Earthwork Volume Optimization Using Imperialistic Competitive Algorithm to Minimize Energy Consumption of Agricultural Land Leveling

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Abstract

Land leveling is one of the most important steps in soil preparation for consequent objectives. Parallel policies need to take both energy and environmental subjects into the account as well as certain financial development and eco-friendly protection. Energy is one of the most important elements in agricultural sector. Nevertheless, pollution is linked with the usage of fossil fuels (particularly gasoline) as an energy source. Earthwork optimization plays an important role in reducing the total cost of highway projects. In this research, ICA has been followed to optimize earthwork volume for minimizing energy consumption of agricultural land leveling compared to minimum least squares, genetic algorithm, particle swarm optimization (PSO) have been employed for developing of optimization the energy related and other parameters. The study was specified based on the proposed land leveling project in district of Ahwaz, Iran. The study farm was a 70 ha area and located in the west of Iran. Topography of the farm was mapped in the scale of mapping as fine as 1:500. The outputs of the plan were length, width and height of points (coordinates of x, y and z) and the grid size in the region was 20 m×20 m. The aim of this work was use of new techniques and specifically optimization methods such as Imperialist competitive algorithm, genetic algorithms and PSO in modeling the leveling plane to minimize cut and fill volume and consequently the amount of energy consumption of leveling operations. It has been assumed that soil cut and fill volumes are equal and no need to move/ remove excessive soil. Therefore, there is no need to define a cut/fill variable in the model based on ICA. The results indicated that ICA offers a plan of earthwork, minimizing energy consumption of land leveling more efficiently than minimum least squares, genetic algorithm and PSO.

Keywords: Optimization, Land leveling, Imperialistic Competitive Algorithm, Earthwork, Cut-Fill Volume (V), Energy.

1- Introduction

During the last century due to increasing human population, demands for agricultural commodities have been enormously increased. Nowadays, one of the cardinal environmental challenges in the world is energy production and consumption. Despite using modern types of energy such as solar energy, inappropriate use and lack of proper management have led to an intense rise in energy consumption in this field. It also should be taken into account that environmental conservation and market globalization will be dependent on food security in the future agriculture (Jat *et al*., 2006). Based on this issue, some special policies should be addressed to consider an energy viewpoint in conjunction with the environmental issues to solve the problem. Land leveling is one of the heaviest and costly operations among agricultural practices that consumes considerable amount of energy (Gebre-Selassie and Willardson, 1991). On the other hand, land leveling simplifies the irrigation, improves field situations in other practices related to agriculture, regulates the soil surface, and normalizes its slope (Byre *et al*., 2006). Reportedly, there are three significant factors affecting grain yield including land leveling, methods of irrigation application and the interaction between land leveling and water applied. (Okasha *et al*., 2013) observed a noteworthy connection between the slope and diverse irrigation scheme in different seasons. Diverse methods of land leveling can affect the physical and chemical properties of the soil and hence can make differences in plant establishment, root growth, aerial cover and eventually crop yield. As a direct result, one of the most important steps in soil preparation and a key factor in food production that should be optimized island leveling (Cassel *et al*., 1982). Besides, decreasing fossil fuel consumption for land leveling diminishes air contaminants and improves the environmental condition. There is a growing understanding of the importance and effects of water and soil management, which in turn reveals the significance of optimized laser land leveling from social, financial and agronomic points of view. (McFarlane *et al*., 2006). (Murderers' and Shams, 2001) suggested a new model to optimize land leveling include leveling plane with different longitudinal and transverse slopes. Also, this model had the best plan for leveling the land with minimum amount of cut and fill volume. Their method was better than analysis, such as linear and nonlinear programing methods. (Canzanescu *et al*., 2010) used simultaneous land scan by laser and controlling the labeling machine. Their aims include creating appropriate slope for run-off and choose the cut and fill places in the appropriate ranges to decrease the distance of soil transfer. So, computer aided design (CAD) and GIS techniques were used for data processing and produce a three-dimensional model based on the gathered data. Also, for determining the farm slope, Least-squares method was used and GIS technique was applied to calculate the amount of soil, cut and fill (Dauda *et al*., 2011). They used a GPS system to gather the soil surface roughness data and investigate the minimum volume of soil transfer using GIS technique. Based on their report 236 m3/ha soil had transpired in the region. (Zhand and Wright, 2004) suggested GPS, CAD, and GIS approaches to optimize the determining small plots of large region and determine optimize strategies to cut and fill the farm. They presented a computational algorithm to solve a model that considers different goals and operate the best type of the leveling. Since, lands leveling with machines requires considerable energy. Thus, optimizing energy consumption in the leveling operation is expected (Guoqiang *et al*., 2010). Goktepe and Lav (2003) suggested a hypothetical weighted ground elevation concept to balance cut-fill volumes and to minimize the total amount of earthwork. In this method, the integration of weighted ground elevations along the centerline defines a hypothetical reference ground line to determine optimum grades for both hand and computer calculations. Later, this method was modified to consider some soil properties essential for an accurate earthwork optimization. Weighted ground line method (WGLM) is a technique proposed by the authors for cut-fill balancing and earthwork minimization. The main principle is to calculate a hypothetical center elevation for each cross section that optimizes the earthwork construction in terms of cut-fill balancing and total earthwork minimization. Furthermore, swelling and shrinkage factors, can be incorporated in the method to achieve better results (Goktepe and Law, 2003; Goktepe and Lav, 2004). The optimization results of these two optimization problems can be integrated in existing computer-aided earthwork systems which have been developed in previous research efforts. This Includes earthwork control systems (Askew *et al*., 2002), earthwork modeling and simulation systems (Ji *et al*., 2009) and 4D virtual road construction frameworks (Askew *et al*., 2002). The design of forest road network optimization with the included ecological criterion respects the principle of the optimum density of forest roads based on the transport segment within the Territorial Plans on Forest Development (Macku, 1996) and all technical requirements (Macku, 1996). As a result, this research aimed to apply the approaches including ICA, GA, PSO and MLS methods for energy consumption optimization in the land leveling. Moreover, since a limited number of studies associated with the energy consumption in land leveling have been done, the objective of current energy and cost research is to find a function for all the indices of the land leveling including the slope and cut-fill volume (V).

2- Materials and methods

2.1- Data collection

In order to verify the accuracy and feasibility of the proposed linear programming model, a case study was specified based on the proposed land levelling project in district of Ahvaz, Iran. The study farm was a 70 ha area and located in the west of Iran, between 31° 28' 42" north latitude and 48° 53' 29" east longitude. Topography of the farm was done at scale of 1:500. Outputs of the plan were length, width and height of points (coordinates of x, y and z). The grid size in the region was 20 m× 20 m.

The study area is located 40 km north of the city the average annual temperature and precipitation for the period of 959–2009 were 25.30 oC and 335.70 mm, respectively. Also, the annual Potential Evapotranspiration (PET) of the area is 1755.82 mm. The shoulder had a slope of approximately 18% and the foot slope had a convex slope of about 14%. A schematic of the topography of the land surface before leveling task can be seen in (Figs. 1 and 2).

