ORIGINAL ARTICLE

Measures to reduce the impacts of the agricultural mechanization on the environment

Medidas para reducir los impactos de la mecanización agrícola sobre el medio ambiente

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ABSTRACT: The conventional intensive agriculture, resultant of the technological and social development is the biggest degrader of waters and agricultural environments. The agricultural mechanization and the irrigation in general are the main causing factors of the degradation, for what should always be used with conservationist and recuperative technologies. Diverse projects and programs of international collaboration related with the protection of the environment have been carried out, among whose objectives are the research of the effects of the agricultural mechanization on the environment, reason why was taking as objective to center the efforts in carrying out a study to determine the possible measures to counteract the negative aspects of this influence, like basis for the elaboration of new research projects of international collaboration. For the study were used the methodologies for the realization of the Participative Diagnostics, which included the realization of surveys, discussion seminars and statistical analysis, with the use of computing tools and programs. Among the main conclusions of the study is the description of the possible measures guided to reduce the impacts of the agricultural mechanization on the environment.

***Keywords*:** Agriculture, Erosion, Soil, Water.

RESUMEN: La agricultura intensiva convencional, resultante del desarrollo tecnológico y social es el mayor degradador de aguas y ambientes agrícolas. La mecanización agrícola en general y el riego son los principales factores causantes de la degradación, por lo que debe utilizarse siempre con un sentido conservacionista y recuperador. Se han estado desarrollando diversos proyectos y programas de colaboración internacional relacionados con la protección medioambiental, entre cuyos objetivos se encuentra la investigación de los efectos de la mecanización agropecuaria sobre el medio ambiente, por lo cual ser trazó como objetivo centrar los esfuerzos en realizar un estudio para determinar las posibles medidas para contrarrestar los aspectos negativos de esta influencia, como base para la fundamentación de nuevos proyectos de investigación y de colaboración internacional. Se emplearon las metodologías para la realización de los Diag nósticos Participativos, la cual comprendió la realización de encuestas, seminarios de discusión, análisis estadístico, con el uso de herramientas y programas de computación. Entre las principales conclusiones del estudio se encuentra la descripción de las posibles medidas encaminadas a reducir los impactos de la mecanización agropecuaria sobre el medio ambiente.

***Palabras clave*:** agricultura, erosión, suelo, agua.

INTRODUCTION

The scientific challenge in the development of the mechanization is linked with the modern concept of appropriate technology (Caballero, 1999). According to Arana *et al.* (1999), the technology is a social phenomenon that arises and spreads in a complex cultural system, where it is necessary to take in consideration the knowledge, habits and valuations that each society imposes by means of singular and universal features. In our country we have clear the concept that the mechanization of the agriculture should be part of a technology appropriate to our biophysical, economic, political and social context.

The peasant's tradition, the characteristics of the development of each region, the pedological conditions and the economic and social imperatives cannot be ignored. Toward the concatenation of these factors has gone guided the policies that have been traced in the field of the mechanization of the agriculture, as much with tractor as with animal traction (Suárez & Ríos, 2018; Gaceta Oficial, 2020a; 2020b).

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The conventional intensive agriculture, resultant of the technological and social development is the biggest degrader of agricultural waters and areas. In this type of agriculture, the agricultural mechanization and the irrigation are in general the main causing factors of the degradation (Domingo *et al.*, 2003).

The mechanization, from its emergence millennia ago, has brought substantial changes: increase of the productivity, improvement of the work conditions, possibility of increment of the productions, etc., but it has also borne negative effects. All type of agricultural machinery impacts with direct and indirect actions on the environment of its application and especially on the soil, although also has effects on the water, the air, the animals, the human beings and the infrastructure works. The machinery is indispensable, but it should always be used with a conservationist and recovering sense.

Neither it is possible to give up the advantages of the irrigation because the irrigated areas are several times more productive that those unirrigated. In Cuba it is dedicated to the irrigation 70% of the available water resources. Nevertheless, vulnerability still exists to the food insecurity given among others factors by the risk of drought and floods in the agricultural areas (Enríquez, 1994).

