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Distribution of tractor power based on output energy: A case study in Iran

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ABSTRACT

One of the important problems in agriculture, especially in developing countries, is the shortage of tractor power in agricultural fields. In this study distribution of available tractor power among provinces of Iran was investigated. Output energy from fields of each province and also potential energy of available tractors was calculated for tree years. These tow factors helped to present a mechanization index (w). This index shows amount of output energy relative to available tractor power for each province. Through all provinces, Kermanshah province had maximum value of this index (27.34) and Hormozgan province had minimum of that (0.39). Provinces were classified according to amount of their need to tractor power using mechanization index (w) and degree. This pattern can be used to distribute power among provinces. Also, in order to raise mechanization index (w) and degree was recommended to use appropriate agronomical pattern so that operations needing to tractors must be optimally spread during year.

Key words*:* Tractor power; Mechanization degree; Energy; Mechanization level

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INTRODUCTION

Today, tractor is one of the most important power sources in agriculture. Effect of tractor power on agriculture is considerable [1]. The use of modern technology during latter decades resulted in rapid growth of farm production. Tractors and farm machinery are important samples of this modern technology[2,3]. The quality of inputs of mechanization and consequently land and labor productivity in both situations, may differ considerably [4-6]. Mechanization planning requires the quantitative assessment of a mechanization index and its impact on agricultural production (yield) and economic and energy factors (cost of cultivation, deployment of animate and mechanical power, economic advantage and energy ratio). Several authors have studied the status of mechanization with reference to the intensity of power or energy availability and its impact on increasing the agricultural productivity. Giles [7]reviewed power availability in different countries and demonstrated that productivity was positively correlated with potential unit farm power. The impact of tractorization on the productivity of land (yield and cropping intensity) and economic growth (income and employment) were previously assessed [8]. The trends of European and Asian countries were, however, distinctly different. Binswanger [9] defined the status of mechanization by the growth of mechanically power operated farm equipment over traditional human and animal power operated equipment. Rijk [10] reviewed the growth of mechanization in different Asian countries and

suggested computer software (MECHMOD) for the formulation of strategy for mechanization policy based on economics of using animate and mechanical power for different field operations. Singh and De [11] reviewed the methodologies adopted by several authors to express a mechanization indicator. A major defect in quantifying a mechanization indicator based on the ratio of mechanical tractive farm power to total farm power is that it does not bring to light the actual use scenario. Whilst unit farm power could be considered as indicative of potential power availability, it may not necessarily be fully utilized on the farms. This may depend upon availability of diesel fuel and electricity and adequate workload. The majority of the farmers in developing countries use tractors for transport of agricultural and non-agricultural commodities.

Mechanization index (IE) expressed by the percentage of machine work (EM) to the sum of manual (EH), animal (EA) and machine work (EM) expressed in energy units, as suggested by Nowacki [12] has been accepted for model forecasting using Eq (1):

$$IE = \frac{EM}{EH + EA + EM} \qquad (1)$$

Despite this, in developing countries such as Iran, shortage of tractor power is one of the most important problems in agriculture. For an agricultural enterprise, tractors are the most expensive farming input after farm buildings [13]. Therefore, available tractors should be used as much as possible. Demirci [14] suggested that minimum tractor usage should be 650 h a year and effective usage should be 850–1000 h a year in Turkey. Sabanci et al. [15] in their study of agricultural mechanization in Turkey, concluded that more emphasis should be placed on improvements such as transition to small but powerful tractors, increasing the annual usage of tractors, diversifying agricultural machinery to use tractors more effectively with planning of mechanization. In this way, it was expected to make better use of mechanization in terms of economics and management.

For macro-level planning, distribution of tractors among different regions must be on the basis of the amount of their need to tractor power. Proper distribution of tractors will cause to increase annual usage of tractors and consequently to increase the mechanization level thorough out the regions. In this study, it is embarked that a pattern to distribute tractors among the provinces of Iran be presented to improve mechanization of the total country by describing mechanization indexes.

MATERIALS AND METHODS

Iran covers an area of approximately 1,648,195 square km and is subdivided into 29 provinces, each governed from a local center, usually the largest local city, which is called the capital of that province (Fig 1). Geographic characteristics of provinces and their capitals are showed in Table 1.