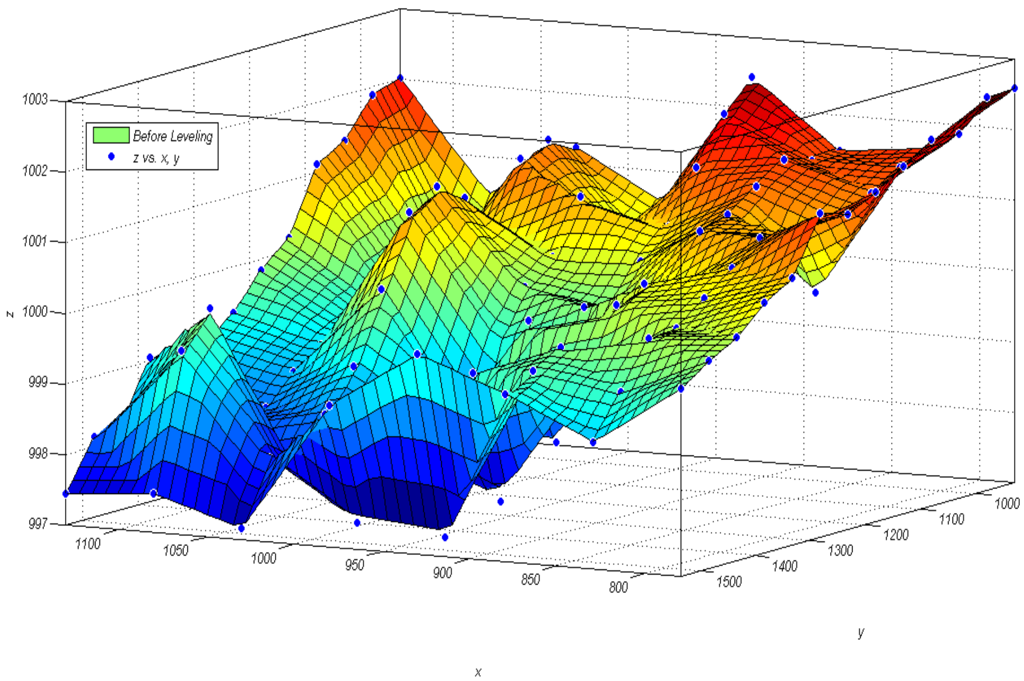

Figure 1) Schematic of the topography of the land before leveling experiment.

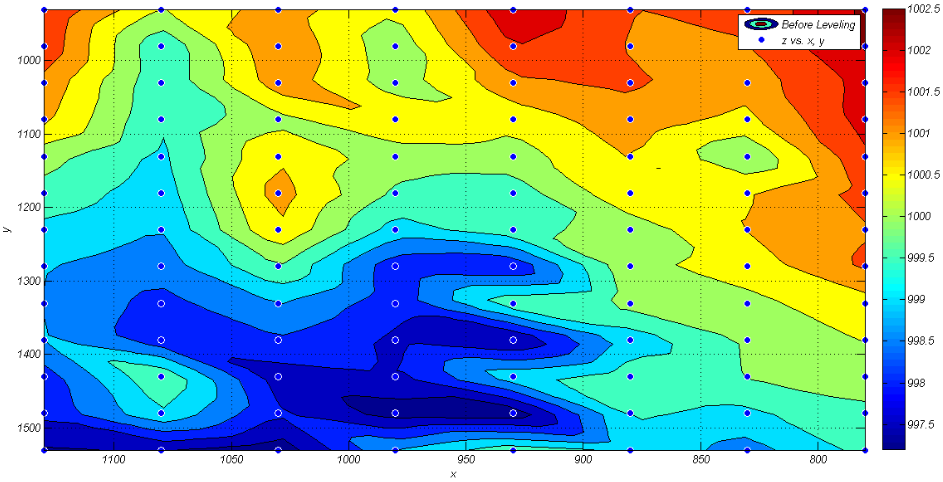

Figure 2) Map Contour map of the topography of the land before leveling.

3- Calculation of energy consumption in the leveling operation

3.1- Data collection

Topographic points the earth, were prepared from three different places with the amount 70 ha. Topography operations by total station topography farm was done at a scale of 1:500.

Data have been obtained by using the graders catalog, Grader width 3m, average grader speed was considered as 5 Km/ha, efficiency (0/65) the total time of operation was determined, graders weight 11390 Km, the number of graders was determined according to the time of operation and the volume of displaced soil. So, in this study 4 graders were used. Energy equivalent was considered as 180 MJ/kg, and total fuel consumption of 20 Lit/ha, energy equivalent of the fuel was determined as 46.8 Mj/lit. Finally, the energy equivalent of human labor was considered as 1.96 Mj/ha.

4- Energy balance analysis method

4.1- Machinery energy

Total energy embodied in machinery included energy for raw materials, manufacturing, repairs and maintenance as well as the transportation energy. Taking into account the total weight and the life of machinery as used in operations, the energy required for land leveling operation was calculated assuming that the embodied energy of machinery would be depreciated during their economic life time (Beheshti Tabar *et al*., 2010). So, their embodied energy was calculated by multiplying the depreciated weight of machinery (kg.ha-1) with their energy coefficient (MJ kg-1). Moreover, the weight of machinery depreciated per hectare of land leveling was calculated as follows (Mousavi Avval *et al*., 2011):

$$TW = \frac{G \times W_h}{T} \qquad (1)$$

where TW is the depreciated weight of machinery (kg ha^{-1}), G is the total machine weight (kg), W_h is the time that machine used per unit area ($h.ha^{-1}$) and T is the economic life time of machine (h).

4.2- Fuel energy

Also, to calculate the fuel energy consumption function, total fuel consumption (20 Lit/ha) was calculated using the number of graders and time of operation and energy equivalent of the fuel that was determined as 46.8 Mj/lit (Table 1). Fuel energy was calculated using the following equation (Asngan *et al*., 2007):

$$f_2(x) = \sum_{i=1}^{n} (q_i \times Eg_{fuel} \times N_i) \qquad (2)$$

where q_i is fuel consumption, E_{gfeel} is energy coefficient of fuel and N_i is number of graders and time of operation.

