Energy and economic costs of YTO DF 15L and DONGFENG DF 151L power tillers in soil preparation

Costos energéticos y económicos de los motocultores YTO DF 15L y DONGFENG DF 151L en la preparación de suelos

Custos energéticos e econômicos das motocultivadoras YTO DF 15L e DONGFENG DF 151L na preparação do solo

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Abstract

The objective of this study was to determine the energy and economic cost of the YTO DF 15L and DONGFENG DF 151L mechanized agricultural sets (double pass of rotovator) in the work of preparation of sandy-clay and loamy-clay soils, respectively. The methodology for determining total energy costs (MJ.h^{-1}) and per worked area (MJ.ha^{-1}) was used; likewise, Cuban Standard NC 34-38:2003 allowed the calculation of total economic costs (USD.h^{-1}) and per worked area (USD.ha^{-1}). The main findings showed that the total energy cost (EST) reached values of 78.50 and 75.30 MJ. h^{-1}, with the energy sequestered by fuel (ESc) indicator prevailing with a share of 55 and 58.4%, in the EST structure, the energy costs per worked area EST (ha) registered 1.574.00 and 1.883.00 MJ.ha^{-1}. On the other hand, the direct operating cost (Gd), reported 5.31 and 5.68 USD.h^{-1}, with the cost per salary (Gs), the indicator that predominated with 68.and 70.4% in the distribution of Gd, and the cost per worked area (Gex), presented figures of 106.20 and 142.00 USD.ha^{-1}, for the YTO DF 15L and DONGFENG DF 151L sets, respectively. The YTO DF 15L power tiller, with rotovator, distinguished itself as the agricultural set with the lowest EST (ha) and Gex, by 16 and 25%, respectively, in the agricultural operation provided.

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Resumen

El objetivo de este estudio fue determinar el costo energético y económico de los conjuntos agrícolas mecanizados YTO DF15L y DONGFENG DF 151L, con doble pase de rotovator, en labor de preparación de suelos franco arenoso arcilloso y arcilloso limoso, respectivamente. Se utilizó la metodología para determinación de costos energéticos totales ($MJ.h^{-1}$) y por área trabajada ($MJ.ha^{-1}$); asimismo, la Norma Cubana NC 34-38:2003 permitió calcular los costos económicos totales ($USD.h^{-1}$) y por área trabajada ($USD.ha^{-1}$). Los principales hallazgos mostraron que el costo energético total (EST) alcanzó valores de 78.50 y 75.30 $MJ.h^{-1}$, prevaleciendo el indicador energía secuestrada por combustible (ESc) con participación de 55 y 58.4%, en la estructura de EST, los costos energéticos por área trabajada EST (ha) registraron 1.574.00 y 1.883.00 $MJ.ha^{-1}$. Por otra parte, el costo directo de operación (Gd) se reportó en 5.31 y 5.68 $USD.h^{-1}$, siendo el costo por salario (Gs) el indicador que predominó con 68 y 70.4% en la distribución de Gd, y el costo por área trabajada (Gex), presentó cifras de 106.20 y 142.00 $USD.ha^{-1}$, para los conjuntos YTO DF 15L y DONGFENG DF 151L, respectivamente. El motocultor YTO DF 15L, con rotovator, se distinguió como el conjunto agrícola con menor EST (ha) y Gex, en 16 y 25%, respectivamente, en la operación agrícola dispuesta.

Palabras clave: Energía secuestrada, costo de operación, labranza rotativa, motocultor.

Resumo

O objetivo deste estudo foi determinar o custo energético e econômico das unidades agrícolas mecanizadas YTO DF 15L e DONGFENG DF 151L, com dupla passagem de rotovator, na preparação de argila arenosa e solos de argila sedimentosa, respectivamente. A metodologia foi utilizada para determinar os custos totais de energia ($MJ.h^{-1}$) e por área trabalhada ($MJ.ha^{-1}$); da mesma forma, a Norma Cubana NC 34-38:2003 permitiu o cálculo dos custos econômicos totais ($USD.h^{-1}$) e por área trabalhada ($USD.ha^{-1}$). As principais descobertas mostraram que o custo total de energia (EST) atingiu valores de 78.50 e 75.30 $MJ.h^{-1}$, prevalecendo o indicador energia sequestrada por combustível (ESc) com participação de 55 e 58.4%, na estrutura do EST, os custos de energia por área trabalhada EST (ha) registraram 1.574.00 e 1.883.00 $MJ.ha^{-1}$. Por outro lado, o custo operacional direto (Gd), informou 5.31 e 5.68 $USD.ha^{-1}$, sendo o custo por salário (Gs), o indicador que predominou com 68 e 70.4% na distribuição de Gd, e o custo por área trabalhada (Gex), apresentou valores de 106.20 e 142.00 $USD.ha^{-1}$, para os conjuntos YTO DF 15L e DONGFENG DF 151L, respectivamente. O motocultivador YTO DF 15L, com rotovator, destacou-se como o conjunto agrícola com o EST (ha) e Gex mais baixos, em 16 e 25%, respectivamente, na operação agrícola arranjada.