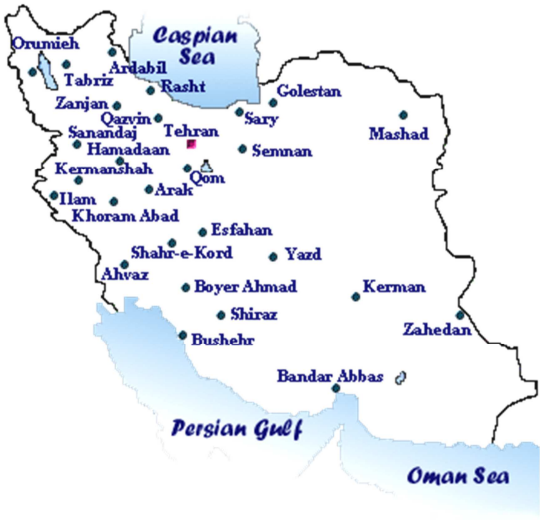

Fig 1. Geographic situation Capitals of provinces in Iran

Table 1. Geographical characteristics of provinces of Iran

province	Capital	Geographic Situation of Capital		Area (km2)	province	Capital	Geographic Situation of Capital		Area (km2)
		longitude	latitude				longitude	latitude	
Ardabil	Ardabil	48°18'	38°15'	17,800	Khorasan	Mashhad	59°36'	36°17'	242,670
Azarbaijan, East	Tabriz	46°17'	38°5'	45,650	Khuzestan	Ahvaz	48°40'	31°19'	64,055
Azarbaijan, West	Urmia	45°2'	37°32'	37,437	Kohgiluyeh and Boyer-Ahmad	Yasuj	51°36'	30°40'	15,504
Bushehr	Bushehr	50°51'	28°59'	22,743	Kurdistan	Sanandaj	47°0'	35°19'	29,137
Chahar Mahaal and Bakhtiari	Shahrekord	50°51'	32°19'	16,332	Lorestan	Khorramabad	48°21'	33°29	28,294
Fars	Shiraz	52°32'	29°37'	122,608	Markazi	Arak	49°42'	34°5'	29,130
Gilan	Rasht	49°35'	37°16'	14,042	Mazandaran	Sari	53°5'	36°34'	23,701
Golestan	Gorgan	54°26'	36°50'	20,195	Qazvin	Qazvin	50°0'	36°16'	15,549
Hamadan	Hamadan	48°31'	34°48'	19,368	Qom	Qom	50°53'	34°38'	11,526
Hormozgan	Bandar Abbas	56°18'	27°11'	70,669	Semnan	Semnan	53°23'	35°34'	97,491
Ilam	Ilam	46°25'	33°38'	20,133	Sistan and Baluchistan	Zahedan	60°52'	29°29'	181,785
Isfahan	Isfahan	51°39'	32°38'	107,029	Tehran	Tehran	51°24'	35°41'	18,814
Jiroft	Jiroft	57°44'	28°40'	13,800	Yazd	Yazd	54°22'	31°53'	129,285
Kerman	Kerman	57°5'	30°17'	180,836	Zanjan	Zanjan	48°28'	36°40'	21,773
Kermanshah	Kermanshah	47°4'	34°18'	24,998					

The number of available tractors for each province and also their areas under cultivation and their crops yield were studied for 2003, 2004 and 2005, separately. Accumulated data was used in this investigation. Mean of drawbar power per unit area for a hectare (Mechanization Level) was calculated by Eq.2:

$$ML = \frac{P_a \times 0.75}{S_T} \qquad (2)$$

where ML is Mechanization Level (kW / ha), P_a is the total available power of tractor in each province (kW) and S_T is Total planted area (ha).

Ratio of mechanized operations to the total operations (Mechanization degree) was calculated by Eq.3:

$$MD = \frac{S_m}{S_T} \qquad (3)$$

where MD is Mechanization degree and S_m is the area under mechanized operations (ha).

Mean of mechanization levels and degrees as well as planted area from 2003 to 2005 related to each province were individually presented in Table 2.

Potential energy of available tractors in a province means to use all the present tractors with their maximum power in total possible time so that maximum energy is produced by tractors. Of course, it can not be occurred. It is imagined that the tractors are used with their maximum power for total workable hours. The workable hours was obtained by number of working days multiplied by 8 working hours. The unworking days that tractors are unusable, are recognized by two factors. First, tractor is needed to work but it is unable because of inappropriate atmospheric condition. This is ordinarily occurred in cold part of year due to snowfall, rainfall, freezing, etc. second, days that tractor is able to work but it is not needed to work tractor because there isn't cultivated farm due to dry weather and water shortage to irrigate. This is ordinarily occurred in hot part of a year. Therefore the number of workable days is equal to the difference between total days (both workable and unworkable) and unworkable days during one year. In order to omit impact of area on the potential energy of available tractors for a region Eq. 4:

$$E_P = \frac{E_{TP}}{S_T} \qquad (4)$$

where E_P is the potential energy of available tractor in unit area (MJ/ha) and E_{TP} is the total potential energy of available tractors (MJ).