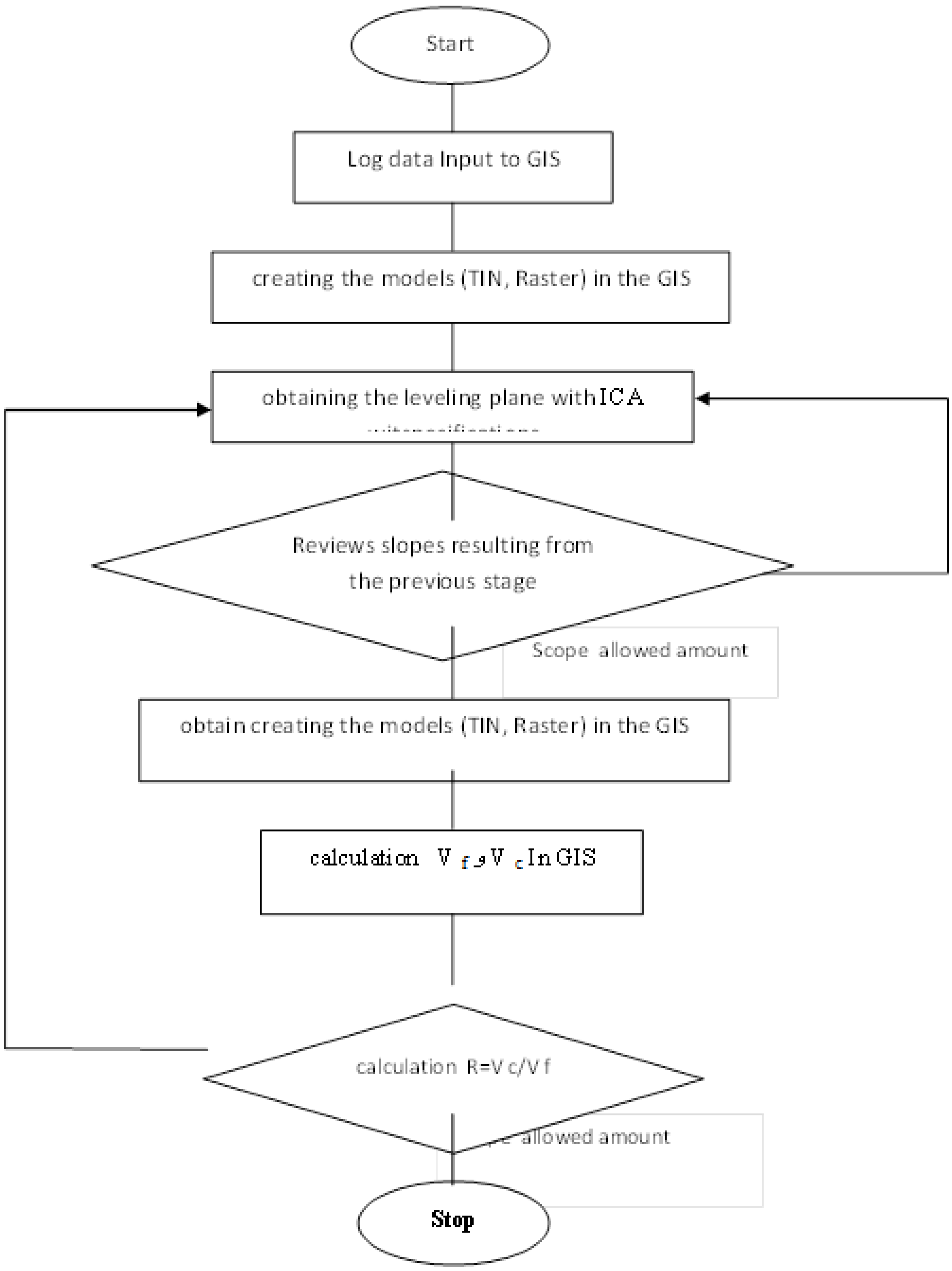

Figure 3) The suggested method in this research.

4.3- Labor Energy

The human energy calculates considering the number of total people involved in the operation. In the calculation of human energy for each grader a driver and driver assistance, a serviceman with 3 hours' work in each 2 days were considered. The energy equivalent may thus be defined as the energy input taking into account all forms of energy in agricultural productions. The energy equivalents were computed for all inputs and outputs using the conversion factors indicated in Table 1. Multiplying the quantity of the inputs used per hectare with their conversion factors gave the energy equivalents. The energy equivalent associated with labor vary considerably, depending on the approach chosen; it must be adapted to the actual living conditions in the target region (Moore, 2010). In this study the energy coefficient of 1.96 MJ h^{-1} (Table 1) was applied. It means only the muscle power used in different field operations of crop production. Labor nergy (LE) was calculated using the following equation:

$$f_3(x) = \sum_{i=1}^{n} (E_{la} \times n_{la} \times t_{la}) \quad (3)$$

where F_3 is Labor energy, E_{la} is Energy coefficient of Labor n_{la} is Number of times labor in the Day and t_{al}: is Number of hours labor in the Day.

Table 1) Energy equivalent of inputs and output

Inputs A. Inputs	Unit	Energy equivalent (MJ Unit^{-1})	Reference
Human labor	h	1.96	(Rafiee *et al.*, 2010)
Diesel fuel	L	47.80	(Canakci *et al.*, 2005)

5- Determining Earthwork Volume (V) by GIS

The volume of the soil, cut and fill obtain by creating the models (TIN, Raster) in the GIS. Having the volume of the soil, cut and fill, the ratio of the soil, cut to fill is calculated and compared with acceptable amount in the literature. If the calculated ratio is within allowable range, the amount of energy consumption will be calculated according to the soil operation volumes. As said in the former section, the number of graders, human labor and grader work time were calculated using Matlab software by considering the volume of soil, cut in the GIS approach and consequently machinery, energy, fuel energy and human energy were obtained (Fig. 3) Suggested method for determining Cut-Fill Volume (V) by GIS.

6- Imperialist competitive algorithm (ICA)

Imperialist competitive algorithm (ICA) is a new swarm-intelligence approach which is applied for optimization of problems in different types. ICA optimization algorithm starts with generating set of random solutions in the search area. In each step, a union of sub groups, colonies, and imperialists assembles the empires. The first population is broken into the subpopulations. Consequently, ICA searches the solution area to find the best solution by considering competition and assimilation operators. During competition and assimilation, empires have interactions with the swarm members. By using assimilation, colonies might reach a better position and it might take the control of the entire empire (kaveh and Talatahari, 2010; Talatahari *et al.*, 2012). In competition part of algorithm, all empires try to take the control of other empires and be the dominant one. Algorithm go forward by the mentioned steps until one empire controls the entire countries. At this time the stop condition is satisfied. For explaining the algorithm practically, the required steps continued as follows:

Step 1: Initializing of the algorithm. Randomized generation of the first solution set and composing the basic solutions in the format of a 1×N_{var} array using the following equation:

$$country = [p_1, p_2, p_3, ..., p_{N_{var}}] \quad (3)$$

where p_i represents variables which are related to socio-political characteristics of the countries such as religion, culture, language, etc. N_{var} denotes the total number of variables for the objective function.

Step 2: in this step the costs of the countries are calculated using the following equation:

$$C = f(country) = f(p_1, p_2, ..., p_{N\,var}) \quad (4)$$

Step 3: Initializing of the empires. In this step, the costs of the imperialist is normalized as follows:

$$NC_n = f_{cost}^{(imp,n)} - \max_i \left(f_{cost}^{(imp,i)} \right) \quad (5)$$

where $f_{cost}^{(imp,n)}$ stands for the cost of n^{th} imperialist and NC_n indicates the normalized cost.

