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Validation of productive practices at intervention sites of the ecoVALOR Project

Validación de prácticas en sitios de intervención del proyecto ecoVALOR

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ABSTRACT: Soil degradation, driven by unsustainable agricultural practices and climate change, threatens food security, ecosystems, and sustainable development. The ecoVALOR Project in Cuba seeks to combat this problem by introducing mechanisms or methods for applying conservation technologies and sustainable agricultural practices. The study was conducted at five intervention sites in three Cuban provinces, in different production units. These units received equipment such as tractors, carts, seeders, and sprayers, allowing for the formation of different work groups. A baseline was identified with geographic indicators, farm management indicators, and soil physical/chemical properties (texture, porosity, organic carbon, etc.), following scientific protocols. Conventional and conservation technologies were compared. Among the main results, through the formation of work groups, improvements in soil properties were found (increased initial humidity, reduced apparent density, increased drainable porosity, increased porosity and structural stability of the soil), economic and environmental benefits (reduction in costs in corn threshing and soil preparation, lower environmental impact with decreased tillage and application of green manures), and strengthening of social indicators, related to the reduction of the use of synthetic inputs and the strengthening of local organizations for sustainable management. The ecoVALOR project, with its multidisciplinary approach (environmental, economic, and social), is replicable to address global challenges such as food security and climate change.
Keywords: ecoVALOR Project, Soil Properties, Conservation Technology.

RESUMEN: La degradación del suelo, impulsada por prácticas agrícolas insostenibles y cambios climáticos, amenaza la seguridad alimentaria, los ecosistemas y el desarrollo sostenible. El Proyecto ecoVALOR en Cuba, busca combatir este problema mediante la introducción medios para la aplicación de tecnologías conservacionistas y prácticas agrícolas sostenibles. El estudio, se desarrolló en 5 sitios de intervención en tres provincias cubanas, en diferentes unidades de producción, las que recibieron equipos como tractores, carretas, sembradoras y asperjadoras, que permitieron conformar diferentes conjuntos de trabajo. Se identificó una línea base con indicadores geográficos, de gestión de fincas, y propiedades físicas/químicas del suelo (textura, porosidad, carbono orgánico, etc.), siguiendo protocolos científicos. Se compararon tecnologías convencionales contra conservacionistas. Entre los principales resultados, mediante la formación de conjuntos de trabajo se encontró mejoras en propiedades del suelo (aumento de humedad inicial, reducción de densidad aparente, aumento de porosidad drenable, incremento de porosidad y estabilidad estructural del suelo) beneficios económicos y ambientales (reducción de costos en la trilla de maíz y la preparación de suelo, menor impacto ambiental con la disminución de laboreo y aplicación de abonos verdes) y fortalecimiento en indicadores sociales, en lo relativo a reducción del uso de insumos sintéticos y fortalecimiento de organizaciones locales para gestión sostenible. El proyecto ecoVALOR con su enfoque multidisciplinario (ambiental, económico y social) es replicable para enfrentar desafíos globales como la seguridad alimentaria y el cambio climático.
Palabras clave: propiedades suelo, degradación, tecnología de conservación, desarrollo sostenible.

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INTRODUCTION

Soils constitute the fundamental basis for sustainable agricultural development, the maintenance of essential ecosystem functions, and food security. However, alterations leading to soil degradation represent a growing global threat, driven by unsustainable management practices, inappropriate land use, and extreme weather events, all linked to socioeconomic and governance factors (FAO, 2015). This degradation, which is advancing at alarming rates, compromises soil fertility and productivity, jeopardizing both the stability of ecosystems and the global food supply. In this context, agri-food systems face the challenge of operating within the limits of finite resources, which requires a comprehensive approach that balances productive efficiency with environmental, economic, and social sustainability. To achieve this, it is imperative to transcend purely productive objectives and incorporate improvements in value chains, along with practices that promote ecosystem conservation (FAO, 2016). In response to these challenges, the ecoVALOR project "Incorporation of multiple environmental considerations and their economic implications in the management of forests, landscapes and productive sectors in Cuba" is aligned with the Economic and Social Development PCC-Cuba, 2021). Its implementation includes economic incentives to achieve financial sustainability in the use of natural resources, combat pollution, mitigate soil degradation, and adapt to climate change. At its intervention sites, the project has incorporated technical equipment specifically designed to halt or significantly reduce soil degradation processes. Central to achieving these objectives is the validation of agricultural technologies, a process recognized as fundamental to promoting sustainable innovations in the sector (FAO & OPS, 2017; Martínez *et al.*, 2017)..This validation requires rigorous assessments that guarantee not only productive efficiency, but also environmental viability and adaptation to specific local contexts, as highlighted by Synergy, 2006; Bell & Morse, 2018). The main objective of this work, based on an established baseline, is to provide the necessary elements to ensure land sustainability at the intervention sites. This will be achieved through integrated agricultural management based on technologies implemented by the ecoVALOR project under diverse soil and climate conditions.

