ORIGINAL ARTICLE

Adequacy of Labras Software in Planning the Preparation of the Soil for Sugarcane

Adecuación del software Labras en la planificación de la preparación del suelo para caña de azúcar

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ABSTRACT: The Sugarcane Research Institute worked on the development of the software (SW) LabraS specialized in the planning of soil tillage processes. Evaluating the functional adequacy of the LabraS software in the planning of the sustainable soil preparation for sugarcane cultivation is the objective of this paper. The work was carried out at "Héctor Rodríguez" Base Business Unit (UEB), of the AZCUBA Sugar Group. The evaluation included the 2020-2021 soil preparation campaign, with 2 619.2 ha, concentrated in 57 blocks dedicated to sugarcane. The research conditions were characterized as complex, with a predominance of poorly drained areas (57%), medium and heavy textured soils (89%), and fallows or cane fields with very low agricultural yields without harvest (67%). The results showed an adequate selection of the technological alternatives, their operational variants and tasks by management condition. In addition, the correct application of the ISMACE criteria (integration of knowledge on soil, machinery, crop and working environment) in the algorithm of the LabraS software, for selecting the technologies with the best technological, economic, energetic and environmental impact, generally demonstrated satisfactory results in the validation of the functional adequacy for the planning of sustainable soil preparation.

Keywords: Functional Completeness, Functional Correctness, Functional Relevance, Software Testing, Agricultural Planning.

RESUMEN: El Instituto de Investigaciones de la Caña de Azúcar trabajó en el desarrollo del software (SW) LabraS especializada en la planificación de los procesos de labranza del suelo. Evaluar la adecuación funcional del software LabraS en la planificación de la preparación sostenible del suelo para el cultivo de caña de azúcar es el objetivo de esta investigación. El trabajo se desarrolló en la Unidad Empresarial de Base (UEB) Héctor Rodríguez, del Grupo Azucarero AZCUBA. La evaluación comprendió la campaña de preparación de suelo 2020-2021, con 2 619,2 ha, concentrado en 57 bloques dedicados a caña. Las condiciones de investigación se caracterizaron por ser complejas, con un predominio de las áreas con mal drenaje (57%), de los suelos de textura media y pesada (89%) y de los barbechos o campos de caña de muy bajo rendimiento agrícola sin cosechar (67%). Los resultados mostraron una adecuada selección de las alternativas tecnológicas, sus variantes operacionales y labores por condición de manejo. Además, aplicación correcta de los criterios ISMACE (Integración de los conocimientos del suelo, la maquinaria, el cultivo con el entorno de trabajo) en el algoritmo del software LabraS, por seleccionar las tecnologías con mejor impacto tecnológico, económico, energético y ambiental, lo que demostró en general resultados satisfactorios en la validación de la adecuación funcional para la planificación de la preparación sostenible del suelo.

Palabras clave: Completitud funcional, corrección funcional, pertinencia funcional, pruebas de software, planeación agrícola.

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INTRODUCTION

Sugar Cane Research Institute (INICA) worked on the development of a computer system, LabraS Software, specialized in planning sustainable processes of soil tillage (Betancourt-Rodríguez *et al.*, 2018; Pérez-Santos, 2018; Betancourt-Rodríguez *et al.*, 2019a). The recommendations considered the results of more than 30 years of research in that field in Cuba (Gómez *et al.*, 1997; Crespo *et al.*, 2013; Gutiérrez *et al.*, 2013; Oliva *et al.*, 2014). The platform was the main working tool of the first offer of soil tillage service aimed to the sugarcane producer (Betancourt-Rodríguez *et al.*, 2018).

On the computer systems development, it is important to consider the quality evaluation of the software product. According to the ISO/IEC 25010 (2011), it is the way the product satisfies the customer's requirements and adds value. The quality model defined in that standard includes eight characteristics: Functional suitability, Performance efficiency, Compatibility, Usability, Reliability, Security, Maintainability and Portability, all composed of sub-characteristics that together facilitate the evaluation process by relevant institutions.

According to Blanquicett *et al.* (2018), software testing is a very important process within the software development cycle and it is characterized by its accuracy, reliability and repeatability, being necessary to know what requirements are tested and to check that the product does what the client expects. In that sense, Pauta & Moscoso (2017) define that in the evaluation of the quality of the software, the slogan of parallel execution of Verification and Validation, also known as V&V, will be applied in the different phases of the life cycle. The complexity of today's software requires that the test runs parallel to the development, so that errors are timely and can be corrected at low cost (Serna *et al.*, 2019; Marin-Diaz *et al.*, 2020).

Functional suitability, specifically, represents one of the important characteristics that determines the ability of the SW product to provide functions that meet user's demand under specified conditions. It is subdivided into three components: Functional completeness, the extent to which the functions cover the tasks and meet the client's objectives; Functional correctness, ability to provide correct results with the level of accuracy required and Functional relevance, possibility of providing an appropriate set of functions for specific tasks and objectives of users (ISO/IEC 25010, 2011).