Step 4: In this step, the colonies are divided among imperialists. This process is done by considering the power of imperialist and relationships between the countries and their interdependent empires. This operation is completed using the following respective equations:

$$Power_n = \left| \frac{NC_n}{\sum_{i=1}^{N_{imp}} NC_i} \right| \quad (6)$$

$$NOC_n = round\{Power_n, N_{col}\} \quad (7)$$

$$N_{col} = N_{pop} - N_{imp} \quad (8)$$

where $Power_n$ is the normalized power of each imperialist, N_{col} and N_{imp} are the given number of colonies and imperialists, respectively. NOC_n represents the total number of colonies possessed by n^{th} empire. **Step 5:** Assimilation strategy. In this step colonies move towards their independent imperialist. In this stage, each movement is performed using the following equation:

$$x \approx U(0, \beta \times d) \qquad \beta > 1 \quad (9)$$

where x denotes a uniformly distributed random number, β denotes a number more than one and d represents the distance of a colony from its related imperialist.

Step 6: Revolution strategy. In this step, the colonies movement is directed by adding a random amount of deviation using the following equation:

$$\theta \approx U(-\gamma, \gamma) \quad (10)$$

where θ denotes a uniformly distributed random number and γ represents an adjusting parameter for the deviation from the initial movement direction.

Step 7: Exchanging phase. In this step a colony reaches to a better position than that of imperialist. Then the colony and imperialist replace their positions.

Step 8: Imperialistic competition phase. Calculating the overall power of an empire that is mainly influenced by the power of empire and its colonies according to the following equation:

$$TC_n = f_{\text{cost}}^{(imp,n)} + \xi . \frac{\sum_{i=1}^{NC_n} f_{\text{cost}}^{(col,i)}}{NC_n} \quad (11)$$

where TC_n represents the total cost of the n^{th} empire, and ζ is a coefficient between 0 and 1.

Step 9: Imperialistic competition strategy. In this step, each empire tries to extend its power for controlling more colonies. So, the strongest empire controls the weakest colony from the weakest empire. The competition operator is designed to dedicate the colonies of the weakest empires to the other empires. Based on TC_n, the normalized total cost is evaluated using the following equation:

$$NTC_n = TC_n - \max_i\{TC_i\} \quad (12)$$

where NTC_n denotes the total normalized cost for the n^{th} empire. According to NTC_n, the possession probability of each empire is computed using the following equation:

$$P_{pn} = \left| \frac{NTC_n}{\sum_{i=1}^{N_{imp}} NTC_i} \right| \quad (13)$$

To find out the winner of competition with less computational effort, the vectors P, R, and D are formed using the following equations:

$$P = [P_{P1}, P_{P2}, ..., P_{PNimp}] \quad (14)$$

$$R = [r_1, r_2, ..., r_{N_{imp}}] \;\; r_1, r_2, r_3, ..., r_{Nimp} \approx U(0,1) \quad (15)$$

$$D = P - R = [P_R] = [D_1, D_2, ..., D_{N_{imp}}] = [P_{P1} - r_1, P_{P2} - r_2, ..., P_{PNimp} - r_{Nimp}] \quad (16)$$

where P denotes the vector of possession probability of the imperialists and R represents a vector with uniformly distributed random values. Maximum index of D decides the winner empire of the competition.

Step 10: Eliminating phase. In this step a powerless empire is removed from the competition when it loses all the controlled colonies.

Step 11: Convergence phase. In convergence phase, the most powerful imperialist governs all the remained colonies. Then, the algorithm is stopped.

Figure 4 shows the flowchart of the Imperialist Competitive Algorithm. This algorithm starts by generating a set of candidate random solutions in the search space of the optimization problem. The generated random points are called the initial countries. Countries in this algorithm are the counterpart of Chromosomes in GAs and Particles in Particle Swarm Optimization (PSO) and it is an array of values of a candidate solution of optimization problem. The cost function of the optimization problem determines the power of each country. Based on their power, some of the best initial countries (the countries with the least cost function value), become Imperialists and start taking control of other countries (called colonies) and form the initial Empires (Atashpaz-Gargari and Lucas, 2007). Two main operators of this algorithm are Assimilation and Revolution. Assimilation makes the colonies of each empire get closer to the imperialist state in the space of socio-political characteristics (optimization search space). Revolution brings about sudden random changes in the position of some of the countries in the search space. During assimilation and revolution a colony might reach a better position and has the chance to take the control of the entire empire and replace the current imperialist state of the empire (Atashpaz-Gargari and Lucas, 2007). Imperialistic Competition is another part of this algorithm. All the empires try to win this game and take possession of colonies of other empires. In each step of the algorithm, based on their power, all the empires have a chance to take control of one or more of the colonies of the weakest empire (Atashpaz-Gargari and Lucas, 2007). Algorithm continues with the mentioned steps (Assimilation, Revolution, Competition) until a stop condition is satisfied.

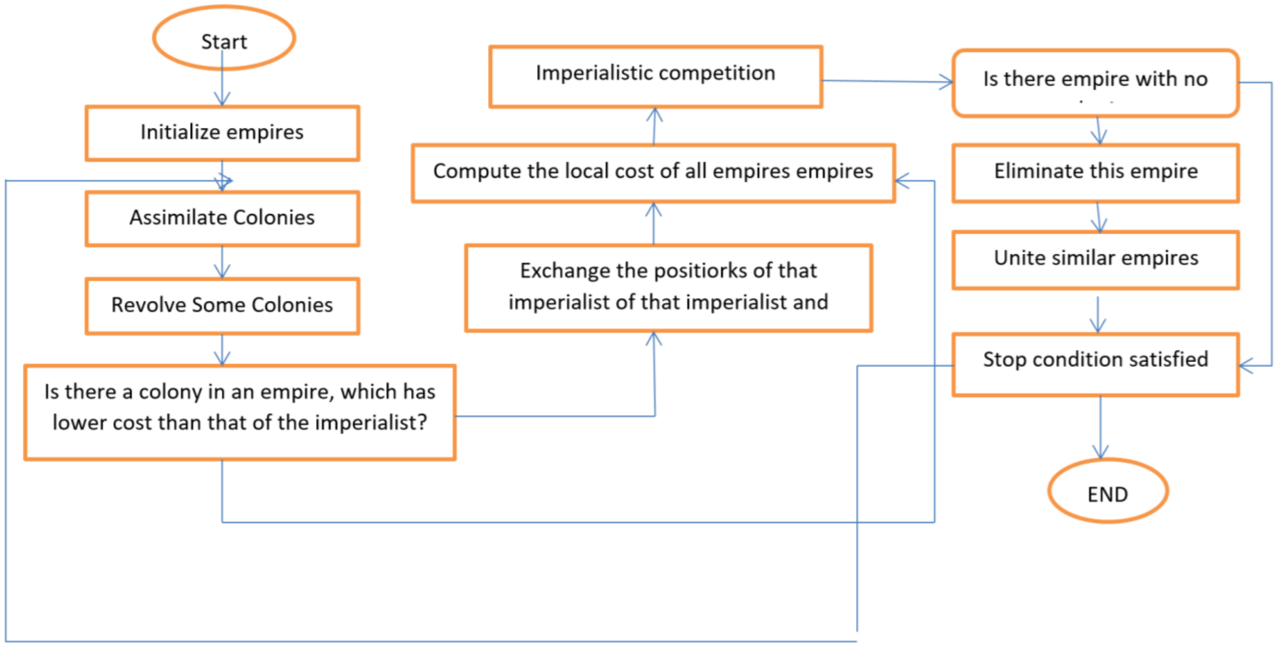

Figure 4) Flowchart of the imperialist competitive algorithm.