Regrettably, many of the works performed with agricultural mechanization are negative, some very negative. This is due to the fact that the layer of profitable soil in the agricultural areas is of scarce centimeters deep and any inadequate or not well used technology can damage its fertility. This layer is formed for the natural action in a process that lasts centuries and even millennia, and it can be destroyed in an incredibly brief period. But the mechanization not always acts in a negative way. With mechanized means can be improved the conditions of the agricultural environment. For example: recovering the soils, facilitating the drainage, diminishing the salinity. The use of renewable or not conventional sources of energy also brings positive effects.

Several Cuban research institutions, among them the Agricultural Engineering Research Institute (IAgric), have been participating in projects of international collaboration related with the protection of the environment and adaptation to the effects of the climatic change, among them the project "Environmental Bases for the Local Food Sustainability" Basal (2023) and the "Country Association Program", supported by agencies of the United Nations, especially the United Nations Development Program (UNDP), the Program of the United Nations for the Environment (PNUMA) and the Food and Agriculture Organization (FAO).

Some of the works carried out in the frame of the participation of the IAgric in these projects of international collaboration had as objective the research of new mechanization and irrigation technologies. The researches include the effects of the agricultural mechanization on the environment, being decided to center the efforts in carrying out a study to determine the possible measures to counteract the negative aspects of this influence, like base of new research projects of international collaboration.

A state politics exists regarding the best use in the agricultural machinery, the irrigation and the drainage, evident, among other documents, in the Ordinance Law and its Regulation relative to guarantee the protection, conservation, improvement and sustainable management of the soils, the environment and the rational use of the water (Gaceta Oficial, 2020a).

It is objective of the present work to show the main results of the study, especially in what refers to the possible measures guided to reduce the impacts of the agricultural mechanization on the environment.

MATERIALS AND METHODS

In the study were used mainly the methodologies proposed by Águila (2000); Díaz & Guerrero (2007); Carballo & Pérez (2011) to evaluate the impact of the agricultural machinery on the natural resources of the environment, especially in what refers to the selection of the fundamental aspects of incidence to consider.

For the participative diagnostic the methodology included the realization of surveys, discussion seminars, statistical analysis, with the use of computing tools and programs. The diagnoses kept in mind the following objectives: Identification of the affectations produced by the agricultural machinery on the soil; negative effects of the mechanized irrigation; use of the animal traction; contamination caused by the mechanization; and use of the energy in the mechanized agricultural works. In all these aspects were discussed the possible measures to counteract the affectations. These activities of diagnostic were made with the participation of specialists, technicians, workers, professors, researchers, students and leaders of the mechanization activity.

It was also gathered information on the topic (published works, papers presented in scientific events, reports of researches, laws, resolutions, institutional policies, etc.) on the influence of the agricultural mechanization in the environment. This information constitutes the base to define options to improve the strategy and policies regarding the environment and the mechanization.

RESULTS

Reduction of hydric and wind erosion

The erosion of the soil is manifested fundamentally in the dragging of the fertile superficial layer by action of the wind, the rain and the irrigation. The effect of the wind is less notorious, but never worthless, mainly in dry seasons in soils of little cohesion. The

hydric erosion is evident in the soils in slopes, but it is also presented in relatively flat soils in rainy periods or for the action of the irrigation. The capacity and erosive action of each irrigation system is different. The leak irrigation is the more suitable system in order to minimizing the induced erosive processes, since dragging doesn't take and the drops not hits the particles of the soil. In sprinkling irrigation, the erosion and the compaction take place fundamentally for the energy of the impact of the water on the soil and the affectation will depend mainly on the size and the speed of fall of the drops. The irrigation for displacement of the water for the furrows is the most negative of all, due to the high consumption of water and to the dragging of the superficial particles, those of more content of organic matter. When the soil is excessively loosed, the dragging due to the rain or irrigation waters, as well as for the wind, sometimes produces irreparable damages (Ríos, 2021).

Reduction of damages due to poor drainage

We always have to speak inseparably of irrigation and drainage. In the areas affected by a great humidity the introduction of the agricultural drainage allows transform unproductive places into areas of high yielding, so much for the effect of reducing the excesses of humidity like for the action in decreasing the salinity (Zamora y Chaterlán, 2003). The drainage is favored with diverse mechanized actions: construction of channels, gutters, deviations, leveling, subsoiling, etc. Among the most important measures is the drainage of the irrigation waters, because if they are not appropriately eliminated, a gradual salinization of the soil takes place as a result of the evaporation.