For sustainable soil management, according to FAO & GTIS (2015), it is necessary to use scientific knowledge, local knowledge, proven evidence-based approaches and technologies to increase food supply, provide a valuable tool for climate regulation and safeguard ecosystem services. Likewise, in a broader vision, it proposes to achieve sustainable development in a balanced and integrated way (FAO, 2019).

From the point of view of tillage, when there is a broad knowledge base, it is possible to apply the principles of sustainability if criteria that integrate knowledge of the soil, machinery, cultivation and the environment are implemented. LabraS software (SW) is a good choice because that integration is applied just at the planning time of the agricultural work.

In order to reduce the environmental impact of tillage, some study recommend the development of alternative mechanical management system that reverses, stops or mitigates soil deterioration, decreasing energy consumption and improving the economic results of sugarcane grower (Grange *et al.*, 2005; Tesouro *et al.*, 2019; Department of Agriculture and Fisheries-Queensland Govemment, 2021). The use of scarifiers, either for stripe or total soil tillage, is a good choice to transform the scenario towards a balanced environment in sugarcane soil preparation (Gómez *et al.*, 1997; Oliva *et al.*, 2014; Tesouro *et al.*, 2019).

Considering the above, the objective of this research is to evaluate the functional suitability of the LabraS software algorithms in the planning sustainable soil preparation for sugarcane.

MATERIALS AND METHODS

The research was carried out in the Base Business Unit (UEB) "Héctor Rodríguez", belonging to the Sugar Company (EA) Villa Clara, both of AZCUBA Sugar Group. Sugarcane is cultivated in 17,004.98 ha. The genetic soil grouping predominant are Gleysol, with more than 30%; Sialitic brown, Vertisol and Ferralitic occupying between 16 and 19%, according to the genetic classification of 2015 proposed by Hernández *et al.* (2015).

The 2020-2021 soil preparation campaign was planned for 2 619,2 ha, concentrated in 57 blocks dedicated to sugarcane. In the UEB, either by inventory equipment or hiring, there are aggregates (tractor and implement) available to perform the work, although there are implements like C101M and Bayamo that require modification to meet the agronomic requirements for each work (Table 1). The Production Units (UP) do not have the means to carry out the technological process.

LabraS SW owns a set of functions available to the user in order to ensure the functional relevance in the tillage process of sugarcane. The definition of tillage soil limiting factors, soil textures and ground conditions, as fundamental components to select machinery and technology of sustainable soil preparation, came from a functionality established in the Codifier or Nomenclators with specific parameters and algorithms (Betancourt-Rodríguez *et al.*, 2019a).

The algorithms used in LabraS integrate knowledge of the soil, machinery, cultivation and work environment into the same procedure for recommendations, called ISMACE criteria (Soil-Machinery-Crop-Work Environment Integration). That means to evaluate the soil limiting factors to solve by tilling or defining the equipment used in order to avoid tool breakage. Also, they provide results that meet, at any time, the crop´s agronomic requirements and considering the environment in which the recommendations are developed, all seen from the origin of the machinery and the impact on the social and environmental level.

The Figure 1 presents LabraS SW general scheme for obtaining the reports. It is important to point out that one of the novelties in the established procedures is that the brigade is not only the system to organize the machinery, but the computing section that facilitates the identification of machinery for the specified environment, as part of the ISMACE criteria established.

The information processing in the AR was established in three stages:

1. Technological Alternative (AT) determination.

In this research, AT means the combination among the components of the factors that make up the technological process. By means of the name of the component and establishing a logical sequence, the name of the alternative is formed, which means that each alternative in its nomenclature contains a condition of agronomic management. Considering the number of factors in soil preparation by Betancourt-Rodríguez *et al.*, (2018), 169 possible technological alternatives were defined by the computer platform.

The input of the algorithm is formed by the sugarcane blocks (B) and the technological process (PT). The output is the AT of each block appropriate to the management conditions (C), then being *n* equal to the total of blocks:

Input: (B, PT)
Output: AT_i
1: **for** I = 1 **to** n **do**
2: C ← **GetConditions (** B_I **)**
3: AT_I ← **Match** AT I
4: **End for**

2. Determination of the Appropriate Variant within the AT

Variant (V) contains the sequence of tasks, sorted according to agronomic criteria to meet the requirements of the crop (Figure 2) and they are specific to each alternative, for that reason, the computer platform handles them independently.