7- PSO algorithm

The PSO algorithm search technique was introduced by Kennedy and Eberhart (1995). Scientists found that the synchrony of flocking behavior was through maintaining optimal distances between individual members and their neighbors. Thus, velocity plays the important role of adjusting each other for the optimal distance. Furthermore, scientists simulated the scenario in which birds search for food and observed their social behavior. They perceived that in order to find food, the individual members determined their velocities by two factors; their own best previous experience and the best experience of all other members. (Kennedy and Eberhart, 1995). Application of PSO is in training of artificial neural network weights, and also a good performance of PSO has been demonstrated on a benchmark function for GAs. In their paper, birds are called particles, each representing a potential solution (Shi and Eberhart, 1998). PSO is one of the optimization algorithms to solve complicated problems. In this study, PSO algorithm was used to optimize volume of soil operation and energy consumption. Like previous part several methods were used to model the leveling plane. After the analysis of the results and calculation of the energy consumption, the best model among optimized ones is selected. Therefore, in this model after obtaining the leveling plane specifications including the plane coefficients, the data enters into the GIS software to calculate the volume of the soil fill and cut and the area. The volume of the soil cut and fill obtain by creating the models (TIN, Raster) in the GIS. Having the volume of the soil cut and fill, the ratio of the soil cut to fill is calculated and compared with acceptable amount in the literature. If the calculated ratio is within allowable range, the amount of energy consumption will be calculated according to the soil operation volumes. As said in the former section, the number of graders, human labor and grader work time were calculated using MATLAB software by considering the volume of soil cut in the GIS approach and consequently machinery energy, fuel energy and human energy were obtained.

8- Genetic algorithm

The concept of genetic algorithm (GA) was firstly introduced by Holland (1962). This algorithms are a particular group of evolutionary algorithms, which working principle is the same of Darwinian selection and evolution (Massone and *et al*., 2017). The principle of GA is to create new generations by using strong individuals and eliminating weak individuals, to obtain better solutions. Individuals are modified by crossover and mutation operations in the same way as biological evolution (Hakli, 2017). The GA algorithm gets rid of minima by using a waste range of population.

Problem Statement:

- Object function, the total volume of cuts and fills must be minimized.
- Up and down limit for lands slope in the X axis direction, lands slope in the X axis direction must lie within specified range. In other words, the slope in X axis direction should not be less than a specified amount (e.g. 1%) and exceed a specified amount (e.g. 5%).
- Cut to fill ratio constraint, it is observed in practice that filled holes subside after moisture absorption. Therefore, it is necessary that the amount of filling should be more than cutting. Thus, in many projects the ratio of total volume of cuts to total volume of fill sum need to fit within a specified range (e.g. 1.1 to 1.2).
- The maximum penstock point's height constraint, if land is leveled for surface irrigation for agricultural purpose, it is necessary that penstock point's height should not be more than the specified amount in order to make water pumping dispensable.

The land can be represented as a uniform grid in which the nodes and arcs are identified in certain points. The coordinate of a node is identified as (i, j). The objective of the problem is to determine the height of each node, by cutting and filling while the following technical considerations are considered.

The discussed spatial optimization problem is formulated as a linear programming model as follows:

objective function (modeling the leveling plane to minimize cut and fill volume) in Eqs. 17-24:

$$\sum_{i=1}^{m}\sum_{j-1}^{n} CUT\,(i,j) \leq MAX\_RATIO \qquad (17)$$

$$\sum_{i=1}^{m}\sum_{i=1}^{n} FIL(i,j) \le MAX\_RATIO \quad (18)$$

$$\frac{\sum_{i=1}^{m}\sum_{j=1}^{n} CUT(i,j)}{\sum_{i=1}^{m}\sum_{j=1}^{n} FIL(i,j)} \le 1 \quad (19)$$

$$MIS_{sx} \le SX(i,j) \le MAS_{sx}, \ \forall i-(m), j \quad (20)$$

$$MIN_{sy} \le SY(i,j) \le MAX_{sy}, \ \forall j-(n), i \quad (21)$$

$$CUT(i,j) \le MAX_{cut} \forall i, j \quad (22)$$

$$CUT(i,j) \ge 0, \ \forall i, j \quad (23)$$

$$FIL(i,j) \ge 0, \ \forall i, j \quad (24)$$

As objective function (modeling the leveling plane to minimize cut and fill volume and consequently the amount of energy consumption of leveling operations) process escaping local optima traps) in Eq. 17, total volume of cuts and fills must be minimized. Based on constraints in Eq. 19 and Eq. 20, lands slope in *X*, *Y*-axis directions must be situated in a specified range. In other words, the slope in *X*-axis direction should not be less than a specified amount (e.g. 2%) and exceed than another value (e.g. 6%). Up and down limits for lands slope in the *X*, *Y*-axis directions are shown in Eqs. 21-22. It is observed in practice that filled holes subside after moisture absorption. Therefore, it is necessary that the amount of filling should be more than cutting. Thus, in many projects the ratio of total volume of cuts to total volume of fill sum needs to fit within interval of 0.1. Description mathematical modeling: SX (i,j): lands slope in X axis direction at node (i,j) after leveling, Z (i,j): lands level at node (i,j) after leveling, Fill (i,j): fill depth at node (i,j), CUT (I,j): cut depth at node (i,j), SY (I,j): lands slope in X axis direction at node (i,j) after leveling, i: set of network nodes in X axis direction i= (1,1,3…..m), j: set of network nodes in Y axis direction j=(1,2,3………n), MIN_RATIO: Minimum permissible cut to fill ratio, MAX_RATIO: Maximum permissible cut to fill ratio, MAX_Z: Maximum permissible penstock point height, MAS_CUT: Maximum permissible cut depth, H (I,j): level of node (i, j) before leveling, MAS_SX: Maximum permissible slope in X axis direction, MIN_SX: Minimum permissible slope in X axis direction, MAS_SY: Maximum permissible slope in Y axis direction, MIN_SY: Minimum permissible slope in Y axis direction.

9- Solution Procedures

Given data: The grid system and all points elevations are giving the limits of all the design parameters are also given.

Calculating initial values of the design slopes

Several methods are available to calculate uniform slopes which fit a given land topography. The most widely used one is the least square method that was being finding here very effective. In this method the slopes in the x and y directions can calculate: (Sarmadian and Mirzaei, 1999):

$$S_x = \frac{(\Sigma yh) - NX_c H_c}{(\Sigma y)^2 - Ny_c^2} \quad (25)$$

$$S_y = \frac{(\Sigma yh) - NY_c H_c}{(\Sigma y)^2 - NY_c^2} \quad (26)$$

where: S_x is the slope of the best fit line through the average, x is direction elevation (H_i), S_y is the slope of the best fit line through the average y-direction elevation, (H_j), N is where is the number of stake columns or rows, X_c is x distance from origin to centroid, Y_c is y distance from origin to centroid, Hc is h height from the origin to centroid, $h^{/}_{0,o}$ is H height in the origin, $h^{/}_{x,y}$ is H hights after land leveling, $h_{x,y}$, height before land leveling.