Soil farming in slopes

Cuba is a country with a high percentage of lands in mountainous areas or with wavy relief. Under these conditions soil farming technologies and anti-erosion measures should be used to conserve the superficial fertile layer. In those areas are preferable the permanent crops such as the coffee, cocoa and forest species, because they don't require removing the soil for the maintenance of the plants. But in the cases of the crops of short cycle, the soil farming should be made if it is possible with implements of horizontal cutting of the soil or with conventional plows, always plowing following the level curves. In slope areas it is very important to avoid the excessive farming. If plowshares implements are used, the soil layer should be turned up to the upper of the slope, never downwards. The creation of barriers to contain the creation of ditches by the action of the natural drainage of the water can be performed with simple implements, and also deviation ditches and other similar measures.

Conservation of the plant's roots

In this sense are very useful the technologies of horizontal tillage that conserve the cohesion of roots of the grasses and other plants but at the same time make that these perish. With this technology this layer of the soil maintains a convenient consistency avoiding the erosion.

Forest activity and erosion

In the first place, the elimination of the trees that cover an area contributes to leave the soil discovered facilitating the erosion. But it should also be considered that the forest activity contributes to form paths and discovered ways for the dragging of the timbers, labor that cause a continue elimination of the superficial layer of the soil and then this is quickly attacked by the gliding of the water, effect that is very harmful in mountains and areas of high slope.

Reduction of the salinization

This type of affectation can take place due to different causes: use of irrigation water with high levels of salts; salinization caused for irrigation in areas having saline rocks; elevation of the phreatic level (due to an excess of irrigation) and evapotranspiration processes. The best action to avoid the salinity is a rational use of the irrigation water, avoiding the overexploitation of the underground aquifers and of other hydraulic resources. Among the mechanized actions to avoid or to combat the salinization are: making of drainage ditches to improve the laundry of the soil; construction of barriers to avoid the penetration of waters coming from the sea or of bordering areas already salinized, among other measures.

Reduction of soil compaction

The agricultural soils are pressed continuously by the weight of the agricultural machinery (tractors, combines, implements, vehicles, animals, etc.). The effect is manifested in the compaction of the superficial layers, a process that decreases the infiltration of the water and hinders the penetration of the roots (Folger, 2022). The actions to avoid or to reduce the compaction can be the following:

Use of slighter agricultural machines

The world tendency in the last decades has been the massive introduction of agricultural machines that are more and more potent and heavy, with tractors, combines, trailers and other means that represent a high productivity in the works. While a tractor of 40-50cv has a mass around 3t, those of 300cv can reach the 12t and even more. In many countries even heavier tractors are regularly used.

To the weight of the tractors is added the weight of the machines or implements that are attached. The most potent and heavy tractors are convenient for big extensions; however, the great majority of our agricultural exploitations is of farms and other small productive units, for what are more economical the use of the tractors of low and mean power whose smaller weight reduces the compaction, as well is important the use of the animal traction in the cases that it is economic and possible.

Use of wider tires

The narrow tires produce a bigger specific pressure on the soil that the so called ball pneumatics that have a wide support surface. A tractor of the class having a traction power of 1,4t, with tires 9-42'', appropriate for work in crops planted in narrow patterns, produces a specific pressure on the soil of 1,06kg/cm^2. If wider tires are used, as the type 15-30'', the specific pressure would be of 0.73kg/cm^2. A modern tractor of 22t with wide tires only has a pressure of 0.6kg/cm^2 on the soil, while a tractor of 3t and 75cv built in the decade of 1970, very used in Cuba, apply a much bigger pressure (around 1.5kg/cm^2) (Newsletters, 2021).

Use of double tires or track-lying (caterpillar) tractors

Another way to reduce the specific pressure on the soil is the use of tires in the back wheels and also in the front ones. With them is also increased the gripping force, more rationally taking advantage of the tractor's power. The use of double tires reduces the specific pressure to the half, reaching values smaller than 0.5kg/cm^2, similar to those of the track-lying tractors, that produces a smaller pressure on the soil. For example, the new John Deere of four bands of tracks 8RX have an enormous track of 4.6m^2, for what the pressure of the contact surface is very low (around 0.4kg/cm^2) (John Deere, 2021).