MATERIALS AND METHODS

EcoVALOR Project Intervention Sites

The ecoVALOR Project encompasses, at the national level, five provinces, 30 municipalities, 15 protected areas, 10 soil, water, and forest polygons, seven forested areas, three fishing centers, four tourism centers, and two hydrocarbon companies. Based on this diversity of actors and ecosystems, five intervention sites were established (Table 1), aimed at validating sustainable agricultural practices with a conservationist approach and compatible with environmental preservation and the maintenance of ecosystem services.

Main agricultural technologies distributed by the ecoVALOR Project

The project intervention sites were equipped with various technological resources for the implementation of agricultural practices with conservationist criteria. Table 2 shows the main technical resources provided by the ecoVALOR Project.

RESULTS AND DISCUSSION

The main objectives of validating incorporated technologies are to provide information on the sustainability they could produce when implemented and to understand the impact on certain soil properties when managed systematically. In this sense Mosquera-Montoya (2021), suggests that a technology should be more effective than those currently implemented and, where possible, reduce production costs, that is, be efficient from an economic and environmental perspective.

The impact of machinery on the environment depends on multiple factors, influencing, among others, soil degradation, a drop in its productive capacity, and water and air pollution, as reported by Lal & Dtewart, 1990; Ríos-Hernández, 2024). These environmental damages can be reduced if the appropriate machinery and technologies are selected. Various authors Lal (2001; 2015); Hobbs *et al.* (2019); Kassam *et al.* (2020) have demonstrated that minimal or reduced tillage and the incorporation of green manures are environmentally friendly practices that maintain ecosystem services. They increase soil organic matter levels and biological activity, improve soil stability, and reduce fuel consumption.

Table 1. Intervention sites ecoVALOR Project

Province	Municipality	Management form	Name	Extension (ha)
Matanzas	Unión de Reyes	CCSF	Antonio López	400.00
	Jagüey Grande	CCS	Israel León	22.50
Las Tunas	Puerto Padre	CCSF	Mártires de Bolivia	46.00
	Jesús Menéndez	UEB	Adolfo Villamar	86.10
Holguín	Banes	UBPC	Antonio Maceo	112.00
				666.60

Table 2. Technical means delivered to the different intervention sites.

Province	Municipality	Management form	Name	Technical means delivered (*)
Matanzas	Unión de Reyes	CCSF	Antonio Lopez	Tractor Cart Seeder
	Jagüey Grande	CCS	Israel León	Tractor Cart Sprayer
Las Tunas	Puerto Padre	CCSF	Mártires de Bolivia	Tractor Cart Seeder
	Jesús Menéndez	UEB	Adolfo Villamar	Tractor Cart Seeder
Holguín	Banes	UBPC	Antonio Maceo	Tractor Cart

As proposed by Gugino (2009), inherent soil quality is related to its composition and natural properties, influenced by soil formation factors and processes in the absence of human impact. These same authors explain that dynamic soil quality is related to those properties that change as a result of soil use and management over the human timescale. As Ossa-Ossa (2016), explains, an agricultural production system is defined as a set of interconnected elements, where "the whole behaves in an organized, coherent manner, as an integrated whole that cannot be deduced from its parts."

Aramburú (2001), pointed out the importance of establishing a baseline or starting point for an activity that can have a positive or negative impact on the environment and of being able to control or monitor negative or positive impacts, which allows for determining the risk of soil degradation or decline in quality.

The baseline was identified from information sources consulted or evaluated, following the methodological structure and criteria defined by Arcia-Porrúa et al. (2024). In all cases, the data recorded correspond to the period prior to the implementation of the technologies provided by the project. Table 3 shows the information considered as the baseline for each of the intervention sites. This information is grouped into value categories, as established by Arcia-Porrúa et al. (2024).

