of the calculations of the land grading project for the rectangular field given in Güngör and Yıldırım (1989) with the least squares method

Şekil 1. Güngör ve Yıldırım (1989)'da verilen dikdörtgen şekilli bir arazi için en küçük kareler yöntemi ile arazi tesviye projesi hesaplarının bir kısmını gösteren Microsoft Excel şablonlarından biri

The following equations (Güngör and Yıldırım, 1989; Yıldırım, 2013) were used to calculate coordinates of origin of field (X_c, Y_c);

$$X_c = \frac{\sum_{j=1}^{n}(S_y D_x)}{\sum_{j=1}^{n}S_y} \qquad (1)$$

$$Y_c = \frac{\sum_{i=1}^{m}(S_x D_y)}{\sum_{i=1}^{m}S_x} \qquad (2)$$

where, n is number of column (cross row) in the X-axis direction, m is number of row in the Y-axis direction; S_x and S_y are sum of area weighting factors at each row and column respectively; D_x and D_y are the unit distances to the axes of each row and column, respectively.

The following equation (Güngör and Yıldırım, 1989; Yıldırım, 2013) was used to calculate elevation of origin of field (H_c);

$$H_c = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n}(H_{ij}S_{ij})}{\sum_{i=1}^{m}\sum_{j=1}^{n}S_{ij}} \qquad (3)$$

where, H_{ij} is elevation of field at each grid point located i^{th} row (m) and j^{th} column (n); S_{ij} is area weighting factor at each grid point located i^{th} row and j^{th} column.

In calculating slopes (M_x, M_y) of grading plane in X and Y directions, the following equations (Güngör and Yıldırım, 1989; Yıldırım, 2013) were used;

$$M_x = \frac{\sum_{j=1}^{n}(H_y D_x) - A_x \sum_{i=1}^{m} H_x}{B_x} \qquad (4)$$

$$M_y = \frac{\sum_{i=1}^{m}(H_x D_y) - A_y \sum_{j=1}^{n} H_y}{B_y} \qquad (5)$$

where, H_x and H_y are the sums of level rod values (elevations) of each row and column respectively; A_x is average of distances of columns along the X axis to the Y axis; A_y is average of distances of rows along the Y axis to the X axis; B_x and B_y are the coefficients related to numbers of rows or columns in the direction slope of best fit, and to numbers of rows or columns transverse to the direction slope of best fit. A_x, A_y, B_x, and B_y coefficients in these equations were determined automatically in Excel by employing the values in the tables by SCS (1961), Güngör and Yıldırım (1989), and Yıldırım (2013). The level rod values of grading plane for origin, and for each grid point (station) were determined using equations (6), and (7) respectively (Güngör and Yıldırım, 1989; Yıldırım, 2013);

$$H_o = H_c - X_c M_x - Y_c M_y \qquad (6)$$

$$H_{ij} = H_o + D_{xj} M_x + D_{yi} M_y \qquad (7)$$

where; H_o is elevation of grading plane for origin (m); H_{ij} is elevation of grading surface for station located i^{th} row and j^{th} column (m); and the other symbols are explained in the previous equations. The values used and determined for all parameters with above equations can be seen in the Excel page (Figure 1). In addition, the used equations and calculations can also be checked when the cursor is on the related cell of the program.

The developed Excel program automatically identifies the stations or grids as excavation (K), fill (D), and natural surface (TZ) stations, taking into account differences between natural surface and grading plane elevations at each station. If the elevation of natural surface is less than the elevation of grading plane at any station, there is a cut, otherwise fill at that station. If there is no any difference, no excavation is done at that station.