10- Calculating the volume of earthworks

There are several methods to calculate the volumes of cut and fill. The most widely used is the four – point method and is adopted in this work. It is basing on the assumption that the ground surface between two stations is a smooth plane. Each grid may have either cut at all four corners or fill at all four corners, fill at all four corners or cut at two opposite corners and fill at the other two. The weighted depths of cuts and fills for the grids are equal to the average of the depths at the grid corners, Therefore, the volumes of cut and fill on an individual grid may be calculated as follows: (Sarmadian and Mirzaei, 1999).

$$V_c = \frac{A}{4}\left[\frac{(\Sigma c)^2}{\Sigma c + \Sigma F}\right] \qquad (27)$$

$$V_f = \frac{A}{4}\left[\frac{(\Sigma F)^2}{\Sigma c + \Sigma F}\right] \qquad (28)$$

Where Vc is volume of cuts (m^3), V_f is volume of fills (m^3), A is grid area m or n (m^2), C is depth of cut at grid point m (m), F is depth of fill at grid point m (m).

10.1- Calculating initial values of the design slopes

Cut/fill ratio was determined using the following equation (Sarmadian and Mirzaei, 1999):

$$R = \frac{\Sigma C_1}{\Sigma F_1} \qquad (29)$$

11- Results

11.1- Least squares method

The volumes of earthworks and energy consumption in least squares method are presented in (Table 2). The Cut/fill ratio soil is 0.67. Because the ground is uneven, extra soil should be cut. In this model soil-fill is higher than soil-cut, so, the soil should be transferred from outside to the ground and the desirable slope should be obtained. If the volume of excess soil be 13908 m^3 and the round trip time assumed to be 20 s, then, the fuel consumption would be 462.67 L and the cost of this operation would account as 145 $. For this operation lorry and wheel loader machines were used. Total energy consumption in this model is 30242 MJ from which the most energy consuming was fuel energy and it has a direct relationship with the machine, it follows by machinery energy. The least consumption of energy belongs to human labor. The most portion of total energy consumption relates to the fuel energy consumption 81.7% and the least consumption of energy belongs to human labor 0.4%. In this model, 17.87% belongs to the machinery energy consumption (Table 2).

Table 2) volume of earthworks and energy consumption, the method of least square.

model	Fill soil (m3)	Cut soil (m3)	Cut to fill ratio	Machinery energy MJ×(104)	Fuel energy (MJ)	Labor energy (MJ)	Total energy consumption MJ×(104)
method of least squares	39646	25738	0.67	0.5407	2.4708	127	3.0242

11.2- Imperialist competitive algorithm model

11.2.1- Calculating the volume of earthworks

In application of ICA model, the volume cut soil and fill soil is same by 33343 m^3 and 33343 m^3, respectively. Therefore, there is no need to move soil from out of field and vice versa. When this ratio is close to 1, the fuel consumption would reduce, total energy consumption in the model is 39172 MJ from which the most energy consuming was fuel energy that has a direct relationship with the machine performance, the least consumption of energy belongs to human labor. The most portion of total energy consumption is for the fuel energy consumption 81.7% and the least consumption of energy belongs to human labour 0.41%. In this model, 17.8% belongs to energy of the machinery consumption. The success rates SR, reveal a robust performance for ICA in tackling leveling task. STD results also demonstrate that the quality of the solutions is acceptable, the results are presented in the (Table 3). By estimating leveling surface and map leveling of ground at different levels using ICA, the cost of energy consumption in land leveling was decreased more than 3760 thousand Rials per hectare (Figs. 5 and 6).

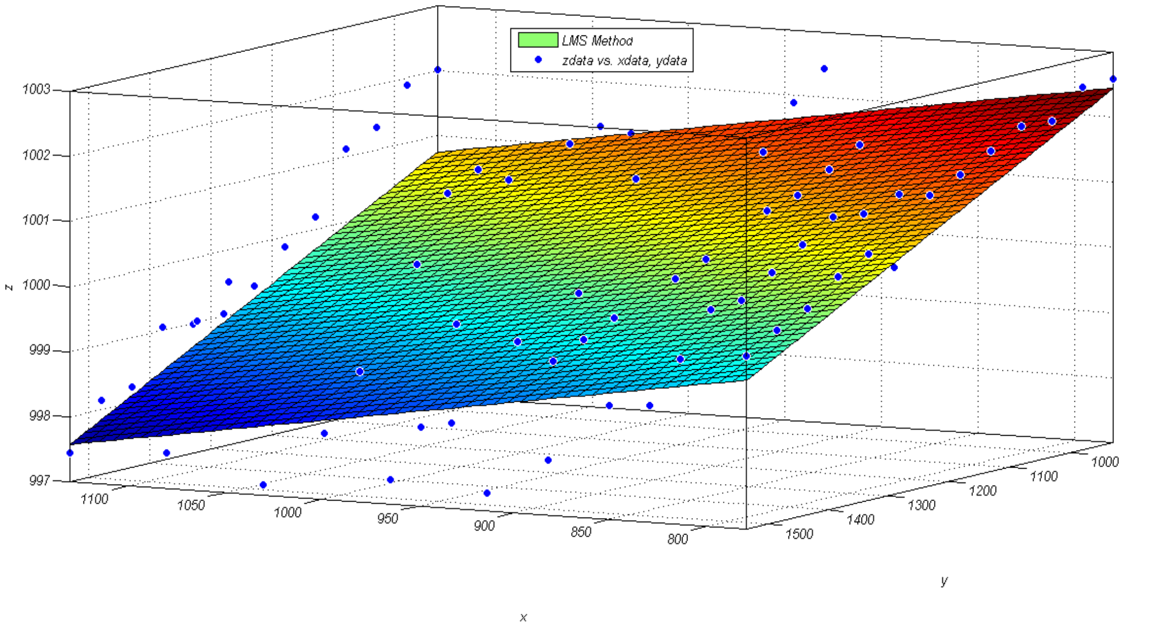

Figure 5) Estimating Leveling Surface by ICA.