Table 2. Mean of mechanization level, degree and planted area from 2003 to 2005.

Province	mechanization level (kW/ha)	mechanization degree (%)	Area (ha)
Ardabil	0.812	0.55	650902
Azarbaijan, East	0.812	0.40	759316
Azarbaijan, West	1.282	0.51	613139
Bushehr	0.315	0.68	211909
Chahar Mahaal and Bakhtiari	1.144	0.52	153047
Fars	0.787	0.56	990144
Gilan	0.704	0.21	248394
Golestan	0.477	0.65	678736
Hamadan	0.712	0.46	640557
Hormozgan	1.217	0.60	60932
Ilam	0.448	0.53	205070
Isfahan	1.512	0.45	330682
jiroft	0.515	0.48	143027
Kerman	1.694	0.51	160474
Kermanshah	0.596	0.54	769009
khorasan	0.737	0.43	1276786
Khuzestan	0.575	0.57	891068
Kohgiluyeh and Boyer-Ahmad	0.270	0.27	200983
Kurdistan	0.722	0.54	651144
Lorestan	0.459	0.45	686063
Markazi	0.860	0.52	338298
Mazandaran	1.745	0.50	401929
Qazvin	0.745	0.54	247116
Qom	0.965	0.70	52840
Semnan	0.467	0.59	109336
Sistan and Baluchistan	1.51	0.29	104685
Tehran	0.837	0.70	162883
Yazd	1.646	0.43	57734
Zanjan	0.512	0.45	492364

In each province, the amount production of different crops was multiplied by their specific energy value individually. It was carried to calculate the produced energy in the agricultural section of each province. The mean output energy in unit area was calculated by Eq.5:

$$E_{out} = \sum_{i=1}^{n} \frac{EV_i . L_i . S_i}{S_T} \qquad (5)$$

where E_{out} is the mean of output energy in unit area (MJ/ha), EV_i is the energy value of i crop (MJ/hg), L_i is the mean of yield of i crop (kg/ha) and S_i is the total planted area of i crop (ha).

E_{out} related to the provinces were calculated for 2003, 2004 and 2005, individually. E_{out}, means how much energy produce in one hectare, on average. In order to recognize ratio of output energy in the agricultural section to the potential energy of available tractors, a mechanization index is offered by Eq. 6:

$$W = \frac{E_{out}}{E_P} \qquad (6)$$

where W is the ratio of the output energy to the potential energy of available tractors.

Mechanization index (w) related to each province was calculated for 2003, 2004 and 2005 separately. It is shown in Table 3 for all provinces. Because this index has no unit, it is comparable among various provinces easily. From the energy aspect, the mechanization index (w) can be used to distribute the tractor power among the provinces favorably.

The F test was used to determine significant the mechanization index (w) significant among the provinces and the Duncanṡ multiple ranges test was used to separate means at a 5% level of significance by using the computer software SPSS 13.0.

Table 3. Mechanization index (w) related to provinces of Iran.

Province	Mechanization index (W)			Province	Mechanization index (W)		
	2003	2004	2005		2003	2004	2005
Ardabil	2.05	2.31	2.65	khorasan	3.52	7.47	1.29
Azarbaijan, East	2.43	2.52	2.69	Khuzestan	15.43	17.82	16.78
Azarbaijan, West	2.13	2.33	2.08	Kohgiluyeh and Boyer-Ahmad	0.93	1.03	0.85
Bushehr	2.17	2.10	2.77	Kurdistan	3.21	3.76	3.49
Chahar Mahaal and Bakhtiari	0.57	0.66	0.64	Lorestan	1.38	1.52	1.45
Fars	22.13	22.86	23.27	Markazi	11.06	13.67	11.82
Gilan	2.81	2.40	2.35	Mazandaran	6.29	6.16	6.61
Golestan	10.40	11.72	10.99	Qazvin	25.11	20.67	28.07
Hamadan	20.45	19.59	16.56	Qom	0.48	0.48	0.52
Hormozgan	0.40	0.40	0.36	Semnan	2.12	2.44	2.27
Ilam	3.39	3.15	3.98	Sistan and Baluchistan	0.80	0.81	1.10
Isfahan	5.74	5.83	5.58	Tehran	10.84	12.33	17.60
jiroft	4.09	4.29	3.32	Yazd	6.20	6.11	5.78
Kerman	1.65	1.73	1.83	Zanjan	13.21	14.55	13.88
Kermanshah	27.20	27.70	27.13				

RESULTS AND DISCUSSION

3.1Mechanization index (w)

The mechanization index (w) shows how output energy in a province is produced by the agricultural section relative to the amount of available tractor power. Comparison of means related to the mechanization index (w) was shown in Table 4.