Palavras-chave: Energia sequestrada, custo de operação, Equador, lavoura rotativa, moto-cultivador.

Introduction

From the perspective of Devkota *et al*. (2020) agriculture has evolved from manual labor to energy-powered machiner for specific purposes, since the industrial revolution of the 18th century. Indeed, the energy is a good that has a strategic character for the countries of the world, intensifying in the last decades the activities related to the energetic chain and its environmental consequences (Livas-García, 2015) Energy analysis identifies and measures the sequestered energy, associated with the manufacture of mechanical equipment, that contained in materials used and transportation to the operation site; and sequestered energy, associated with non-recoverable consumables, such as fuels, fertilizers and seeds (Paneque *et al*., 2002; Nourani and Bencheikh, 2017); whereby, the use of machines and chemicals established energy as a key input in agriculture (Bojacá *et al*., 2012).

Undoubtedly, operating costs are an important tool for the farmer or agricultural entrepreneur (Reina and Hetz, 2010). The economic evaluation determines the direct operating costs and other economic effectiveness indexes, conclusive factors in the success of machined works (De las Cuevas *et al*., 2008; Ramos and Lora, 2013)

Evidently, fuel is an important indicator of the operating costs of mechanized means in agriculture (Fluck and Baird, 1980). However, salaries, which are a fundamental component of these costs, deserve substantial attention because of the currency, the U.S. dollar, which is full and unique legal tender, adopted by Ecuador as of the year 2000.

It should be specified that the power tiller with rotovator, a primary tillage set used in small farms and mountain agriculture, is mainly designed for rotational tillage, in order to, prepare the soil properly for sowing and eradicating the weeds for seeds; as well as, spraying operations (Rasool and Raheman, 2015; Pushpitha *et al*., 2018)

Although the technological level of the Ecuadorian agricultural sector and in the province of Manabi is low, it has availability of 165 $days.year^{-1}$ net, to carry out the mechanized tillage and sowing of crops such as corn, peanuts and watermelon (Reina and Hetz, 2010), without forgetting rice cultivation in the Rocafuerte and Sucre cantons (Charapotó parish). Therefore, it is essential that the national and local governments, through public policies, promote and implement projects and programs for agricultural innovation and technification, technical assistance and training for producers, as well as constant monitoring and evaluation, and relevant restructuring in the same (Shkiliova *et al*., 2019).

Considering the above, the objective of the study is to determine the total energy cost and the direct operating cost, and per unit of work area, of the YTO DF 15L and DONGFENG DF 151L power tillers with rotovator (double pass), in preparation of sandy clay loam and silty clay soils to cultivate watermelon and corn, respectively.

Materials and methods

The field study took place at Comuna Joá, located at 1º 22’ 55’’ LS and 80º 36’ 39’’ LO, with an altitude of 247 mamsl; and Finca Juanito (Estero Hondo site) located at 1º 19’ 46’’ LS and 80º 35’ 3’’ LO, with an altitude of 469 mamsl, both located in the Jipijapa canton, province of Manabí, Ecuador.

The information on experimental conditions was obtained through the methodology of the Cuban standard NC 34-47 (2003) supported by analyses in laboratories of Universidad Técnica de Manabí (UTM) and Instituto Nacional de Investigaciones Agropecuarias INIAP - Manabí.

The YTO DF 15L and DONGFENG DF 151L power tillers with rotovator, whose technical specifications are detailed in table 1, were evaluated between 2018 and 2020 in soil preparation for corn and watermelon sowing, respectively.

On the other hand, to precise total energy costs, direct operating costs and costs per unit of worked area, of the agricultural sets, information obtained in the field and under literature review was used (table 2).