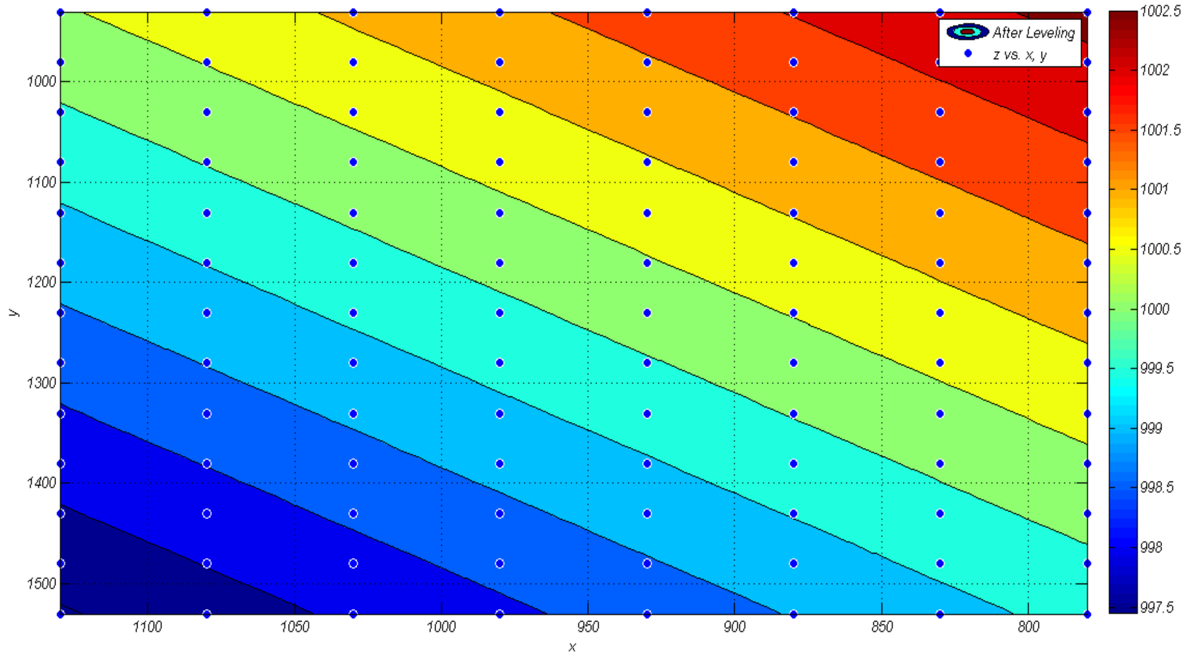

Figure 6) Map leveling of ground at different levels by ICA.

Table 3) Volume of earthworks and energy consumption on ICA.

model	SR	meanF±STD	Cutting soil (m3)	Filling soil (m3)	Cut to fill ratio	Machinery energy 104×(Mj)	Fuel energy 104×(Mj)	Labor energy (Mj)	Total energy consumption 104×(Mj)
1	29	0±1.03E-02	33343	33343	1	0.7005	3.2009	157.57	3.9172
2	30	0±1.21E-03	45683	45683	1	0.9597	4.3859	207.19	5.3660
3	30	0±2.42E-04	31850	31850	1	0.6691	3.0576	151.57	3.7419
4	28	0±0.78E-02	31344	31344	1	0.6585	3.0090	149.54	3.9825
5	30	0±0.26E-04	66258	66258	1	1.3920	6.3608	313.43	7.7842

12- Genetic algorithm model

Based on the results of GA, the ratio of soil cut/fill from model one to model seven increases from 1.032 to 1.31. In this model soil cut is higher than soil fill because the ground is uneven, transport the surplus soil to out of land. This work increases the cost of fuel and machinery for transport. Total energy consumption in model 1 is 30242 MJ from which the most energy consuming was fuel energy and it has a direct relationship with the machine. The least consumption of energy belongs to human labor. The most portion of total energy consumption is for the fuel energy consumption 81.7% and the least consumption of energy belongs to human labor 0.4% .In this model, 17.87% belongs to the machinery energy consumption that are presented in the Table 3. the cost of energy consumption in land leveling was decreased more than, 1918 thousand Rials per hectare (Table 4).

12.1- PSO model

Based on the results of PSO, the ratio of soil cut/fill from model one to model seven increases from 1.032 to 1.35. In this model soil cut is higher than soil fill because the ground is uneven, transport the surplus soil to out of land. This work increases the cost of fuel and machinery for transport. Total energy consumption in model 1 is 62554 MJ from which the most energy consuming was fuel energy and it has a direct relationship with the machine. The least consumption of energy belongs to human labor. The most portion of total energy consumption is for the fuel energy consumption 81.73% and the least consumption of energy belongs to human labor 0.37%. In this model, 17.9% belongs to the machinery energy consumption. The cost of energy consumption in land leveling was decreased more than 2028 thousand Riels per hectare (Table 5).

12.2- Comparing the different methods on volume of earthworks and energy consumption

Comparison volume of earthworks at different method

Volumes of earthworks at different methods are presented in (Fig. 7). Increasing cut-fill volume in the method of least square, the model of GA and model of PSO algorithm, respectively. Decreasing cut-fill volume (V) in the model of ICA1.

12.3- Comparison cost saving in energy consumption for different models

As Figure 8 is indicating, the highest decrease ratio in cost of energy was found for Imperialist Competitive Algorithm (ICA1), the model 1 of Genetic Algorithm (GA1) and PSO Algorithm, respectively. So that the Imperialist Competitive Algorithm (ICA), the cost of energy consumption in land leveling was decreased more than 3760 thousand Rials per hectare. Also the Genetics Algorithm Method and the PSO Algorithm Method. Imperialist Competitive Algorithm (ICA1) caused a decrease 1918 and 1341 thousand Rials in cost of energy consumption, respectively. In conclusion, the least sparing in cost of energy was associated with the Method of Least Square.

12.4- Comparison of decrease in working hours of the machine for different models

As Figure 7 indicates, the highest percentage of decrease in working hours of the machine was found in ICA1. So that working hours of machine in land leveling declined 52% of in ICA1. GA and PSO Algorithm method caused a decrease of 27% and 19% in working hours of the machine, respectively.

12.-5 Comparison in total consumption energy ratio for different models

As shown in Figure 10, review and analysis of the results shows the highest decrease ratio in cost of energy was found for ICA1, the cost of energy consumption in land leveling was decreased more than 3760 thousand Rials per hectare. The highest percentage of decrease in working hours of the machine was found in ICA. This method declined 52% of working hours of machine in land leveling. The highest percentage of decrease in total energy was found in ICA1. So that, ICA1 declined 137% of total consuming energy in land leveling.

Table 4) Volume of earthworks and energy consumption for GA.

model	SR	meanF±STD	Cutting soil (m3)	Filling soil (m3)	Cut to fill ratio	Machinery energy 104×(Mj)	Fuel energy 104×(Mj)	Labor energy (Mj)	Total energy consumption 104×(Mj)
1	15	1652±1.12E^{-02}	53258	51606	1/032	1/1189	5/1128	237/65	6/2554
2	19	3518±3.73E^{-03}	64337	60819	1/057	1/3517	6/1763	305/71	7/5586
3	20	5181±5.45E^{-04}	66609	61428	1/084	1/3994	6/3945	314.84	7/8254
4	21	13885±1.96E^{-01}	68211	54326	1/25	1/4320	6/5483	321.3	8/0131
5	24	9322±2.49E^{-04}	68636	59314	1/15	1/4421	6/5891	322/99	8/0623
6	14	8241±1.24E^{+00}	70456	62215	1/13	1/4802	6/7638	330/31	8/2770
7	26	17818±1.12E^{+01}	75009	57191	1/31	1/5759	7/2009	348/64	8/8116