In the land grading projects, it is desirable to have a larger volume of cut than fill to obtain a balance. This is because when the determined volume of soil is excavated, the volume increases in the result of swelling, and when the same soil is laid down and compacted in fill, it becomes less voluminous than the natural volume in the resulting shrinkage. In practice, it is desirable that the ratio of cut to fill volumes ($\Sigma K/\Sigma D$) while changing according to the soil texture is between 1.15 and 1.80; and it is around 1.50 as an average value, otherwise lowering whole grading plane to a certain amount without changing the determined slopes of grading plane may be necessary. The ratio of cut to fill depends on type of soil and the operating conditions during land grading (Walker and Skogerboe, 1987). That is, the fill volume is reduced while the cut volume is increased. If the ratio of cut to fill volumes is higher than desired, the process is reversed and the grading plane is increased by a certain amount. In these conditions, the calculation of the amount to be lowered or raised in the grading plane has been determined using Equation 8 (Güngör and Yıldırım, 1989; Yıldırım, 2013);

$$e = \frac{R \sum d - \sum k}{Rp + r + S} \qquad (8)$$

where; e, the amount (cm) required to raise or lower the grading plane; R is the desired ratio of cut to fill volumes; Σd, the total amount of fill (cm); $\sum k$, total amount of cut (cm); p, the number of fill stations; r, the number of cut stations and; s, the number of natural surface stations. In Microsoft Excel, the calculations for the above formulas have been performed using Excel functions such as IF, SUMIFS, SUBTOTAL, ABS, COUNTIF, COUNTIFS, and SUM. In order to determine the grading type, the amount of excavation per unit area is found by dividing

4

the total cut volume (m^3) to the total area (da); and then the grading type is automatically determined according to the value found (Light: cut volume less than 50 m^3/da, Middle: cut volume between 50 and 100 m^3/da, Heavy: cut volume between 100 and 150 m^3/da, and Very Heavy: cut volume more than 150 m^3/da). In the ninth phase of land grading design in Excel, a plan of volumes of earthwork showing the cut-, fill-, and original surface-grids of the field is prepared automatically. The purpose herein is to inform the practitioner about the location and direction of the excavation material. In the volume distribution plan, the cutting areas are automatically scanned in red, and filling areas in white colors. In the last phase, threedimensional perspective views before and after grading according to elevations in grid or station centers are created using the three-dimensional surface option of Microsoft Excel's existing chart options.

The developed Microsoft Excel program can work for the fields formed by 1x1, 1x2, ..., 1x10; 2x1, 2x2, ..., 2x10; ...; 10x1, 10x2, ..., 10x10 dimensional grids or stations (maximum 100) with the square or rectangular shapes. That is, when the grid numbers change in X and Y directions (maximum 10), the program runs. Also, since no locks are placed on the program cells, the user can simply extend the program by copying and pasting the relevant lines or columns and modifying it for fields with more numbered grids or stations. In addition, the program can work within different station spacings (10, 15, 20, 25, 30, 35, 50, ..., 100 m). In the program, the homepage and interfaces are accessed through the pages that Excel opens automatically (Figure 1) and the hyperlinks. In the developed Microsoft Excel land grading program, when user only enters the original elevation and the area weighting factor for each grid point, the general soil structure of the field, and the distance between stations, the program automatically gives the project outputs such as cut or fill depths for each station, whether a station is a cut-, a fill-, or an original surface-station, post-grading slopes in X and Y directions, elevation of grading plane for each station, cut-fill ratio for whole field, a plan of volumes of earthwork showing cut-, fill-, and original surface-grids of field, grading type, and three-dimensional perspective views before and after grading.

3. Results and Discussion

The developed program provides saving labor force, efficient use of time, and topographic revives visually before and after leveling of land in user mind. Land grading projects is usually carried out with the projects of land consolidation in Turkey. Some companies have developed computer programs for land grading design in MATLAB, FORTRAN, and BASIC computer programming languages. These programs can only be used by trained persons, they are difficult to use and require training, they are hard to access and expensive programs, and there is no feature of three-dimensional perspective view for displaying field topography before and after grading, or it is weak. The developed Microsoft Excel program does not use any computer program code and can be used free of charge by all Microsoft Excel program users. This program can be used for the calculations of land grading designs for academicians, farmers, contractors, enterprises and state institutions that are involved in land grading projects.