It should be noted that the salary of operators covered five hours a day. The following methodologies were used to specify the energy and economic cost records of the mechanized agricultural sets:

Energy costs

With the method used by Hetz and Barrios (1997), Paneque *et al*. (2002) and Paneque and Sánchez (2006) the total energy costs were determined (MJ.h^{-1}); adding the energy sequestered in the construction materials including manufacturing and transportation, fuel, lubricants/filters, repairs/maintenance, and necessary labor; as well as, per unit of worked area (MJ.ha^{-1}).

Table 1. Technical characteristics of power tillers and implements.

Indicators	U/M	YTO	DONGFENG
Country of origin		The People's Republic of China	
Model		DF 15L	DF 151L
Dimensions (L x W x H)	mm	2680 x 960 x 1250	2680 x 960 x 1290
Engine	-	S1100A2N	ZS1100N
Fuel type	-	Diesel	
Diesel tank capacity	L	16	12
Power output	kW/ hp	12/16	10.5/14
Rated speed	rpm	2.200	
Traction force	kN	2.2	2.3
Tires/pressure	PSI	6.00-12/ 25	6.00-12/ 22
Mass without rotovator	kg	394	360
		Rotovator	
Implement width	mm	620	
Working width	mm	600	
Rotovator mass	kg	105	85
Rotovator speed m^{-1}	baja/alta	211/345	207/340
Blades	PCS	18	

Source: MAGAP (2014) and DFMA (2020).

Table 2. Inputs for methodological development of energy and economic costs.

		Power tillers		**Rotovator**	
Supplies	**U/M**	**YTO DF15L**	**DONGFENG DF 151L**	**YTO**	**DONGFENG**
Shelf life[*]	h-años	5.000 – 10		1.500 - 3	
Diesel price[+]	USD.L^{-1}	0.27		-	-
Depreciation Coeff.[++]	%	12		10	
Repair and maintenance coeff.[++]	%	7		15	
Productivity (**W$_{07}$**)[^ >]	ha.h^{-1}	0.05[^]	0.04[>]	-	-
Hourly fuel consumption **(gtc)**[^ >]	L.h^{-1}	0.91[^]	0.92[>]	-	-

Source: *Hetz *et al.,*1997, [+]Terneus and Viteri, 2020, [++] Frank, 1998, [^]Quimis-Guerrido and Shkiliova, 2019 and [>]Quimís-Guerrido *et al.*, 2020.

Table 3 shows the energy equivalents that allowed the development of the aforementioned methodology.

Table 3. Energy equivalences of inputs.

Supplies	Equivalents	U/M	
Man day (8 hours)	18.2	$MJ.h^{-1}$	Fluck, 1981
1 kg of power tiller	109.0	$MJ.kg^{-1}$	Fluck, 1992
1 kg of rotovator	66.8	$MJ.kg^{-1}$	Fluck, 1992
1 L of diesel	47.8	$MJ.L^{-1}$	Fluck, 1992

Economic costs

For the determination of the direct costs of hourly operation ($USD.h^{-1}$) and per unit of worked area ($USD.ha^{-1}$), the Cuban standard NC 34-38 (2003) was used, which includes costs for salaries, amortization, repair-maintenance and fuel.

Data recording and processing was carried out with Infostat (version 2017) statistical software .

Results and discussion

Determination of test site conditions

Table 4 details the experimental conditions where the operators, in command of the agricultural equipment, carried out the soil preparation work.

Table 4. Characterization of the study areas (Comuna Joá and Finca Juanito).

Denomination	U/M	Comuna Joá	Finca Juanito
Type of soil	-	Sandy loam Clayey loam	Clay-loam
Relief	%	< 2 (Plain)	10 -12 (High slope)
Average temperature	oC	24 – 29	
Apparent density	$g.cm^{-3}$	1.31	1.28
Gravimetric humidity	%	18.52	13.00
Penetration resistance	MPa	1.00	1.80
Crop obstruction	$kg.ha^{-1}$	1.200.00	0.21

Through field research, acquisition values of 2.738 USD and 2.584 USD for the power tillers and for the rotovator of 370 USD and 329 USD were known (ILGA, 2021). In addition, the average annual workload was 420 h and 400 h for YTO DF 15L and DONGFENG DF 151L agricultural sets, respectively, according to the range (400 - 450 $h.year^{-1}$) recommended by Márquez (2010). The salary of operators (five-hour day) was USD 18 and USD 20 for YTO DF 15L and DONGFENG DF 151L, in accordance with the provisions of Ministerio de trabajo del Ecuador (Ledesma, 2018 and Madero, 2019).