TABLE 1. Aggregates available by labors and implements situation

Labors	Aggregates available	Situation of the implements		
		Inventory	Modification	Hiring
Land leveling	YTO 1604 with AF Leveler			X
Break (Discs) and Crossing (Discs)	YTO 1604 with AT-90	X		
Raise the strain and break (Arrows)	YTO 1604 with C101M		X	
De-Crown and heavy harrow	Komatsu D80 with Heavy Discs Harrow			X
De-Crown and medium harrow	YTO 1604 with GAPCR Discs Harrow	X		
Light harrow	YTO 1604 with Rome Discs Harrow			X
Raise the strain and break (Arrows), Break (Arrows) and Crossing (Arrows)	YTO 1604 with Bayamo (Modified)		X	
Subsolation	Komatsu D80 with SP 280H			X

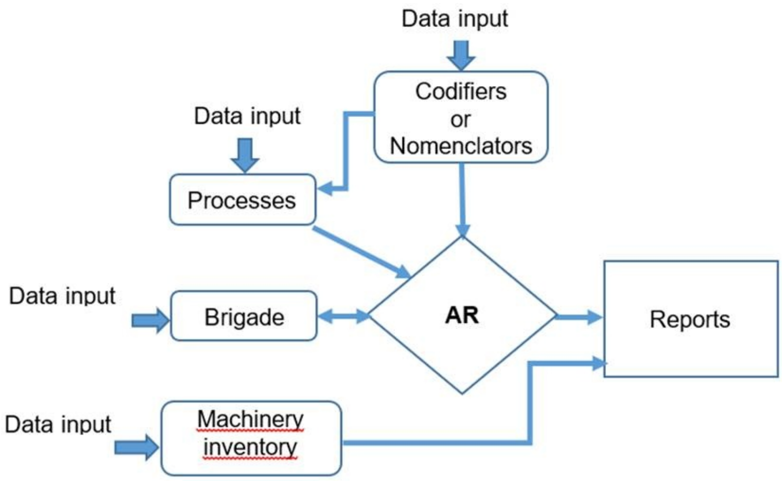

FIGURE 1. Scheme for data input, processing and report. AR- Algorithms for recommendation.

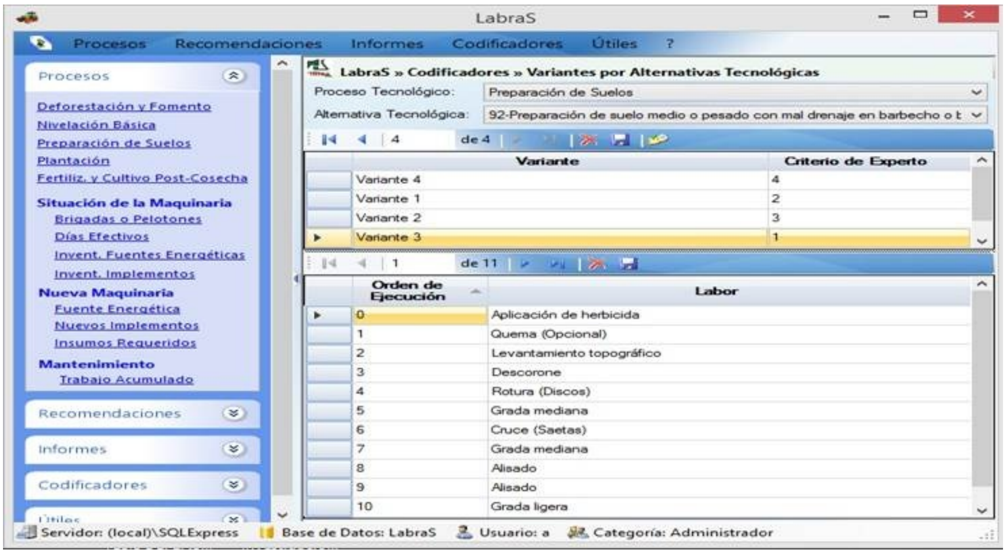

FIGURE 2. Variant for AT in LabraS SW.

In the SW design, the possibility that one or several variants integrate the AT was established, including also the *expert criteria* to set an order of selection by the user, providing more options and flexibility.

A specific nomenclature is used for the tasks, which constitutes another level of selection that broadens the range of possibilities for the user and facilitates the application of the ISMACE system. An example is that of the work Rotura, which in production conditions uses that single term to refer to everything related to the initial work of plowing the soil. However, in the coding of the work in the LabraS platform there are several terminologies such as Rupture (Discs), for primary tillage with plows and disc harrows and Rupture (Arrows), for primary tillage with chisel plows with bolts or winged plows as they are also known. Considering *n* as the total number of blocks to process, the algorithm proceeds by the following steps:

Input: (B, AT)
Output: (V_I)
1. **For** I = 1 **to** n **do**
2. Variants ← **GetVariants (** $B_{I,}$ AT_I **)**
3. **If Defined (** ExpertJudgment **)**
4. Variants ← **OrderByExpertJudgment (** variants **)**
5. **Else**
6. variants ← **OrderByJobsCount (** variants **)**
7. **While Not** Complete Variant is Found **do**
8. Jobs ← **GetJobs (** $variants_I$ **)**
9. V_I ← **MatchJobAg g rega tes (** jobs **)**
10. **End While**
11. **Set (**V_I)
12. End for

In the evaluation of the recommended labors, those concerning to the preparation of the field, such as herbicide application and grass cutting, were not considered, because they do not belong directly to the technological process of soil preparation.