In our study, the program calculated X_c and Y_c values by equations (1) and (2) as 2.462 and 3.581 units for Güngör and Yıldırım (1989), and 2.858 and 3.637 units for Yıldırım (2013), respectively. The values of these parameters are 2.46 units and 3.58 units in Güngör and Yıldırım (1989), and 2.86 and 3.64 units in Yıldırım (2013), respectively. Therefore, the coordinates of origin of grading plane for the fields both given in the source books and calculated by the program are the same. The program calculated the value of H_c by using Equation (3) as 1.611 m for the example in Güngör and Yıldırım (1989), and 2.627 m for the example in Yıldırım (2013). On the other hand, the H_c values for the same examples given in the source books are 1.611 and 2.627 m, respectively. As can be seen, these obtained results are same. The M_x and M_y slope values calculated using Equation (4) and (5) in the program are - 0.074 m/30 m and + 0.108

5

m/30 m for the example of Güngör and Yıldırım (1989), respectively. The same slopes values were given in Güngör and Yıldırım (1989). On the other hand, the slopes calculated for the example of Yıldırım (1989) are + 0.161 m/30 m and - 0.137 m/30 m, respectively. The same slopes values were also given in Yıldırım (1989). In the program, grading plane elevation values of all stations belonging to field are calculated, rounded to centimeter, and written on cells (in green color) of the plan just below the elevation cells (in blue color) of natural surface for all stations (Figure 1). When the values calculated in the program are compared with the values given in Güngör and Yıldırım (1989) and Yıldırım (2013), there is only 0.01 m difference in two of the 24 stations, and in one of the 30 stations, respectively. These differences are due to the fact that the results of manual calculations of the samples given in the source books were rounded to millimeter, however in the program more digits than millimeters were considered.

By using Equation 8, the program calculated the amounts of the grading plane to be lowered as 2.089 cm and 2.398 cm for Güngör and Yıldırım (1989), and Yıldırım (2013), respectively. On the other hand, the values to be lowered on the grading plane in the source books were given as 2 cm. The differences in these values are due to rounding the values of the source books to the lower integer (2 cm), while not rounding off the values of the but taking the same values in the program. While the determined volumes of cut and fill are 1394.9 m^3 and 940.2 m^3, respectively, and the cut-fill ratio is 1.5 in the case of Güngör and Yıldırım (1989); the given volumes of cut and fill in the source book are 1361.7 and 939.6 m^3, respectively, and the cut-fill ratio is 1.45. In addition, the determined volumes of cut and fill are 1933.1 and 1293.1 m^3, respectively, and the cut-fill ratio is 1.5 in the case of Yıldırım (2013); the given volumes of cut and fill in the source book are

1873.6 and 1321.1 m^3, respectively, and the cut-fill ratio is 1.42. The excess account of program for the volumes of cut is due to not rounding off the amounts of the grading plane to be lowered as mentioned before. In addition, the program produced less fill volume for Yıldırım (2013) sample. The program determined the volumes of cut falling to decares as 64.1 m^3/da and 72.4 m^3/da for the examples of Güngör and Yıldırım (1989), and Yıldırım (2013), respectively; and the leveling type as medium level for both examples. On the other hand in the source books, the volumes of cut per decares were given as 62.6 m^3/da and 70.2 m^3/da, respectively. As a result, while the program performs the grading project so that the exact desired cut-fill ratio (1.5) is obtained, the examples in the source books slightly deviate from this claim.

The Excel program-automatically created plans of volumes of earthwork showing cut, fill, and original surface grids of fields are given in Figure 2. The plans given are almost the same as given the Figure 4.17 in Güngör and Yıldırım (1989) and the Figure 6.8 in Yıldırım (2013). For the example of Güngör and Yıldırım (1989), the source book provided information on an original ground elevated station, while the program identified this original ground station (the third station from the top of the right side of the field) as a 0.6 cm depth cut station. The reason for this is that, as stated earlier, the grading plane to be lowered calculated by the program is larger than the value given in the book. Three-dimensional perspective views of the original appearance of the fields with the original level rod values, and the post-grading situations are drawn automatically by the Microsoft Excel program as given in Figures 3 and 4, respectively. These perspectives are not even in the source books used as references, but allow users to visualize the topography of fields in three dimensions before and after grading.