Determination of energy costs of the sets

Through the methodology used, the values of the total hourly energy cost (EST) in ($MJ.h^{-1}$) and the energy cost per worked area EST (ha) in ($MJ.ha^{-1}$), presenting the results of the energy indicator calculations in figure 1.

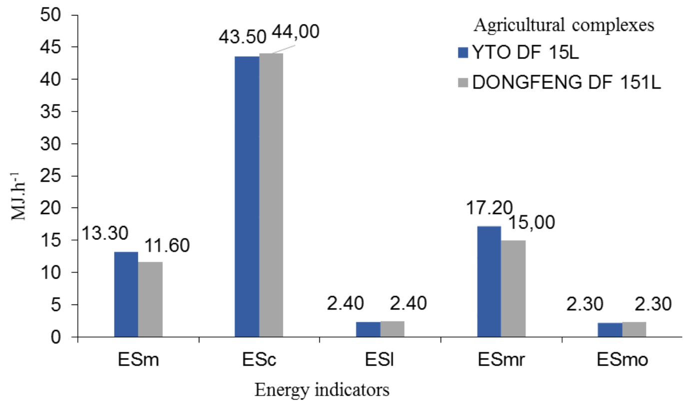

Figure 1. Value of total energy cost indicators, in $MJ.h^{-1}$

Energy sequestered in fuel (ESc), in materials, manufacturing and transportation (ESm), and in repairs and maintenance (ESmr), were the characteristic indicators in the operation of the equipment, with 55 and 58.4%, 22 and 20%, and 17 and 15.4% for the YTO DF 15L and DONGFENG DF 151L sets, respectively.

For both sets, energy sequestered in fuel (ESc) was the indicator with the highest proportionality in the total energy cost structure (EST), a finding similar to that reported by Miranda *et al*., (2009) and Crespo (2018).

Likewise, in the two agricultural sets, the energy sequestered in lubricants/filters (ESl) and the energy sequestered in repairs and maintenance (ESmr) made up only 3% of the distribution of the total energy cost (EST).

Table 5 shows the values achieved by the agricultural sets for the total energy cost (EST) and per unit of worked area EST (ha).

Table 5. Energy cost values of the equipment.

Parameters	U/M	Agricultural assemblies	
		YTO DF 15L	DONGFENG DF 151L
Total energy cost (EST)	$MJ.h^{-1}$	78.70	75.30
Per unit area worked EST (ha)	$MJ.ha^{-1}$	1.574.00	1.883.00

The total energy cost (EST) reported 78.70 and 75.30 $MJ.h^{-1}$ for YTO DF 15L and DONGFENG DF 151L, respectively. On the other hand, the cost per unit of worked area EST (ha) of the DONGFENG DF 151L set reached 1.883.00 $MJ.ha^{-1}$, 16% higher than the value of the YTO DF 15L set which was 1.574.00 $MJ.ha^{-1}$. However, these figures exceed the reported EST (ha) of 1.191.61 $MJ.ha^{-1}$ by the Mahindra-Yuvraj mini tractor (15 hp) in soil preparation labor (Dabhi *et al*., 2016). It is worth mentioning that the equipment used for this research, manifest certain constructive and technical similarities, such as the implement working width (0.60 m); however, they differ in masses, being the YTO DF 15L set 54.00 kg higher than the DONGFENG DF 151L (table 1).

On the other hand, the records reported between EST and EST (ha) agree with the inverse proportionality, caused by better productivity in the field, proposed by Paneque and Soto (2007).

Determination of the direct operating costs of the sets

The direct operating costs (Gd) in ($USD.h^{-1}$) and per worked area (Gex) in ($USD.ha^{-1}$), of the agricultural sets in soil preparation were calculated based on the methodology of the Cuban standard NC 34-38 (2003), showing records in figure 2.