3. Selection of an aggregate for each labor that makes up the selected variant.

The aggregate (A) is nothing more than the set formed by the union of the tractor with the agricultural implement. To carry out a labor within the variant, it is possible to find different aggregates in the inventory of machinery that can perform it or that are not always available at the required time. With *P* being the brigade, the procedure is as follows:

Input: (V, P)
Output: ($A_{I,}$ $jobs_I$)
1: jobs ← **GetJobs (** V **)**
2: **for** I = 1 **to** jobs **.count do**
3: a ggregates ← **Get Aggregates (**$jobs_{I)}$
4:
5: **If Defined (** ExpertJudgment **)**
6: a ggregates ← **OrderByExpertJudgment (**aggregates, **ASC)**
7: **Else**
8: a ggregates ← **OrderByGenera lCriteria (**aggregates, **ASC)**
9: **End If**
10:
11: **While** Aggregates **.next do**
12: **If IsIn (** A_I , P **) And IsAvailable (** A_I **)**
13: **Set (** $A_{I,}$ $jobs_I$ **)**
14: **Exit While**
15: **End If**
16: **End While**
17: **End for**

In the selection of the aggregate as in the variant, the user also has the option of establishing *expert criteria*, which broadens the range of possibilities by being able to define one of several existing, regardless of the exploitation criteria.

From the three exploitation criteria defined in the computer program to choose the aggregate (Productivity, $ha.day^{-1}$, Specific fuel cost, $L.ha^{-1}$ and

Cost, pesos.ha^{-1}), the cost was selected to perform the recommendations.

RESULTS AND DISCUSSION

The distribution of the limiting factor for the tillage mechanization showed a predominance of areas with poor drainage problems with around 57%, followed by the problems of stony (14%), salinity (5%) and effective depth (1%), finding the areas without limitations for tillage at approximately 22% (Figure 3), respect to 2619, 2 ha of soil preparation. In that sense, the recommendation of labor and equipment should be directed to face the limitations and create favorable conditions for the creation of an adequate plantation (Crespo *et al.*, 2013; Oliva *et al.*, 2014; Betancourt-Rodríguez *et al.*, 2018).

From the point of view of soil texture, following the classification given by Betancourt-Rodríguez *et al.* (2019b), those of medium and heavy texture predominated, occupying 2331 ha, leaving the remaining 288 ha on light soils (11%).

The conditions on the ground surface (Figure 4) indicated predominance of fallow or sugarcane of very low crop yields, not harvested areas, representing 67 % (1744 ha), being on demolition the remaining (33%) and those from the rotation shall be null. This situation complicates the planning of soil preparation since the prevailing scenario demands a longer period between labor and total soil preparation time, further aggravated by the possible presence of shrub vegetation that requires robust equipment with greater power, and consequently, the need for hiring with other company.

In all cases, their identification and inclusion within the algorithms creates the conditions for more precise planning, where the most varied and complex conditions find a solution for agronomic management opportunely. It is important to note the need to incorporate area from rotation with other crops by having the ground conditions more suitable for tillage work according to Gutiérrez *et al.* (2013), as well as incorporating other benefits such as the diversification of production.

The analysis of the AT recommended (Table 2) showed good relationship with the management conditions, which is shown in that the sum of the total area by AT coincides with the total area of soil preparation of the campaign (2619, 2 ha) and the sum of frequency by AT with the total of processed blocks (57 blocks).

On the other hand, the AT 92, 89 and 83 covering 57% of the soil with poor drainage, correspond with the predominant MLF in the conditions under study. It happens similarly in the demolition conditions present in AT 100.112, 33, 9, 89, 144 covering 876 ha, and in all cases with medium and heavy texture that prevails in the UEB.

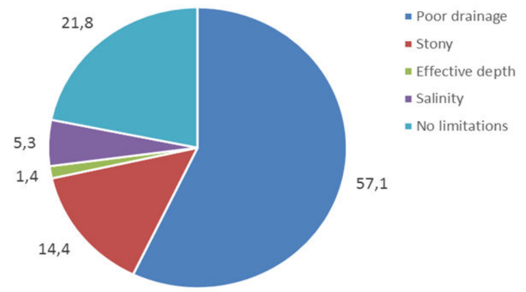

FIGURE 3. Percentage of most limiting factors for tillage mechanization.