K	K	D	K	T.Z	T.Z	T.Z	T.Z	T.Z	T.Z		K	Cut
8.3	4.9	-11.5	7.1	0.0	0.0	0.0	0.0	0.0	0.0		D	Fill
K	K	K	K	T.Z	T.Z	T.Z	T.Z	T.Z	T.Z		T.Z	Natural Surface
4.0	13.6	7.2	14.8	0.0	0.0	0.0	0.0	0.0	0.0			
D	K	D	K	T.Z	T.Z	T.Z	T.Z	T.Z	T.Z			
-8.2	6.4	-9.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0			
K	D	D	K	T.Z	T.Z	T.Z	T.Z	T.Z	T.Z			
13.6	-34.8	-25.2	2.4	0.0	0.0	0.0	0.0	0.0	0.0			
K	D	K	K	T.Z	T.Z	T.Z	T.Z	T.Z	T.Z			
19.3	-10.1	19.5	17.1	0.0	0.0	0.0	0.0	0.0	0.0			
K	K	K	D	T.Z	T.Z	T.Z	T.Z	T.Z	T.Z			
3.1	2.7	11.3	-5.1	0.0	0.0	0.0	0.0	0.0	0.0			
T.Z	T.Z	T.Z	T.Z	T.Z	T.Z	T.Z	T.Z	T.Z	T.Z			
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
T.Z	T.Z	T.Z	T.Z	T.Z	T.Z	T.Z	T.Z	T.Z	T.Z			
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
T.Z	T.Z	T.Z	T.Z	T.Z	T.Z	T.Z	T.Z	T.Z	T.Z			
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
T.Z	T.Z	T.Z	T.Z	T.Z	T.Z	T.Z	T.Z	T.Z	T.Z			
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			

| K	K	K	D	K	T.Z	T.Z	T.Z	T.Z	T.Z		K	Cut
14.2	26.3	5.4	-1.5	41.6	0.0	0.0	0.0	0.0	0.0		D	Fill
D	D	K	K	K	T.Z	T.Z	T.Z	T.Z	T.Z		T.Z	Natural Surface
-2.5	-8.4	4.7	3.8	22.0	0.0	0.0	0.0	0.0	0.0			
K	D	D	D	D	T.Z	T.Z	T.Z	T.Z	T.Z			
1.8	-16.1	-47.9	-28.8	-36.7	0.0	0.0	0.0	0.0	0.0			
K	K	D	K	K	T.Z	T.Z	T.Z	T.Z	T.Z			
1.2	16.9	-8.6	3.5	2.6	0.0	0.0	0.0	0.0	0.0			
K	K	D	K	K	T.Z	T.Z	T.Z	T.Z	T.Z			
3.5	15.6	-5.3	6.9	14.0	0.0	0.0	0.0	0.0	0.0			
K	K	K	K	K	T.Z	T.Z	T.Z	T.Z	T.Z			
18.8	4.0	1.1	8.2	16.3	0.0	0.0	0.0	0.0	0.0			
T.Z	T.Z	T.Z	T.Z	T.Z	T.Z	T.Z	T.Z	T.Z	T.Z			
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
T.Z	T.Z	T.Z	T.Z	T.Z	T.Z	T.Z	T.Z	T.Z	T.Z			
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
T.Z	T.Z	T.Z	T.Z	T.Z	T.Z	T.Z	T.Z	T.Z	T.Z			
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
T.Z	T.Z	T.Z	T.Z	T.Z	T.Z	T.Z	T.Z	T.Z	T.Z			
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			

Figure 2. The cut-fill volume distribution plans automatically generated by the Microsoft Excel land grading program for the sample fields (the upper plan for the field given in Güngör and Yıldırım (1989), the lower plan for the field given in Yıldırım (2013))