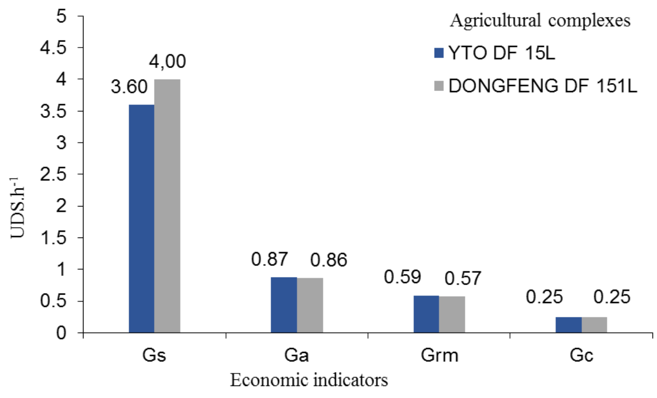

Figure 2. Indicator values of the direct cost of operation, in USD.h^{-1}.

Indeed, the cost per salary (Gs) was the indicator with the highest disposition with 68 and 70.4%, followed by the amortization cost (Ga) with 16.3 and 15.2%, the cost for repairs and maintenance (Grm) with 11 and 10%, and with less incidence, due to the diesel subsidy in Ecuador (Terneus and Viteri, 2020), the cost per fuel (Gc) that represented 4.7 and 4.4% in the organization of the direct operating cost (Gd), for the YTO DF 15L and DONGFENG DF 151L sets, respectively.

The aforementioned differs from the work of Ramos and Lora (2013) and Crespo *et al*. (2018), who indicated that the highest indicators in Gd were the cost of fuel consumption (Gc) and the cost of maintenance and repairs (Grm), respectively. The variabilities are subject to experimental, currency, cost and annual workload factors of the equipment.

Consequently, table 6 shows the values achieved by the sets under study regarding to the direct hourly operating cost (Gd) and per unit of worked area (Gex).

Table 6. Economic cost values of the equipment.

Parameters	U/M	Agricultural assemblies	
		YTO DF 15L	DONGFENG DF 151L
Direct operating cost (Gd)	USD.h^{-1}	5.31	5.68
Per unit area worked (Gex)	USD.ha^{-1}	106.20	142.00

As can be observed, the hourly direct operating cost (Gd) reported 5.31 and 5.68 USD.h^{-1} for the YTO DF 15L and DONGFENG DF 151L sets, respectively. The direct hourly operating cost (Gd) of the latter set was 0.37 USD.h^{-1} higher. It should be noted that the highest hourly direct operating cost (Gd) and the lowest field productivity of the DONGFENG DF 151L set, caused that the direct operating cost per unit of worked area (Gex) of 142.00 USD.ha^{-1} was 25% higher than that achieved by the YTO DF 15L set of 106.20 USD. ha^{-1}.

In addition, the results obtained in this study for Gex, exceed the reported by the Indian manufacturing equipment, the Mahindra -Yuvraj (15 hp) mini tractor and by the VST Shakti 130 DI (13 hp) power tiller of 35.00 and 40.90 USD.ha^{-1} (Dabhi *et al.*, 2016; and Rangapara *et al.*, 2017), respectively.

It is evident that these records are not conclusive; since, socioeconomic and edaphoclimatic variables of experimentation in the realization of agricultural operations differ.

Conclusions

The total energy cost of agricultural operations in soil preparation (EST) for the YTO DF 15L set is 78.50 MJ. h^{-1} and for DONGFENG DF 151L is 75.30 MJ. h^{-1}. The dominant indicator is the energy sequestered by fuel (ESc), which represents 55 and 58.4% of the EST distribution. Likewise, the energy cost per unit of worked area EST (ha) amounts to 1.574.00 and 1.883.00 MJ.ha^{-1} for the YTO DF 15L and DONGFENG DF 151L sets, respectively.

On the other hand, the direct operating cost (Gd) reached 5.31 and 5.68 USD.h^{-1}, with the cost per salary (Gs) being the indicator with the highest participation in the Gd structure, with 68 and 70.4%. The operating cost per unit of worked area (Gex) registered 106.20 and 142.00 USD.ha^{-1}, for the YTO DF 15L and DONGFENG DF 151L sets, respectively.

The YTO DF 15L set presents lower energy and operating cost, per unit of worked area, EST (ha) and (Gex), in 16 and 25%, correspondingly, in relation to the DONGFENG DF 151L set, in the arranged agricultural operation.

Cited literature

Bojacá, C. R., Casilimas, H. A., Gil, R., y Schrevens, E. (2012). Extending the input-output energy balance methodology in agriculture through cluster analysis. *Energy*, *47*(1), 465–470. https://doi.org/10.1016/j.energy.2012.09.051

Crespo-Amaya, R., Paneque-Rondón, P., y Miranda-Caballero, A. (2018). Determinación del costo energético y de explotación de la cosecha mecanizada del arroz. *Revista Ciencias Técnicas Agropecuarias*, *27*(2), 1–10.