Table 4. Comparison of means related to mechanization index (w).

Province	Mechanization index (w)	Province	Mechanization index (w)	Province	Mechanization index (w)
Kermanshah	27.34a	Yazd	6.03gh	Semnan	2.28jkl
Qazvin	24.62b	Isfahan	5.72ghi	Azarbaijan, West	2.18jkl
Fars	22.75b	khorasan	4.09hij	Kerman	1.74jkl
Hamadan	18.87c	jiroft	3.90hij	Lorestan	1.45kl
Khuzestan	16.67d	Ilam	3.50ijk	Kohgiluyeh and Boyer-Ahmad	0.94l
Zanjan	13.88e	Kurdistan	3.49ijk	Sistan and Baluchistan	0.90l
Tehran	13.59e	Azarbaijan, East	2.55jkl	Chahar Mahaal and Bakhtiari	0.62l
Markazi	12.18ef	Gilan	2.52jkl	Qom	0.49l
Golestan	11.03f	Bushehr	2.34jkl	Hormozgan	0.39l
Mazandaran	6.35g	Ardabil	2.33jkl		

The means with minimum common letter are not significantly different ($P<0.05$) according to Duncan's multiple ranges test

It is clear that the output energy depends on yield of crops and yield depends not only on available power in the province but also on importance and numerous factors such as soil texture, amount of rainfall, condition of irrigation and management level, etc. Therefore it is possible that some provinces, enough power of tractors is available but their output energy level is low. It occurs when other factors are unfavorable. Furthermore it is possible that in some provinces this occur conversely. It means that shortage of tractor power is principal restrictive factor in farming of these provinces. Therefore in some condition, shortage of tractor power for many provinces is principal factor of restrictive and for other provinces is slight factor. In other word, impact of shortage of tractor power on yield in the various provinces is different. Accordingly, the amount of needs to new tractor power in unit area is different thorough provinces.

Therefore some provinces need to more tractor power than other provinces. Distribution method of new tractors must be on the basis of their need intensity to new power. This method will have more productivity than other methods, because in this method new tractors are able to remove more limitation against the farming in the total area of country. In Iran, distribution of tractors is typically done on the basis of the mechanization level. But it can not be a good index, alone, and the mechanization degree too. But the mechanization index (w) and the mechanization degree, together are able to manage distribution of tractors among provinces, favorably.

3.2 Classification of provinces according to their need to tractor

Provinces were grouped into four categories according to the mechanization index (w) and degree. Four groups were as follows:

Group 1: In these provinces the values of their mechanization index (w) and degree are low
Group 2: In these provinces the value of their mechanization index (w) is low but their mechanization degree is high
Group 3: In these provinces the value of their mechanization index (w) is high but their mechanization degree is low
Group 4: In these provinces values of their mechanization index (w) and degree are high

Table 5. Classified provinces on basis of their priority to be allotted new tractors.

First priority	Next priorities
Ardabil	—
Azarbaijan, East	—
Azarbaijan, West	—
Bushehr	—
Chahar Mahaal and Bakhtiari	—
Fars	Bushehr, Golestan, Hormozgan, , Khuzestan, Qom, Semnan and Tehran
Gilan	—
Golestan	Bushehr and Qom
Hamadan	Ardabil, Bushehr, Chahar Mahaal and Bakhtiari, Golestan, Hormozgan, Ilam, jiroft, Kerman, Khuzestan, Kurdistan, Markazi, Mazandaran, Qom, Semnan and Tehran
Hormozgan	—
Ilam	Hormozgan and Qom
Isfahan	Ardabil, Azarbaijan, West, Bushehr, Chahar Mahaal and Bakhtiari, Hormozgan, Kerman, Qom and Semnan
jiroft	Chahar Mahaal and Bakhtiari, Hormozgan and Qom
Kerman	—
Kermanshah	Ardabil, Bushehr, Fars, Golestan, Hormozgan, Khuzestan, Qom, Semnan and Tehran
khorasan	Chahar Mahaal and Bakhtiari, Hormozgan, Lorestan and Qom
Khuzestan	Bushehr, Golestan, Hormozgan, Qom, Semnan and Tehran
Kohgiluyeh and Boyer-Ahmad	—
Kurdistan	Hormozgan and Qom
Lorestan	—
Markazi	Ardabil, Bushehr, Hormozgan, Kurdistan, Qom and Semnan
Mazandaran	Ardabil, Azarbaijan, West, Bushehr, Chahar Mahaal and Bakhtiari, Hormozgan, Ilam, Kurdistan, Qom and Semnan
Qazvin	Ardabil, Bushehr, Golestan, Hormozgan, Khuzestan, Kurdistan, Qom, Semnan and Tehran
Qom	—
Semnan	—
Sistan and Baluchistan	—
Tehran	—
Yazd	Ardabil, Azarbaijan, West, Bushehr, Chahar Mahaal and Bakhtiari, Hormozgan, Ilam, Kerman, Kurdistan, Lorestan, Qom and Semnan
Zanjan	Ardabil, Azarbaijan, West, Bushehr, Chahar Mahaal and Bakhtiari, Golestan, Hormozgan, Ilam, jiroft, Kerman, Kurdistan, Mazandaran, Qom and Semnan