***Şekil 2**. Örnek araziler için Microsoft Excel arazi tesviye programı tarafından otomatik olarak oluşturulan kazı-dolgu hacmi dağılım planları (üstteki plan Güngör ve Yıldırım (1989)'da verilen arazi için, alttaki plan ise Yıldırım (2013)'te verilen arazi içindir)*
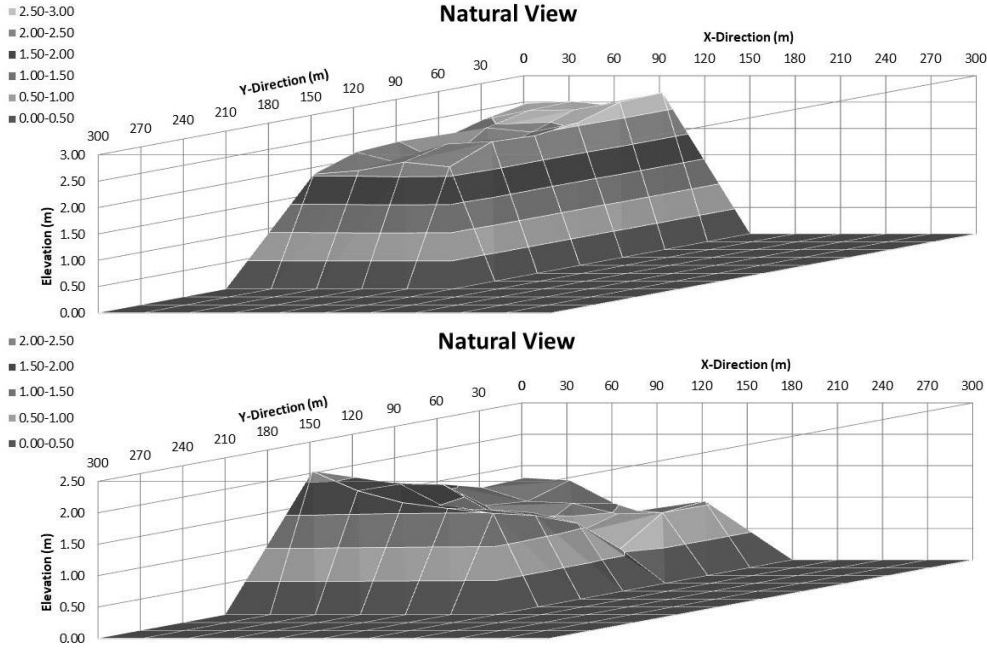
Figure 3. The automatic visualization of the perspectives of the sample fields before land grading in the Microsoft Excel land grading program environment (the upper perspective for the field given in Güngör and Yıldırım (1989), the lower perspective for the field given in Yıldırım (2013))

Şekil 3*. Arazi tesviyesi öncesi örnek arazi perspektiflerinin Microsoft Excel arazi tesviye programı ortamında otomatik olarak görselleştirilmesi (üstteki perspektif Güngör ve Yıldırım (1989)'da verilen arazi, alttaki ise Yıldırım (2013)'te verilen arazi içindir)*
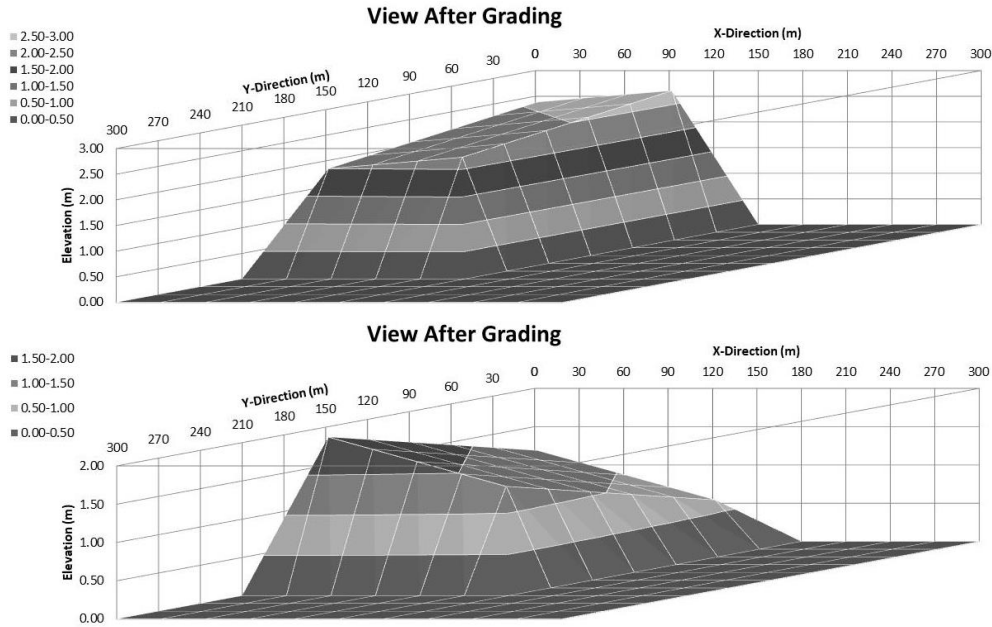
Figure 4. Automatic visualization of the perspectives of the sample fields after land grading in the Microsoft Excel land leveling program environment (the upper perspective for the field given in Güngör and Yıldırım (1989), the lower perspective for the field given in Yıldırım (2013)