Reduction of skidding

When the tires are worn away the skidding is increased and this is also an important cause of compaction of the soil. The big tires and the track-lying tractors have a bigger support surface reducing the compaction in the deepest layers in the soil. These tires have less resistance to skidding, what means smaller fuel consumption and, therefore, less emissions of CO_2. The tests have demonstrated that the fuel consumption can decrease this way in 10%; for what it can contribute actively to the protection of the environment (John Deere, 2021; Newsletters, 2021).

Reduction of the quantity of works

In many productive technologies in use the tendency is manifested to carry out an excessive number of works represented by successive passes on the same area. For example, the traditional technologies of soil farming sometimes involves the primary tillage, one or two perpendicular tillage works (known as crossings), several passes of harrows, tillers and other works for conditioning the soil for sowing. The same thing happens with the cultivation, the application of fertilizers and chemical products, harvesting, transport of products and others. It is evident that to smaller number of works, minor are the damages. There are several methods to achieve it. In the first place, by means of the use of appropriate implements that allows the soil tillage and clods crushing in a minimum of passes.

Use of combined implements

It should also be generalized the use of combined machines or implements that in one or two passes leave ready the soil by mean of to do at the same time several works as soil ploughing, clods crushing, pulverization of the soil and leveling, or also combining the final conditioning of the soil with the furrowing and the sowing.

Minimum tillage

This is the technology of performing a much reduced number of works, generally only one or two. It can be achieved especially in crops that are planted immediately after the harvesting of potatoes and other tubers or roots, when the soil is with a grade of appropriate pulverization. The conservation agriculture is based in reducing or eliminating soil plowing, and for that are required the use of machines that allow to plant the seeds and to apply the fertilizers through the layer of remains of the previous crops that stays in a permanent way on the surface of the soil (FAO, 2022).

Located farming

Sometimes is not necessary the farming of the whole surface of the soil. It can be sufficient doing it only in the fringe necessary to place the seeds or in the in the spaces that requires of cultivation actions. This is normal in fruit plantations, but it can also be achieved in other crops.

Negative effects of the implements that turn down the upper layer of the soil

The most characteristic action in plowing is the fractioning of the soil layer to produce an appropriate bed for the development of the plants including good air circulation, easiness of infiltration of the water and little resistance to the penetration of the roots. This can be carried out with or without mixing the layers of the soil. Soil farming (plowing or cultivation) with disks or moldboard plows produces the cut of a

layer of soil that immediately is turned down, for that that the superficial layer, the most fertile, is buried far of the surface where the roots of the plants has to obtain the nutrients. This is totally negative for multiple factors, especially because the decomposition of the organic matter is incomplete when it is buried so losing a substantial part of its nutrients. Also, are buried the seeds deposited in the surface, contributing to the propagation of the weeds (Milanés, 2009).

Farming without turning of the soil

This is the most convenient technology, because don't mix the layers of the soil neither the seeds are buried, favoring the decomposition of the organic matter and reducing the weeds. The more representative implements working under this principle is the so called "multiplow", that is basic for the conservationist farming. This implement is of Cuban patent, with arrows for cutting horizontally the soil. The arrows have a little angle of incidence (22º) that contributes to the fracturing of the plowed layer. An additional advantage of this type of implement is that it reduces almost in the half the traction force as compared with traditional disk of moldboard ploughs of similar work wide.

Reduction of the term between the crop and the new sowing

If it is allowed that a soil remain a lot of time without being sowed after the new crop a quick sprouting of the weeds takes place, being necessary to perform additional works of plowing or application of herbicides.

Increase of the use of the animal traction

Animal traction and manual works are the less aggressive technologies for the soil. But unfortunately the scarce productivity and the high consumption of work force in these barely mechanized systems have resulted in a high grade of tractorization, even in wide areas of the fewer industrialized countries.

In Cuba more than 30% of the mechanized agricultural works are currently made with animal traction, of there the importance of these technologies. With the employment of work animals are saved fuel, expensive and complex machinery and their components and also the resources for maintenance and repair.