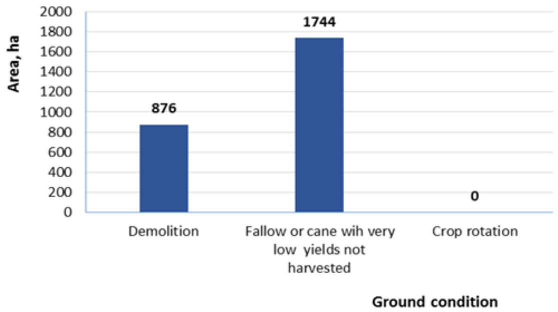

FIGURE 4. Ground condition in the areas of soil preparation.

Furthermore, AT 112, 116, 64, 92 and 89 were recommended five or more times; being AT 92 the one with the highest frequency with 19 times in the technology charts, therefore, the one that determines with the greatest weight the demand for work and the type of equipment to be used.

All of the above shows an adequate functional correction of LabraS SW in the determination of AT by management condition, also demonstrating satisfactory results of the recommendation algorithms in the first stage.

For the selection of the labor and the aggregates, 29 variants (V) were processed in the 12 recommended AT, with possibilities to choose from one to five (Table 3). The sums of the frequency of recommendation match with the number of blocks (57). Further selection was not always in the first variant, but according to the procedures established in the ISMACE criteria, as it observes in the AT 144 with three variants, only V3 was recommended, or also in the AT 89 with five possibilities, the choice was concentrated on V4 and V5.

The use of the *expert criteria* (CE) in the selection of variants as an option to expand the range of possibilities for the user was validated on AT 92 where variant 3 is recommended 17 times for having CE equal to 1. The machinery availability as a factor to be considered in the algorithms is demonstrated in the same AT, where variant 2 is recommended twice, as a result of that equipment were used at the same time. This part demonstrated, as established in the ISO

TABLE 2. Recommendation of technological alternatives for management conditions

Number-Alternative Name	Frequency	Area, ha	%
100-Preparation of light soil with stony and / or rockiness in demolition and change of furrow.	4	149	6
112-Preparation of medium or heavy soil with stony and/or rockiness in demolition and change of furrow.	5	97	4
116-Preparation of medium or heavy soil with stony and/or rockiness in fallow or low yield and change of furrow.	5	132	5
128-Preparation of medium or heavy soil with problem of effective depth in fallow or low yield and change of furrow.	1	36	1
33-Preparation of medium and heavy soil without limitations on demolition and furrow changes.	1	167	6
64-Preparation of medium or heavy soil without limitations in fallow or low yield and change of furrow.	1	271	10
9-Preparation of light soil without limitations on demolition and change of furrow.	4	133	5
92-Preparation of medium or heavy soil with poor drainage in fallow or low yield that requires land levelling and change of furrow.	8	1170	45
89-Preparation of medium or heavy soil with poor drainage in demolition that requires land levelling and change of furrow.	1	275	10
83-Preparation of light soil with poor drainage in fallow or low yield that requires land levelling and change of furrow.	6	51	2
144-Preparation of medium or heavy soil with salinity problem in demolition that requires land levelling and change of furrow.	19	55	2
147-Preparation of medium or heavy soil with salinity problem in fallow or low yield that requires land levelling and change of furrow.	2	84	3

TABLE 3. AT variants and frequency of recommendation

AT Number	AT Variants	Variants recommendation frequency				
		Variant 1	Variant 2	Variant 3	Variant 4	Variant 5
100	1	4				
112	1	5				
116	2		5			
128	2	1				
144	3			1		
147	2	1				
33	3		4			
64	2		8			
83	1	1				
89	5				2	4
92	4		2	17		
9	3			2		

Standard ISO/IEC 25010 (2011), the fulfillment of the three subcharacteristics of the functional suitability of LabraS SW: completeness, correctness and functional relevance.

The variants, although independent, cannot be seen isolated from the labor and aggregates, in this sense and in order to achieve greater understanding, in Tables 4 and 5, the AT-Variant-Labor relationship is shown, where the labors recommended by AT can be identified, but without maintaining the sequence of the technology chart.

For soil preparation, 11 labors were recommended. The De-Crown was aimed for medium and heavy textured soils on demolition, where a soil mound was formed on the surface that restricted the movement of the equipment, perpendicular or oblique with respect to the direction of the furrows. In such cases, where complex conditions limited the use of the middle disc harrow, such as the presence of shrubby vegetation, only heavy disc harrow was recommended.

Scarifier was recommended for total and localized primary tillage in proper conditions, as De-crown and Break (Arrows), Break (Arrows) and Cross (Arrows) (AT 144, 89, 147, 128, 33, 92), which satisfies algorithms for choosing which has fewer operating costs. It is also convenient to point out that collaterally it incorporates technological, energy and environmental benefits in minimum tillage of soil (Gómez *et al.*, 1997; Crespo *et al.*, 2013; Oliva *et al.*, 2014); Tesouro *et al.*, 2019) and follows the principles established by the FAO in soil tillage (FAO & GTIS, 2015; FAO, 2019).