The low mechanization index (w) (in groups 1 and 2) may be due to either low yield of crops or high amount of tractor power in the region. In these provinces, if the mechanization degree is high, shortage of tractor power has a little share on restrictive factors in farming. Furthermore, the high mechanization index (w) (in groups 3 and 4) may be due to either high yield or low amount of tractor power in the region. In these provinces, if mechanization degree is low, shortage of tractor power has a big share on restrictive factors in farming. Therefore, the provinces included in group 3 have priority to be allotted new tractors. Because they have both higher the mechanization index (w) and lower the mechanization degree compared to other provinces. For instance Fars province has priority to be allotted

new tractors compared to Tehran province. Because their mechanization index (w) and degree are respectively, 22.7 and 0.57 for Fars province, while for Tehran province the corresponding values are 13.59 and 0.70, respectively. But Golestan and Azarbaijan East provinces can not be compared together, because the mechanization index (w) and degree are 11.03 and 0.66 for Golestan and 2.55, 0.41 for Azarbaijan, East, respectively. Although mechanization index (w) of Golestan is higher than that of Azarbaijan East but its mechanization degree is not lower. Based on that, all provinces of country were compared together. Consequences of performed comparisons are shown in Table 5. As seen in this table, for example, Markazi province has priority to be allotted in comparison with Ardabil, Bushehr, Hormozgan, Kurdistan, Qom and Semnan provinces.

One of the important factors which are caused to prevent promotion of the mechanization degree is peak of operations needing to tractor. In some provinces, their agronomical patterns are inappropriately so that most farming operations must be carried out within short limit of time. It is caused to decrease the mechanization degree because available tractors are not able to carry out all farming operations within that short limit of time. These regions will need to more tractor power in order to increase mechanization degree. Increasing of tractor power in these regions will cause to increase in mechanization degree, but decrease in mechanization index (w). It is occurred due to inappropriate agronomical patterns because tractors remain unused within a long time of year. Therefore it is suggested that in each province, appropriate agronomical patterns are selected so that operations that need tractors be optimally spread during year

CONCLUSION

1. For macro-level planning, distribution of tractors among different regions must be on the basis of the amount of their need to tractor power. Proper distribution of tractors will cause to increase annual usage of tractors and consequently to increase the mechanization level thorough out the regions.

2.From the energy aspect, the presented mechanization index (w) in this study can be used to distribute the tractor power among the provinces favorably.The mechanization index (w) shows how output energy in a province is produced by the agricultural section relative to the amount of available tractor power.

3. The mechanization index (w) and the mechanization degree together are able to manage distribution of tractors among provinces, favorably.

4.To classifyof provinces according to their need to tractor,Provinces were grouped into four categories according to the mechanization index (w) and degree.

5. To increase of mechanization degree, it is suggested that in each province, appropriate agronomical patterns are selected so that operations that need tractors be optimally spread during year.

Notation

E_{out}	mean of output energy in unit area, MJ ha^{-1}	ML	Mechanization Level, kW ha^{-1}
E_P	potential energy of available tractor in unit area, MJ ha^{-1}	P_a	total available power of tractor in each province, kW
E_{TP}	total potential energy of available tractors, MJ	S_i	total planted area of i crop, ha
EV_i	energy value of i crop, MJ hg^{-1}	S_m	area under mechanized operations, ha
L_i	mean of yield of i crop, kg ha^{-1}	S_T	Total planted area, ha
MD	Mechanization degree	W	ratio of the output energy to the potential energy of available tractors

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