This is a very important aspect in the ecological aspect, by the fact we have analyzed previously that the tractor and the other machinery sensibly affect the mechanical and physical characteristics of the soil, contributing to its degradation. The work animals and the implements and machines used with animal traction (primary tillage, clods crushing, crop cultivation, plants protection, transport, etc.) don't produce compaction. Their effects are minimal as compared with the tractors, the implements, trucks and other heavy machines (Ríos, 2004).

To avoid affectations to the flora and the fauna

During the process of installation of a mechanized system (of a crop, of an irrigation system, of a cattle exploitation, etc.) the fauna and the flora can be affected by the elimination of the natural vegetation, the arboreal barriers and other trees or bushes. Equally, the construction of ditches and earth movements has a direct effect causing the death of the wildlife, elimination of niches of reproduction and loss of roads for passing the fauna. The areas under irrigation suffer a modification in the microclimate, with the consequent natural selection of the species better adapted to the new conditions. As consequence of that takes place the decrease and change in the distribution of the populations, disappearance of some species and introduction of other (Zamora & Chaterlán, 2003; Arana *et al.*, 1999).

Reduction of the contamination for residuals

The repair and maintenance shops, the forges and other similar facilities are a substantial part of the agricultural mechanization. It would seem that their effect is minimal to the environment, but it is not this way. In the shops, especially those of service and maintenance, are produced several types of residuals. The most important are those linked to hydrocarbons: fats, oils and fuels. The water coming from the laundry of the tractors, machines and implements are generally the vehicle that carries these residuals and if there are not taken special measures, it will pass to the aquifers or drainages. Under these conditions it is necessary the placement of traps for the greases and oils, contention barriers and other measures. Special protection measures and care should be had with the chemical products that are residuals of the laundry of sprayers, fertilizers, vehicles and other machines. Accidental escapes of polluting matters can also take place such as fuels, acids of batteries, and others.

Contamination for ferrous or not ferrous wastes

All the shops produce wastes. Among these are: pieces and rejected parts, discarded machinery and useless pieces, chips coming from the working of metals, etc. All this is generally known with the generic name of scraps. When theses scraps spill indiscriminately in the areas around the shops several types of damages are produced to the environment. In the first place are lost high valued recyclable materials. In second place, the areas polluted with irons and other similar materials affected the mechanization. In third place, some materials are very noxious, as the lead coming from the wasted batteries.

Other pollutants

In the shops also take place other actions that cause pollution to the environment: among them are the noise, the powder, the gases of escape of motors, the electric welding arches, the acids of batteries, etc. The market offers now tractors and other machines that allow the reduction of fuel consumption, diminishing costs and emissions (Infoagro, 2023). An advance that it is already experiencing is the use of tractors moved by electric batteries.

Other mechanized actions to improve the quality of the soil

The increase of the speed of mineralization of the organic matter, together with the decrease of the residues of crops, impoverishes the organic elements in the soils. It is important the incorporation of diverse types of organic matters. In the agricultural areas the fundamental organic matter comes from the vegetable remains product of the harvesting, of green fertilizers (species that brings fertilizer action) or of external contributions (manure or worm humus). The product is commonly distributed by superficial spreading and incorporated during the tillage. The green fertilizers constitute an alternative of great interest and perspectives in our country. The leguminous plants fix the nitrogen to the soil and they can contribute more than 60% of the requirements of nitrogen of the soil, in the range of 80kg of nitrogen for hectare (Ríos, 2021).

Rational use of the fuel

The rational use of the tractors and its machines and implements in the agricultural processes constitute the biggest potential of saving of fuel and to the decrease of the contamination (Herrera *et al.*, 2011). Among the conventional energy sources more used in the mechanized processes of the agriculture we have the liquid fuels (gasoline, diesel and other products of the crude oil), gas (methane) and solids (mineral coal, firewood coal, wood), as well as the electricity. All these energy sources come from the combustion of organic substances or minerals and they produce gases that contaminate the atmosphere, causing very undesirable actions as the hothouse effect and the damage to the layer of ozone, among others.

In the agricultural mechanization the reduction of fuel consumption can be achieved by different measures: the use of more efficient motors, the use of technologies of minimum farming, a correct correspondence among the tractors and the machines or implements that are added, the electrification, the use of the animal traction in the works that it is possible from the technical and economic point of view, etc.