Şekil 4*. Microsoft Excel arazi tesviye programı ortamında arazi tesviyesi sonrasında örnek arazilere ait perspektiflerinin otomatik olarak görselleştirilmesi (üstteki perspektif Güngör ve Yıldırım (1989)'da verilen arazi, alttaki ise Yıldırım (2013)'te verilen arazi içindir)*

4. Conclusions

A Microsoft Excel program as an Excel spreadsheet template for designing land grade projects has been developed. The most people can easily reach to this program in case of requesting from the authors. The developed program has been tested with two examples from two different textbooks. For example, the calculations for grading design of a 250 decares field can be done in as little as ten minutes with the program, while an engineer could possibly make this calculation more than a day. The program presents cut-fill volume distribution plan for a field in such a short time, as well as three-dimensional perspective views of before and after grading of field, which is very difficult to draw by hand. The developed program is also available for further development for users with a little bit of Excel knowledge. The developed Excel program and this article with these features is an original work. In addition, the value of the article depends on the knowledge of the reader on land grading, and his/her projecting experience, as long as the reader does know the labor involved in land grading projecs. The use of methods other than the least squares for both rectangular and nonrectangular fields in land grading projects with Microsoft Excel is under investigation.

References

Carlson Agster by Carlson Software Inc. (2018). www. carlsonsw. com/ solutions/ agriculture/agstar/

Chugg, G. E. 1947. Calculations for Land Gradation. Agricultural Engineering 28(10): 461-463.

Çınar, H. 1982. Arazi Tesviyesi. Köy İşleri ve Kooperatifler Bakanlığı Topraksu Genel Müdürlüğü Yayınları. Ankara

Ditch Assist by Botterill Sales (2018). https://ditchassist.com

Ezigrade by Foresoft Pty. Ltd. (2018). www.foresoft.com/cds_ezigrade.php

Gebre-Selassie, N.A., and L.S. Willardson. 1991. Application of least-squares land leveling. Journal of Irrigation and Drainage Engineering 117(6): 962-966.

Givan, G. E. (1940). Land grading calculations. Agric. Eng., 21(1), 11-12.

GradePlane (2018). www.gradeplane.com

Güngör, Y. ve O. Yıldırım. 1989. Tarla Sulama Sistemleri Kitabı. Ankara Üniversitesi Ziraat Fakültesi. 350 s.

Korukçu, A. 1981. Tarımsal Arazilerin Sulamaya Hazırlanmasında Doğrusal Programlama Tekniğinden Yararlanma Olanakları. Yöneylem Araştırması VII. Ulusal Kongresi. 2-4 Eylül 1981. İstanbul. 17 s.

MultiPlane Land-Farming Design Software by Lasemen Inc. (2018). www.lasermonca.com/catalog/agriculture/mapping-and-gis-software/

OptiSurface by Davco Farming (2018). www.optisurface.com

Reddy, S. L. 1996. Optimal land grading based on genetic algorithms. Journal of Irrigation and Drainage Engineering. 122(4): 183-188

SCS (U.S. Soil Conservation Service). 1961. Land Leveling, In: Irrigation, National Engineering Handbook, Sect. 15, Chap. 12, Washington, DC.

Walker, W.R., and Skogerboe, G.V. 1987. Surface Irrigation: Theory and Practice. Prentice Hall, Englewood Cliffs, New Jersey, 386 p.

Yıldırım, O. 2013. Sulama Sistemlerinin Tasarımı. Ankara Üniversitesi Ziraat Fakültesi, Yayın No: 1594, Ders Kitabı: 546 (4. Baskı), 367 s.