On the other hand, the scarifier was also avoided in the areas affected by rocks and stones (AT 100, 112 and 116), thereby, the occurrence of damage that

TABLE 4. Technological alternatives (AT), variants (V) and labor relationship in primary tillage

AT	De-Crown				RSB (Arrows)		Break (Discs)			Break (Arrows)			Crossing (Discs)			Crossing (Arrows)				Subsolation			
	V1	V2	V3	V4	V3	V5	V1	V2	V3	V1	V2	V3	V1	V2	V3	V1	V2	V3	V5	V1	V2	V3	V4
100							4						4										
112	5						5						5										
116																					5		
128										1						1							
144					1													1					
147										1						1							
33		4						4									4						
64																					8		
83																				1			
89				2		4								2					2				2
92			17					2	17								2	17					
9									2						2								

TABLE 5. Alternative technology (AT), variants (V) and labor relationship in secondary operation

AT	Heavy discs harrow				Median discs harrow					Land leveling					Light discs harrow				
	V1	V2	V3	V4	V1	V2	V3	V4	V5	V1	V2	V3	V4	V5	V1	V2	V3	V4	V5
100					4										4				
112					5										5				
116		5				5										5			
128					1										1				
144							1					1				1			
147					1					1					1				
33						4										4			
64		8				8										8			
83					1					1					1				
89								2	4				2	4				2	4
92						2	17				2	17				2	17		
9							2										2		

could completely invalidate the implement. So the integration soil-machinery in the algorithms and the adequate functional correction of the SW was demonstrated, not only to solve the limitations of the soil for the development of the crop, but also in the appropriate selection of equipment.

For the areas with rockiness and stony problems, Break (Discs) and Crossing (Discs) (AT 100 and 112) were recommended, which agrees with what was suggested by Crespo *et al.* (2013); Oliva *et al.* (2014); Betancourt-Rodríguez *et al.* (2018). It was also proposed on soils without limitations (AT 9 and 89) because the scarifiers were not available on the starting date. An example of that is in the AT 89 with five variants, where variant that combines both types of equipment (scarifier and those with discs) was recommended, also due to the availability of the implements on the specified date established in the algorithms.

The other part of the tools to meet the technological chart come from hiring, whose timely identification facilitates work planning itself, being in this case, implements for subsolation, heavy disc harrow and enlistment labors (Land leveling and Light disc harrow) carried out by the TRANZMEC company. This result demonstrates the application of the ISMACE criterion in the algorithms for planning, specifically regarding the brigade as a computational environment for linking the recommendations with the work environment.

The heavy harrow complemented the work with subsoilers for fallow conditions or low yield block due to the presence of shrub vegetation (AT 116, 64, 83), or in medium textured soils with poor internal drainage (AT 89). The land leveling is associated with the need identified by the grower; in this sense, a preponderance was observed in the AT 92, because it contains the predominant handling condition. Median and light harrow are recommended in all conditions to satisfy the requirement of achieving an adequate proportion of soil aggregates to ensure good furrowing and covering of seed.

The total area for the planned work indicated that the scarifier was recommended only in 11% of the area (Figure 5), low level compared to the height potential of the area (85%). That situation was due to the predominance of fallow land conditions or low yields not harvested (67%).

It is important to remark that the balance did not include those with stony or rockiness problems; on the other hand, Break (Disks) and subsolation were proposed. In the case of subsolation, two passes were planned, representing 1209 ha. It is important to specify that scarification was not conceived in the UEB Technical-Economic Plan, which shows the potentiality of LabraS SW in the proper planning of the soil preparation labor.

Median discs harrow is the predominant according to the level of work, proposed in two passes and occupying 88% of the area, the remaining is labored with heavy discs harrow directed for De-crown in the most complex conditions by the existence of shrubby vegetation such as *Dichrostachys cinerea* (Marabú), *Albizia procera* (Algarrobillo) and *Leucaena leucocephala* (Leucaena). The light disc harrow was recommended at least in one pass to the end of the preparation, representing 100% of the area, and land leveling with two passes for the demanded area, which justifies its application in around 2800 hectares.

It is important to point out that since the entire area is in conditions of furrow change and with a predominance of fallow or low yield, there are limitations to recommend localized tillage technology (LL), leaving total preparation with and without turning up soil the prism for being the most suitable.

The satisfactory result of LabraS SW in the completeness, correctness and functional relevance in the planning of the sustainable soil preparation for sugarcane is due to the performing of parallel development testing on each built-in functionality, coinciding with what was proposed by Serna *et al.* (2019) and Marin-Diaz *et al.* (2020).