Table 4 shows some changes in soil properties, such as initial moisture content, bulk density, porosity, and drainable porosity, in the Antonio Lopez Production Unit, in the Unión de Reyes Municipality. These changes are slightly increased with the use of conservation technology. This unit is home to black Rendzina soil with a slope that ranges from undulating to steeply undulating, which favors erosion when conservation management practices are not used. Given the shallow effective soil depth, slope, and some rocky terrain that characterize the areas, the tractor-cart system requires conservation technology, which also includes the use of organic matter with the tractor-cart system. In the case of the Israel León Production Unit, part of the Jagüey Grande Municipality, the soil is Ferralitic Red, but with a significant percentage of rockiness (10.0-25.0%), which limits the use of soil preparation practices with vertical soil management. Other conservation-oriented practices are being implemented, for example, the use of the tractor-cart combination provided to this unit allowed for the application of organic matter at a rate of 15 t/ha. This, combined with the tractor-sprayer combination, allowed for the application of biostimulants, biopesticides, etc. Table 5 shows the changes in some soil properties of the aforementioned Production Unit. In the case of the Province of La Tunas, the Mártires de Bolivia Units, belonging to the Puerto Padre Municipality, have a Red Rendzina soil, with little effective depth (25-50 cm), the tractor-seeder set, taking advantage of the working organs of this implement, carried out vertical preparation work, this practice brought benefits mainly in the apparent density and porosity of the soil, this Unit also benefited from the delivery of the tractor-cart set, aimed at the application of compost (20 t/ha). These practices, as a whole, brought benefits in general terms to the soil characteristics shown in Table 6. In this Province (Las Tunas), the Adolfo Villamar Production Unit, located in the Jesús Menéndez Municipality, was also an intervention site, which has a Dark Plastic soil. The tractor-seeder combination, taking advantage of the working organs of this implement, carried out vertical soil preparation tasks. This practice brought benefits, among which are shown in Table 7, highlighting the decrease in apparent density, increase in porosity and drainable porosity. These results allow for better use in the managed areas, which are located on two center pivot machines with efficient water management for irrigation.

In the Province of Holguín, the Antonio Maceo UBPC, located in the Municipality of Banes, was evaluated. The soil present is Red Rendiza with a shallow effective depth (50-25 cm). The tractor-seeder set, which took advantage of the working organs of this implement, carried out vertical preparation work. This practice brought benefits mainly observed in favorable changes in apparent density with an average decrease greater than 2% and an average increase in porosity of 1%, as shown in Table 8.

Table 3. Baseline of the indicators identified in the different intervention sites

INDICATORS		MUNICIPALITIES				
		Unión de Reyes	Jagüey Grande	Puerto Padre	Jesús Menéndez	Banes
		NAME PRODUCTIVE FORM				
		Antonio López	Israel León	Mártires de Bolivia	Adolfo Villamar	Antonio Maceo
Geographical/ edaphic	Relief (%)	Ondulado-Fuertemento ondulado (4.0-16.0)	Llano-Muy llano (< 1.0)	Llano-Muy llano (< 1.0)	Llano-Muy llano (< 1.0)	Casi llano (1.0-2.0)
	Degree of erosion (%)	Pérdida del horizonte "A" desde 27	Pérdida del horizonte "A" < 25	Pérdida del horizonte "A" < 25	Pérdida del horizonte "A" < 25	Pérdida del horiznte "A" entre el 25 - 75
	Effective soil depth (cm)	< 25	150-90	50-25	150-90	50-25
	Stonyness (%)	0.2-4.0	0.1-02	0.2-4.0	< 2.0	0.2-4.0
	Rockiness (%)	2.0-10.0	10.0 -25.0	2.0-10.0	< 2.0	2.0-10.0
Farm Management (cropping system, water)	Management of agricultural inputs	En ocasiones (Aplicación esporádica y no aplican productos químicos)	Alto (Manejo de agro insumos)	Combinado (Uso de agroinsumo y productos químicos)	Combinado (Uso de agroinsumo y productos químicos)	Combinado (Uso de agroinsumo y productos químicos)
	Soil management systems	Tradicional (Preparación con maquinaria agrícola, sin aplicación de materia orgánica)	Tradicional (Labores de manejo del suelo por medios mecánicos y tracción animal y aplicación de materia orgánica)	Tradicional (Labores de manejo del suelo por medios mecánicos y tracción animal y aplicación de materia orgánica)	Tradicional (Labores de manejo del suelo por medios mecánicos y tracción animal y aplicación de materia orgánica)	Tradicional (Labores de manejo del suelo por medios mecánicos y tracción animal y aplicación de materia orgánica)
	Average agricultural yields (% of potential)	< 30	30-50	30-50	50-70	30-50
Physical, Hydrophysical, Chemical and Biological Properties	Texture (%)	De 20 a 40 arcilla y > 20 limo	De 20 a 40 arcilla y > 20 limo	De 20 a 40 arcilla y > 20 limo	> 40 arcilla ó > 60 limo	De 20 a 40 arcilla y > 20 limo
	Porosity (%)	30 -50	30 -50	30 -50	50 - 60	30 -50
	Drainable porosity	10-5	20-10	20-10	10-5	20-10
	Apparent density (g/cm $^{-3}$)	1.50-1.65	1.35-1.50	1.35-1.50	1.20-1.35	1.35-1.50
	pH in water	6.4 - 5.5 ó 7.8 -8.4	6.5-7.4	6.4 - 5.5 ó 7.8 -8.4	6.4 - 5.5 ó 7.8 -8.4	6.4 - 5.5 ó 7.8 -8.4
	Electrical conductivity (dS m $^{-1}$ a 25º C)	> 0.98	> 0.98	> 0.98	0.98 -1.71	> 0.98
	Organic carbon content (%)	2.0 - 1.0	4.0 - 2.0	6.0 - 4.1	4.0 - 2.0	2.0 - 1.0