Table 5) Summary of results obtained from PSO algorithm for the curve model.

model	SR	meanF±STD	Cutting soil (m^3)	Filling soil (m^3)	Cut to fill ratio	Machinery energy 10^4×(Mj)	Fuel energy 10^4×(Mj)	Labor energy (Mj)	Total energy consumption 10^4×(Mj)
1	15	1652±1.12E^{-02}	67713	51606	1/032	1/1189	5/1128	237/65	6/2554
2	19	3518±3.73E-03	54014	60819	1/057	1/3517	6/1763	305/71	7/5586
3	20	5181±5.45E-04	51971	61428	1/084	1/3994	6/3945	314.84	7/8254
4	21	13885±1.96E-01	59655	54326	1/25	1/4320	6/5483	321.3	8/0131

13- Discussion

Among seven effective parameters on Labor Energy (LE), Fuel energy (FE) and Machinery Energy (TME), only three of them had significant effect. Soil cut/fill volume was recognized as the most significant parameter that are shown in (Table 1). Increasing the cut/fill volume of a soil would lead to an increase in all the number of the required machinery, work hour, number of labours and also total cost of operation. It is obvious that these in turn will intensify the energy consumption in all four evaluated parameters. Embankment and excavation are the most part of the land levelling operation such as preparing lands for irrigation, building infrastructures and airports and road constructions, so, it is sensible to minimize the energy consumption of this operation. A proper solution for reducing the amount of required energy for soil cut/fill volume during land levelling operations diminishes the cost of such operations. Avoiding excessive cut/fill volume and lessening the displaced volume of soil will directly reduce the amount of required energy and cost. The soil parameters, cut-fill volume, slope and sand percent have the greatest impact on amount of energy used in land-levelling. So that the results show the relationship of land leveling in the energy with the slope of the land, swelling coefficient and soil type is significant. By increasing land slope, volume of excavation and embankment increases and the number of sweep and distance travelled levelling machines also increases and fuel consumption will increase. Increase in soil swelling factor, increases the volume of the embankment and increase in volume of the embankment also increases the demand on fuel and energy.

Ayranci and Temizel (2011) applied a new method (volume equalization method-VEM) which has been developed to perform land grading design in designing the uniform sloped grading in one direction. The main goal of their method was to minimize the volumes of earth work required for acceptable smooth surface.

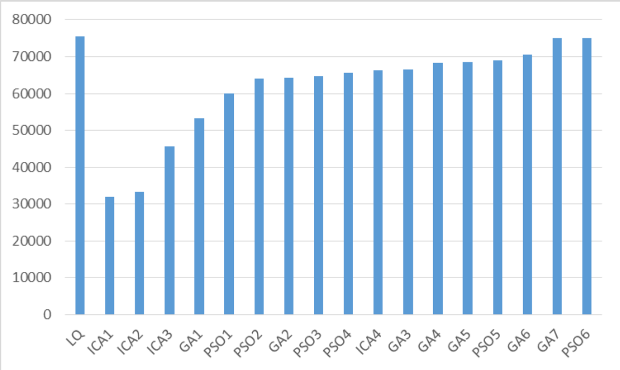

Figure 7) Volume of earthworks at different methods (M3).

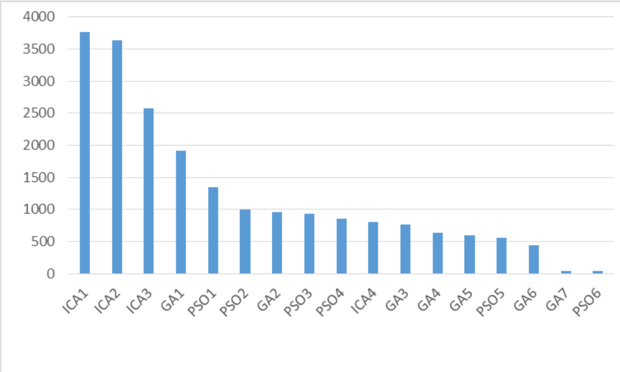

Figure 8) Cost saving in energy consumption for different models (Thousand Rials).

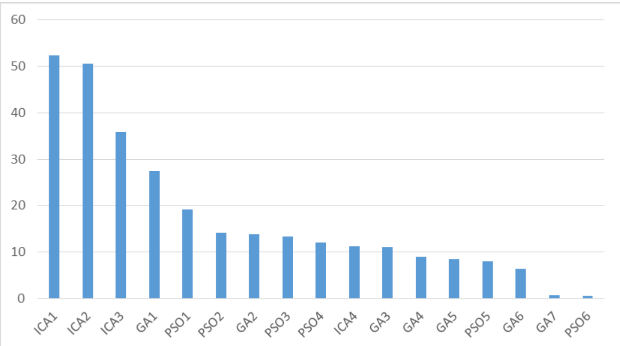

Figure 9) Percentage of decrease in working hours for different models (h).

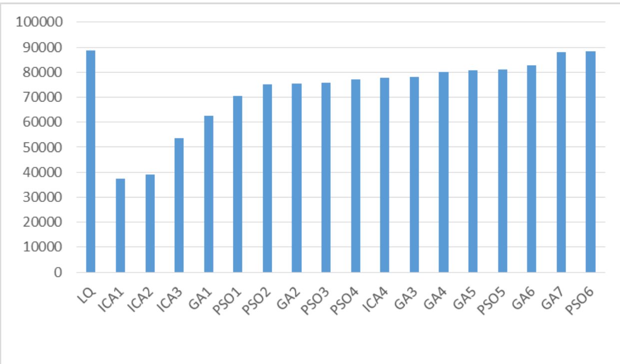

Figure 10) Percentage of decrease in total consumption energy ratio for different models (MJ).

According to the results of the application of the complete design procedure to a hypothetical area about 2.21 ha, the method was as accurate as the conventional least-squares method in rectangular fields. Wang *et al*. (2010) attempted to find an optimal process is a GIS–based approach which solves the transportation problem by determine the designed terrain level and optimal hauling distances that result in the lowest hauling cost. They results showed that the optimal average hauling distance calculated from the proposed linear programming model was 79.53 m shorter than that estimated using the empirical method, and the unit cost calculated from the linear programming model was 33.4% lower than the experienced cost. The improvements in the optimization of the hauling distance showed that the cost of the agricultural land levelling could be efficiently lowered if an appropriate linear programming model is used.

14- Conclusion

In this study the leveling of the land was modeled using ICA algorithm programing in the Matlab software and by determining the volume of the soil cut and fill, the energy consumption was calculated. The main results include:

- Create limitations such as the maximum depth of cutting and the ratio of cut to fill are important and is possible in the suggested method.
- The estimation of specifications of the leveling plane is affected by the minimum and maximum amount of slopes of plane. From trial and error method, the best combination of input parameters had selected.
- The abilities of GIS approach in estimation of soil volume operation by the available functions in this software and graphical illustration provide an appropriate capability for comparison and analysis of the results.

The results of ICA show that the use of this algorithm similar to the genetic algorithm reduces the energy consumption in the leveling operation and reduces the human labor energy consumption as 23.3%.

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