All the procedures presented are the bases to conform the technological charts block by block, such as it was presented in the sugarcane plantation process by Betancourt-Rodríguez *et al.* (2019b), and represent a choice to transform the scenario towards a balanced environment in sugarcane soil preparation.

CONCLUSIONS

- The research conditions were characterized by the existence of a high complexity for soil preparation, where predominated areas with poor drainage (57%), soils of medium and heavy texture (89%) and the fallow land or sugarcane of very low agricultural yield without harvesting (67%).
- The technological alternatives, their variants, tasks and operations, were selected appropriately by management condition. The ISMACE criteria in the algorithm of the LabraS software allowed the selection of the technologies with better economic, energy and environmental impact, also taking in to account the role of machinery respect to its ownership, based on:
- To recommend the scarifiers satisfactorily at the break (11%) and the crossing (57%) operation, although very low compared to the potential of the area, close to 85%, due to the complex surface conditions.
- To direct properly the use of heavy tracked equipment, such as the Komatsu tractor with the heavy harrow and the SP 280 subsoilers, towards woody plant areas regardless of non-UEB machinery.
- To recommend the use of traditional means such as discs plows and harrows in areas with stony and rocky problems, regardless of whether they do not have better exploitation criteria, to avoid breakage in the scarifiers.
- The LabraS Software showed satisfactory results in the validation of the functional suitability for the planning sustainable soil preparation in the specified circumstances

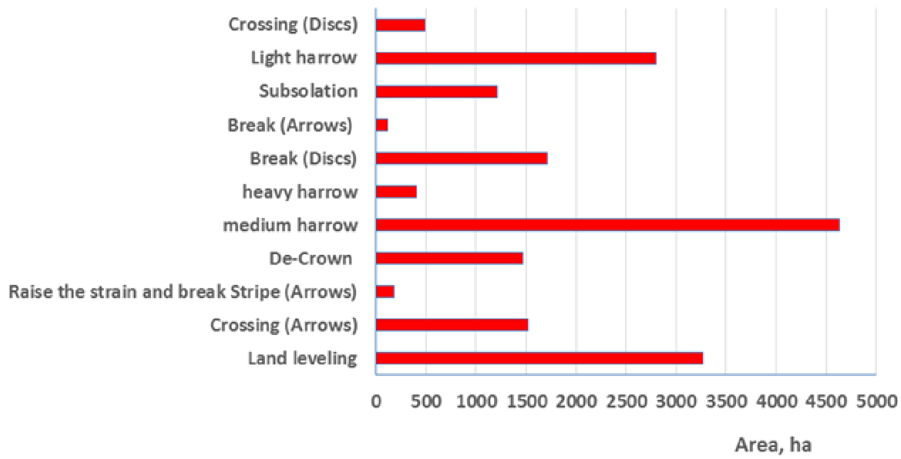

FIGURE 5. Total area by labor.

REFERENCES

BETANCOURT-RODRÍGUEZ, Y.; ALONSO-CAMACHO, D.; GONZÁLEZ-MORALES, A.B.; LA ROSA-AGRAMONTE, A.J.: "Sistema automatizado LabraS para la planificación de la labranza de suelo en caña de azúcar", *Revista Ciencias Técnicas Agropecuarias*, 28(4), 2019a, ISSN: 1010-2760, e-ISSN: 2071-0054.

BETANCOURT-RODRÍGUEZ, Y.; GUILLÉN-SOSA, S.; RODRÍGUEZ-RODRÍGUEZ, J.F.; ALFONSO-VILLEGAS, A.; SÁNCHEZ-RODRÍGUEZ, R.; OLIVA-ÁGRA, L.: "Servicio para la asistencia técnica en la labranza de suelos dedicados a caña de azúcar", *Revista Ciencias Técnicas Agropecuarias*, 27(2): 1-13, 2018, ISSN: 1010-2760, e-ISSN: 2071-0054.

BETANCOURT-RODRÍGUEZ, Y.; PÉREZ-SANTOS, D.; ÁLVAREZ-ROJAS, A.: "Asistencia técnica de la labranza en el control de arvenses en caña de azúcar", *Ingeniería Agrícola*, 9(3), 2019b, ISSN: 2306-1545, e-ISSN: 2227-8761.

BLANQUICETT, L.A.; BONFANTE, M.C.; ACOSTA-SOLANO, J.: "Prácticas de pruebas desde la industria de software. La plataforma asisto como caso de estudio", *Información tecnológica*, 29(1): 11-18, 2018, ISSN: 0718-0764.

CRESPO, F.R.; PÉREZ, H.I.; RODRÍGUEZ, I.; GARCÍA, I.: *Manejo sostenible de tierras en la producción de caña de azúcar*, Agronomía ed., La Habana, Cuba, 119-146 p., Capítulo 6. Agronomía, 2013, ISBN: 978-959-300-051-2.