Dabhi, K. L., Godhani, R. S., y Swarnkar, R. (2016). Comparative performance of mini tractor draw tillage implements for seed bed preparation under sandy loam conditions of middle Gujarat. *International Journal of Agricultural Engineering*, *9*(1), 53–61. https://doi.org/10.15740/HAS/IJAE/9.1/53-61

De las Cuevas, H. R., Hernández, R. T., Herrera, P. M., y Paneque, R. P. (2008). Software para la evaluación tecnológica de las máquinas agrícolas. *Revista Ciencias Técnicas Agropecuarias*, *17*(2), 24–28.

Devkota, R., Pant, L. P., Gartaula, H. N., Patel, K., Gauchan, D., Hambly-Odame, H., Thapa, B., y Raizada, M. N. (2020). Responsible agricultural mechanization innovation for the sustainable development of Nepal's hillside farming system. *Sustainability (Switzerland)*, *12*(1), 1–24. https://doi.org/10.3390/SU12010374

DFMA. (2020). *Fabricante de tractores de 4 ruedas y motocultores en China desde 1952*. Changzhou Dongfeng Agricultural Machinery Group Co., Ltd. http://dftractor.es/2b-DF-15L-walking-tractor.html

Fluck, R C, y Baird, C. D. (1980). *Agricultural Energetics*. AVI Publishing Company. https://books.google.com.na/books?id=aXFRAAAAMAAJ

Fluck, Richard C. (1992). Energy for farm production. In *Energy for World Agriculture* (Vol. 6, p. 287). Elsevier, Amsterdam.

Fluck, Richard C. (1981). Net energy sequestered in agricultural labor. *Transactions of the ASAE*, *24*(6), 1449–1455.

Frank, L. (1998). *Costos de la Maquinaria Agrícola, Cátedra de Administración Rural* (2da. ed.). FAUBA.

Hetz, E., Huerta, A., Villar, S., y López, M. (1997). *Evaluación Económica de los Tractores Agrícolas Comercializados en Chile*. Universidad de Concepción-Facultad de Ingeniería Agrícola. Chillán, Chile. http://revistas.uach.cl/html/agrosur/v26n2/body/art04.htm

Hetz, E. J., y Barrios, A. I. (1997). Costo Energético de las Operaciones Agrícolas Mecanizadas más Comunes en Chile. *Agro Sur*, *25*(2), 146–161. https://doi.org/10.4206/agrosur.1997.v25n2-03

ILGA. (2021). *Motocultor DongFeng*. Importadora ILGA. https://ilgaimportadora.com/productos/motocultor-dong-feng/#

InfoStat. (2017). *InfoStat-Software estadístico versión 2017*. https://www.infostat.com.ar/index.php?mod=noticia&id=49

Ledesma, R. (2018). *República del Ecuador. Ministerio del Trabajo. Acuerdo Ministerial Nro. MDT-2018-0001*. Ministerio Del Trabajo. https://www.trabajo.gob.ec/wp-content/uploads/downloads/2018/01/mdt-2018-0001_fijación_de_sueldo_salarios_tarifas_para_el_sector_privado_de_las_diferentes_comisiones_sectoriales.pdf?x42051

Livas-García, A. (2015). Análisis de insumo-producto de energía y observaciones sobre el desarrollo sustentable, caso mexicano 1970-2010. *Ingeniería, Investigación y Tecnología*, *16*(2), 239–251. https://doi.org/10.1016/j.riit.2015.03.008

Madero, A. (2019). *República del Ecuador. Ministerio del Trabajo. Acuerdo Ministerial Nro. MDT-2019-394*. Ministerio Del Trabajo. https://www.trabajo.gob.ec/wp-content/uploads/downloads/2020/01/2019-Acuerdo-Ministerial-MDT-2019-394-SALARIO-BÁSICO.pdf

MAGAP. (2014). *Contratación de mantenimiento preventivo y puesta en marcha de 74 motocultores marca YTO, a través del procedimiento de menor cuantía bienes y servicios.*

Márquez, L. (2010). La Mecanización Agrícola en Pequeñas Propiedades Rurales. *IX Congreso Latinoamericano y Del Caribe de Ingeniería Agrícola - CLIA 2010.*, 1–18. https://doi.org/10.1017/CBO9781107415324.004

Miranda, C. A., Paneque, R. P., Abraham, F. N., y Suárez, G. M. (2009). Análisis comparativo de los costos totales energéticos, de explotación y consumo de combustible del cultivo del arroz en las tecnologías en seco y fangueo directo. *Revista Ciencias Técnicas Agropecuarias*, *18*(3), 70–75.