Table 4. Changes in some physical-chemical indicators evaluated with the conservationist management of the soil, in the Antonio López Production Unit, in the Unión de Reyes Municipality

Intervention site	Sampling depth	Initial humidity	D.A	Porosity	Humidity under tension	Drainable porosity	pH	CE
		(gr/gr)	(gr cm^{-3})	(%)	(100 cm (cm3 cm^{-3})	(%)	(agua)	(dSm^{-1})
Unión de Reyes Productor: Juan E. Ramírez				Conventional Technology				
	0-10	29.40	1.08	38.50	0.24	10.25	7.50	0.01
	10-20	28.50	1.02	37.70	0.20	10.18	7.80	0.01
	20-30							
				Conservation Technology				
	0-10	32.50	0.99	39.50	0.30	10.30	7.60	0.01
	10-20	30.80	0.98	38.30	0.25	10.28	7.70	0.01
	20-30							

Table 5. Changes in some physical-chemical indicators evaluated with the conservationist management of the soil, in the Los Olivos Production Unit of the Jagüey Grande Municipality

Intervention site	Sampling depth	Initial humidity	D.A	Porosity	Humidity under tension	Drainable porosity	pH	CE
		(gr/gr)	(gr cm^{-3})	(%)	(100 cm (cm3 cm^{-3})	(%)	(agua)	(dSm^{-1})
Jagüey Grande finca: Los Olivos				Conventional Technology				
	0-10	37.9	1.20	44.2	0.34	10.5	7.0	0.8
	10-20	37.5	1.16	47.4	0.42	5.2	7.2	0.8
	20-30	33.4	1.15	44.8	0.39	8.0	7.1	0.8
				Conservation Technology				
	0-10	35.6	0.86	60.7	0.38	22.6	7.1	0.79
	10-20	36.7	1.03	55.5	0.44	11.4	7.1	0.79
	20-30	33.3	1.00	54.7	0.38	16.6	7.2	0.78

Table 6. Changes in some physical-chemical indicators evaluated with the conservationist management of the soil, in the Mártires de Bolivia Production Unit located in the Puerto Padre Municipality

Intervention site	Sampling depth	Initial humidity	D.A	Porosity	Humidity under tension	Drainable porosity	pH	CE
		(gr/gr)	(gr cm^{-3})	(%)	(100 cm (cm3 cm^{-3})	(%)	(agua)	(dSm^{-1})
Puerto Padre CCS Mártires de Bolivia. Productor: Dainer de la Cruz				Conventional Technology				
	0-10	25.1	0.98	56.9	0.46	11.1	7.8	0.1
	10-20	32.2	0.74	42.4	0.37	12.2	8.1	0.1
	20-30	33.7	0.73	55.6	0.37	18.5	8.0	0.1
				Conservation Technology				
	0-10	30.9	0.95	58.7	0.31	11.2	7.9	0.1
	10-20	18.7	0.71	48.8	0.19	24.4	8.1	0.1
	20-30	35.9	0.71	60.1	0.36	18.7	8.0	0.1