DEPARTMENT OF AGRICULTURE AND FISHERIES-QUEENSLAND GOVEMMENT: *Sugarcane Improved Practices Guide: Burdekin*, [*en línea*], Inst. Department of Agriculture and Fisheries-Queensland Govemment, Australia, 2021, *Disponible en:* http://www.publicationsqld.gov.au/dataset/05fe1bbd-1933-4205-851b-a469f915327e/resource/0de77def-fd92-4cf7-a325-bcd51cde562e/download/burdekin-sugarcane-ipc-guide.pdf.

FAO: *El apoyo de la FAO para alcanzar los Objetivos de Desarrollo Sostenible en América del Sur - Panorama*, Ed. FAO, Santiago de Chile, Chile, 72 p., Licencia: CC BY-NC-SA 3.0 IGO, 2019, ISBN: 978-92-5-131350-3.

FAO & GTIS: *Estado mundial del recurso suelo (EMRS)*, Ed. FAO, Roma. Italia, 79 p., Resumen Técnico (Organización de las Naciones Unidas para la Alimentación y Agricultura y Grupo Técnico Intergubernamental del Suelo, 2015, ISBN: 978-92-5-308960-4.

GÓMEZ, A.; VELARDE, E.; CÓRDOBA, R.: "Nuevas soluciones para la preparación de suelos en Cuba", *Revista Cuba & caña*, 2(3): 31-36, 1997, ISSN: 1028-6527.

GRANGE, I.; PRAMMANEE, P.; PRASERTSAK, P.: "Comparative analysis of different tillage systems used in sugarcane (Thailand)", *Australian Farm Business Management Journal*, 2(1): 46-50, 2005, ISSN: 1449-5937.

GUTIÉRREZ, A.; DÍAZ, F.; VIDAL, L.; RODRÍGUEZ, I.; PINEDA, E.; BETANCOURT, Y.; GÓMEZ, J.: "Manual de buenas prácticas agrícolas para el cultivo de la caña de azúcar en los suelos arcillosos pesados con regadío superficial", *Revista Cuba & Caña,* 1: 15, Suplemento Especial, 2013, ISSN: 1028-6527.

HERNÁNDEZ, J.; PÉREZ, J.; BOSCH, I.; CASTRO, S.: *Clasificación de los suelos de Cuba 2015*, Inst. Instituto de Suelos. La Habana, Cuba: INCA, San José de las Lajas, Mayabeque, Cuba, 92 p., Mayabeque, Cuba: Ediciones INCA, 2015.

ISO/ IEC 25010: *Systems and software engineering_ Systems and software Quality*, Inst. ISO/IEC 25010. International Standard, Requirements and Evaluation, 33 p., Systems and software quality models (SQuaRE), 2011.

MARIN-DIAZ, A.; TRUJILLO-CASAÑOLA, Y.; BUEDO-HIDALGO, D.: "Estrategia de pruebas para organizaciones desarrolladoras de software", *Revista Cubana de Ciencias Informáticas*, 14(3): 83-104, 2020, ISSN: 2227-1899.

OLIVA, L.M.; GALLEGO, R.; FERNÁNDEZ, G.; RUBÉN, H.: "Fomento y reposición", En: *Instructivo técnico para el manejo de la caña de azúcar*, Ed. Editorial AMA, 2da edición ed., La Habana, Cuba, pp. 79-106, En: Instituto de Investigación de la Caña de Azúcar (Cuba), edit. Ignacio Santana, Maribel González, Sergio Guillen Sosa, Ramón Crespo, 2014, ISBN: 978-959-300-036-9.

PAUTA, L.; MOSCOSO, S.: "Verificación y Validación de Software", *Revista Killkana Técnica*, 1(3): 25-32, 2017.

PÉREZ-SANTOS, D.: *Planificación de la labranza de suelo en caña de azúcar mediante el sistema automatizado LabraS*, Universidad Central "Marta Abreu" de la Villas, Tesis presentada en opción al título académico de Máster en Ingeniería Agrícola, Santa Clara, Villa Clara, Cuba, 75 p., publisher: Universidad Central" Marta Abreu" de Las Villas. Facultad de Ciencias …, 2018.

SERNA, E.; MARTÍNEZ, R.; TAMAYO, P.: "Una revisión a la realidad de la automatización de las pruebas del software", *Computación y Sistemas*, 23(1): 169-183, 2019, ISSN: 1405-5546.

TESOURO, M.O.; FERNANDEZ, U.E.; VENTURELLI, L.; ROBA, M.A.; ROMITO, A.; DONATO, L.B.; BONGIOVANNI, R.; ERAZZU, L.E.; FONTANA, P.D.; PERALTA, A.: "Yields and economic results of sugarcane cultivation under an alternative system compared to traditional management", En: *International Society of Sugar Cane Technologists*, Ed. International Society of Sugar Cane Technologists, pp. 584-590, 2019.

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