Nourani, A., y Bencheikh, A. (2017). Energy Balance Analysis and Mechanization Indexfor Greenhouse Vegetable Production in Southern of Algeria. An Overview of Biskra province. *INMATEH - Agricultural Engineering*, *19*(4), 76–82.

National Standardization Office. (2003). *Cuban Standard NC 34-38: 2003. Forestry and Agricultural Machines. Methodology for Economic Evaluation* (2da. ed.).

National Standardization Office. (2003). *Cuban Standard NC 34-47: 2003. Foresty and Agricultural Machines. Metodology for Determination of Testing Conditions*.

Paneque, P., y Soto, D. (2007). Costo energético de las labores de preparación de suelo en Cuba. *Revista Ciencias Técnicas Agropecuarias*, *16*(4), 17–22.

Paneque, R. P., Fernández, H. C., y Donizette de Oliveria, A. (2002). Comparación de cuatro sistemas de labranza/siembra en relación con su costo energético. *Revistas Ciencias Técnicas Agropecuarias*, *11*(2), 1–7.

Paneque, R. P., y Sánchez, R. Y. (2006). Costo energético de la cosecha mecanizada del arroz en Cuba. *Revista Ciencias Técnicas Agropecuarias*, *15*(1), 19–23.

Pushpitha, N. P. G., Weerasinghe, K. D. N., y Maier, D. (2018). Modification of a two-wheel tractor as a versatile power machine for post disaster recovery programs. *Procedia Engineering*, *212*(2017), 614–621. https://doi.org/10.1016/j.proeng.2018.01.079

Quimís-Guerrido, B., Franco-Plaza, F., Loor-Guerrero, C., Sempertegui-Campi, V., y Quimís-Pin, J. (2020). Evaluación tecnológica explotativa del motocultor Dongfeng DF 151L en preparación de suelo para sembrar maíz. *La Técnica: Revista de Las Agrociencias. ISSN 2477-8982*, *Agricultura y Silvicultura. Edición Especial (Octubre)*, 47–64. https://revistas.utm.edu.ec/index.php/latecnica/article/view/2216

Quimis-Guerrido, B., y Shkiliova, L. (2019). Technological and Operation Evaluation of the YTO DF-15L Rototiller in Soil Preparation for Watermelon. *Revista Ciencias Técnicas Agropecuarias*, *28*(2), 1–10. http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S2071-00542019000200007&lng=es&nrm=iso&tlng=es

Ramos, G. R., y Lora, C. D. (2013). Determinación de parámetros de explotación y económicos en el corte de forraje con diferentes máquinas cosechadoras. *Revista Ingeniería Agrícola*, *3*(2), 31–38. http://dima.chapingo.mx/revista/Vol_3_n_2_2013/pdf/IA05213.pdf

Rangapara, D. K., Dabhi, K. L., y Makwana, A. D. (2017). Comparative Performance of Tractor Drawn Implements Tillage System With Rotavator Tillage System. *International Journal of Agriculture Sciences*, *9*(5), 3743–3748.

Rasool, S., y Raheman, H. (2015). Suitability of rubber track as traction device for power tillers. *Journal of Terramechanics*, *66*, 41–47. https://doi.org/10.1016/j.jterra.2015.08.003

Reina, L., y Hetz, E. (2010). Gestión integral de un sistema mecanizado para una finca del Valle del Río Portoviejo, Manabí, Ecuador. *La Técnica: Revista de Las Agrociencias. ISSN 2477-8982*, *2*, 33. https://doi.org/10.33936/la_tecnica.v0i2.642

Shkiliova, L., Cevallos, M. R., y Iglesias, C. C. (2019). Agricultural mechanization in Ecuador. *AMA, Agricultural Mechanization in Asia, Africa and Latin America*, *50*(2), 72–77.

Terneus, P. C., y Viteri, S. O. (2020). Analysis of agro-food transport in Ecuador faced with a possible reduction in the subsidy of diesel. *Energy Policy*, *144*(January), 2–12. https://doi.org/10.1016/j.enpol.2020.111713