Table 7. Changes in some physical-chemical indicators evaluated with the conservationist management of the soil, in the Adolfo Villamar Production Unit located in the Jesús Menéndez Municipality

Intervention site	Sampling depth	Initial humidity	D.A	Porosity	Humidity under tension	Drainable porosity	pH	CE
		(gr/gr)	(gr cm^{-3})	(%)	(100 cm (cm^3 cm^{-3})	(%)	(agua)	(dSm^{-1})
Jesús Menéndez UEB Productor: Adolfo Villamar				Conventional Technology				
	0-10	33.3	1.27	62.7	0.57	6.0	8.7	0.1
	10-20	31.9	1.23	61.7	0.57	5.0	8.7	0.1
	20-30	39.1	1.09	66.5	0.59	7.5	8.6	0.1
				Conservation Technology				
	0-10	46.7	1.10	65.5	0.61	5.8	8.4	0.1
	10-20	47.4	1.09	65.6	0.60	5.2	8.4	0.1
	20-30	41.7	1.09	64.9	0.61	7.0	8.3	0.1

Table 8. Changes in some of the physical-chemical indicators evaluated with the conservationist management of the soil, in the Antonio Maceo Production Unit, Banes Municipality.

Intervention site	Sampling depth	Initial humidity (gr/gr)	D.A (gr cm^{-3})	Porosity (%)	Humidity under tension (100 cm (cm^3 cm^{-3})	Drainable porosity (%)	pH (agua)	CE (dSm^{-1})
UBPC Antonio Maceo, Municipio Banes				Conventional Technology				
	0-10	33.0	0.96	61.7	0.45	16.9	8.3	0.2
	10-20	32.5	1.01	60.1	0.57	13.3	8.2	0.1
	20-30	35.1	0.83	56.8	0.53	13.5	8.2	0.1
				Conservation Technology				
	0-10	37.4	0.80	63.4	0.47	13.5	8.1	0.1
	10-20	40.4	0.70	60.2	0.44	15.6	7.9	0.1
	20-30	40.9	0.95	65.9	0.53	16.0	8.7	0,1

Coinciding with our results, Idowu *et al.* (2009), recognize that excessive mechanization, the absence of crop rotations and lack of addition of organic matter produce a decrease in some soil properties, with the consequent decrease in the productive potential of the soils, for this reason, soil health and its maintenance have received increasing attention of farmers. Conservation practices not only regenerate soils, but also strengthen communities, balance ecosystems, and generate more resilient rural economies. Integrating social, environmental, and economic indicators is key to assessing their success and scaling up their adoption (Burbano-Orjuela, 2017).

Among the social impacts of conservation-based practices, according to Prodi *et al.*, (2001) and (Pretty *et al.*, 2006), is the strengthening of local organizations for sustainable resource management. Among the economic indicators, Lal (2015), suggests lower expenditures on synthetic inputs (fertilizers, pesticides) by leveraging local resources.

As an example, and based on the criteria of the producers benefiting from the ecoVALOR Project, in the Province of Holguín, in the Production Unit located in the Municipality of Banes, the environmental impact was observed. With the application of organic waste and ecological soil management of more than 30 t/ha, the benefits were primarily observed from an economic perspective, with an increase in yields of between 20 and 25% for all the crops grown there (tomatoes, chili peppers, etc.).

Reduction in production costs. With the incorporation of the technological resources provided by the Project, costs have been reduced. For example, corn threshing, which previously cost $27,600/t, is now reduced by $16,100/t. Furthermore, soil preparation, which previously (using traditional techniques) cost $3,500.00/ha, has now achieved savings of $2,300.00/ha with the incorporation of new technologies.

CONCLUSIONS

- With the implementation of various technological resources, it is evident that sustainable agricultural practices positively influence some soil indicators (decreased bulk density and increased porosity) at intervention sites in Matanzas Province.
- At the intervention sites in Las Tunas Province, soil porosity and structural stability increased.
- At the intervention sites in Holguín, bulk density decreased and porosity increased.
- Through a multidisciplinary approach (environmental, economic, and social), the Production Unit located in the Banes Municipality (Holguín Province) achieved yield increases of more than 30 t/ha, reduced corn threshing costs by approximately $11,500/t, and achieved savings of $2,300/ha in soil preparation.

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