All decrease in the consumption of fuel is equivalent to a favorable action from the environmental point of view. In Cuba more than 60% of the tractors have more than 20years of exploitation with great deterioration and obsolescence with indexes of fuel consumption up to 1.5L/h bigger than modern tractors under the same work conditions. The renovation of these tractors can diminish the consumption of fuel until 20% maintaining the same activity level. A study carried out in the Agrarian University of Havana Herrera *et al.* (2011), allowed to determine that the reduction 3500L per year in the consumption of diesel fuel, with measures conducting to a rational use of the agricultural machinery would avoid emissions of pollutants of 28kg of Nox that cause sour rains; of 2.1kg of CO_2 harmful to the atmosphere; of 10451kg of CO that increase the hothouse effect; and of 0.42kg of hydrocarbons and 1.39kg of SO_2 that cause the sour rains.

Electric power saving

Although a great part of the agricultural machines (tractors, combines, irrigation machines, etc.) are moved by motors of internal combustion, the employment of the electric power is indispensable in industrial works and of services like the repair and maintenance shops, warehouses, etc. At world level the saving of electric power is one of the biggest contributions that one can make to the environment protection, because the power plants are as a rule highly polluting. It is for it that is necessary to promote actions for the use of nonconventional sources of energy. The savings of electricity can also be obtained by means of the accommodations of power loads, the employment of lights of little consumption of electric energy, the amplification of the natural illumination in industrial buildings and shops with the use of translucent tiles, etc. Nevertheless, it is necessary also to consider that is more convenient the substitution by electric motors the ones using diesel or gasoline that are highly consumers of fuel, like it is the case of the irrigation machines (Ríos, 2021).

Use of renewable energy

The production of biogas for domestic use or in facilities for processing of agricultural products contributes to the saving of other fuels. This technology also has a beneficial effect for the fact that it is avoided that the organic residuals, specially the excreta of the animals, pass to the aquifers or the fluvial sources, and at the same time is obtained a high value fertilizer for the agricultural production. It also avoids the propagation of pathogenic organisms present in the excreta.

In the works related with the agricultural mechanization, the correct use of the solar energy has a notable ecological and environmental impact because it is a renewable resource, non-pollutant

and economic. The utility of solar energy has three main aspects: the use for generation of electricity, for illumination and for the production of heat. The use of panels of photoelectric cells to generate direct electricity is an option as a source of energy for the electric fences in dairy farms and for other diverse domestic and productive tasks in the agriculture.

It is also important the utilization of the heating energy of the sun in the drying of agricultural products, the heating of water and other processes. In the shops of agricultural machinery, stores and other agricultural facilities can be saved a substantial part of the energy used in the illumination by means of the employment of translucent tiles and other measures that unblock of the solar light.

Although our country is not characterized by the predominance of sustained strong winds, the Eolic energy is broadly used to move the windmills for extraction of water in remote areas, method that has a great importance with the current climatic tendency toward periods of more and more lingering drought. This type of mills can also be convenient in the production of electricity.

The hydraulic energy also represents a source of non-pollutant and very economic energy. The generation of electricity is an example of the use of the water sources in the mechanization of the agriculture with mini-hydroelectric plants, the utilization of fluvial sources or the rains for the furrow irrigation and other uses, the hydraulic rams to elevate the water, etc. The water is one of our main natural resources, with the disadvantage that contrary to the soil and the air, its readiness is cyclical and almost always in shortage. Water use in the agricultural works or in industrial facilities should be limited only to the indispensable needs (Minag-Cuba, 2002).

CONCLUSIONS

In the study were determined the factors that impact on the environment in the sphere of the agricultural mechanization, and the measures to be taken to minimize their negative effects as contribution to the protection of the resources and of the environment.

The negative factors that have been analyzed serve like base for the elaboration of the research projects related with the agricultural mechanization so that the damages that take place are minimal using appropriate, conservationist technologies for the recovering, regeneration and improvement of the quality of the soil, the air, and the water.

RECOMMENDATIONS

It is recommended to increase the environmental education in the agricultural mechanization, with actions directed to the acquisition and generation of knowledge, to the development of habits, abilities, changes of behaviors and formation of values toward new forms of relationship of the human beings with the nature.

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