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SIS-ICLF: A SOFTWARE SUITE FOR THE MANAGEMENT OF FOREST PLANTATIONS IN ICLF SYSTEMS

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ABSTRACT
SisICLF is a software suite that can be used to manage and plan the forest component of integrated crop-livestock-forest (ICLF) systems with Pine, Eucalyptus, *Toona ciliata*, *Khaya ivorensis*, and *Tectona grandis*. The software supports decision making related to how, when, and how much to thin, and when to conduct the final harvest. Based on inventory data, the software allows users to: simulate all tree component management options of ICLFs; forecast present and future production; conduct economic analyses; and decide on the best alternatives to manage their plantation. The software suite was developed by Embrapa, the Brazilian Agricultural Research Corporation, and is available for download on Embrapa Forestry's website (www.embrapa.br/florestas).
Key words: Precision management; carbon; methane

INTRODUCTION

Beginning in the 1980s, the Brazilian Agricultural Research Corporation (Embrapa Forestry) has been developing software to simulate the growth and yield of forests, mainly for precision management of planted forests (OLIVEIRA, 2011). The development of such tools was driven by partnerships with companies in the commercial forestry sector, which provided forest inventory data. These data enabled the development of algorithms, which led to the creation of several software programs, initially in the programming language Pascal and later in Delphi.

Each software suite, named 'Sis' followed by the popular name of the species or genera (i.e., SisEucalyptus, SisPinus, SisTeak, etc.; SisEucalyptus-ICLF, SisPinus-ICLF, SisTeak-ICLF, etc.), describes the growth and yield of forest plantations (monoculture or integrated crop-livestock-forest-ICLF) based on management regimes defined by the user. The software Planin provides parameters for the economic analysis of forest production (OLIVEIRA, 2021). For ICLF systems, Embrapa initially built SisILPF_Eucalyptus, with the version for *E. urograndis* presented at Expoforest and the IV Brazilian Silviculture Meeting in 2018 (OLIVEIRA et al., 2018). SisICLF is a software suite that assists in the management, economic analysis, and planning of the forest component of integrated crop-livestock-forest (ICLF) systems with Pine, Eucalyptus, *Toona ciliata*, *Khaya ivorensis*, and *Tectona grandis*. In this paper, key features of SisICLF will be presented.

MATERIAL AND METHODS

To describe the software, an example of an ICLF system will be used. The example will consider an ICLF with 500 *Eucalyptus urograndis* (*E. urophylla* x *E. grandis*) hybrids, planted in triple rows, with 3 m between rows and 20 m between strip rows. The Site Index is 29.0 m. For this example, we will implement a mixed thinning at 7 years, with a systemic removal of 30% of trees in the system, followed by a selective removal to achieve a population of 150 trees. The final harvest will be at 12 years. To calculate the resulting production, we will use a diameter class interval of 2 cm, classifying the wood into the following two end products: sawlog (Length = 2.6m, Minimum diameter = 18.0

cm) and fuel (no restrictions). These represent the basic information that should be entered in the initial SisILCF data entry screen.

RESULTS AND DISCUSSIONS

Figure 1 shows how the data describing the ICLF system and thinning should be input. The user must choose one of the three forms of inventory available on the screen. The Site Index is always required. The option "Number of trees planted per hectare" assumes that the data provided corresponds to a recently planted forest, or one that has not yet experienced much growth. In the appropriate boxes, the user indicates the number of trees planted per hectare and the rate of survival in the first year. With the option "Number of trees per hectare at a defined age", the previous data input option is deactivated. The option "Trees per hectare and basal area or mean diameter at a defined age" is the most complete, resulting in a more precise and accurate simulation.

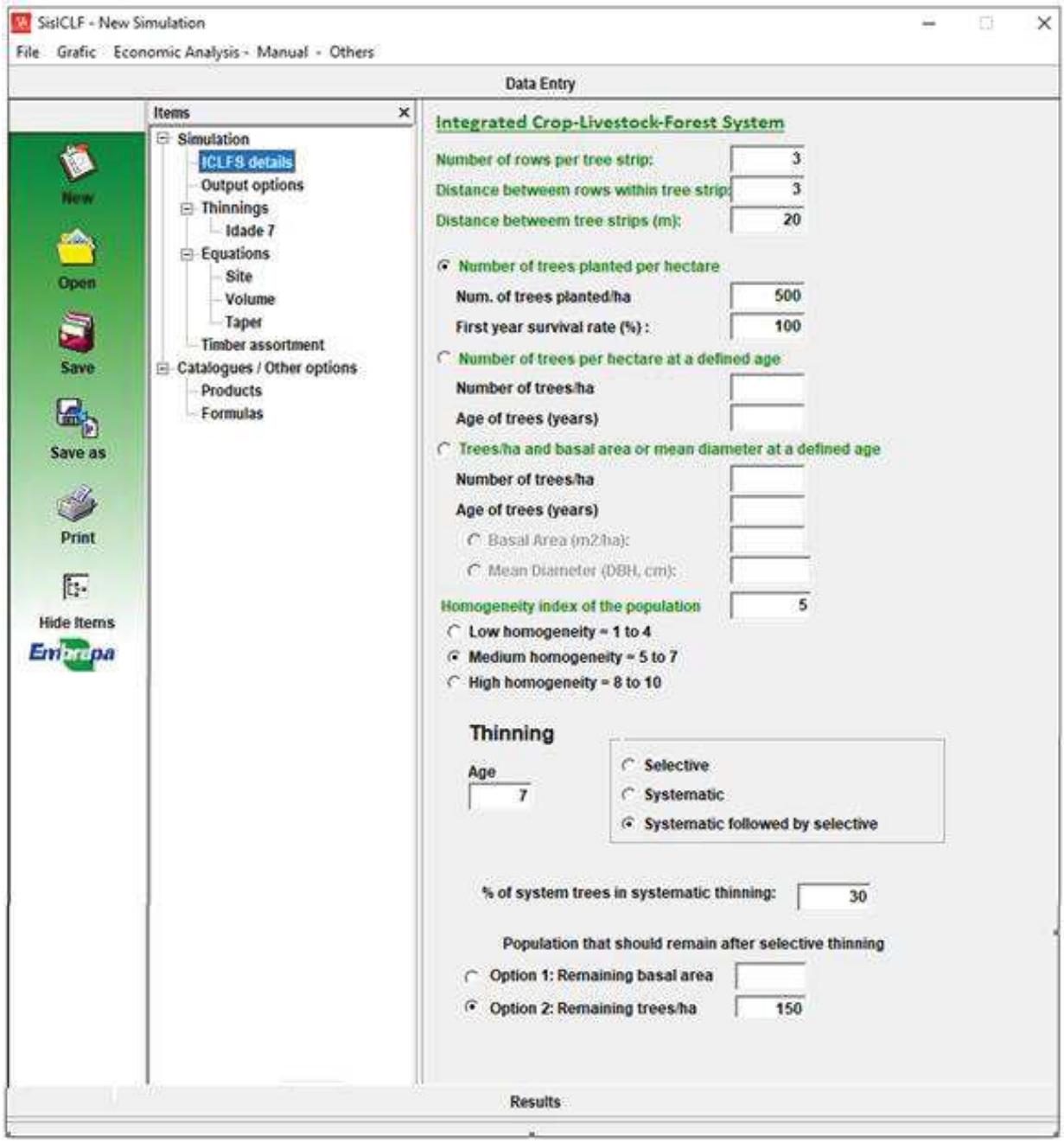
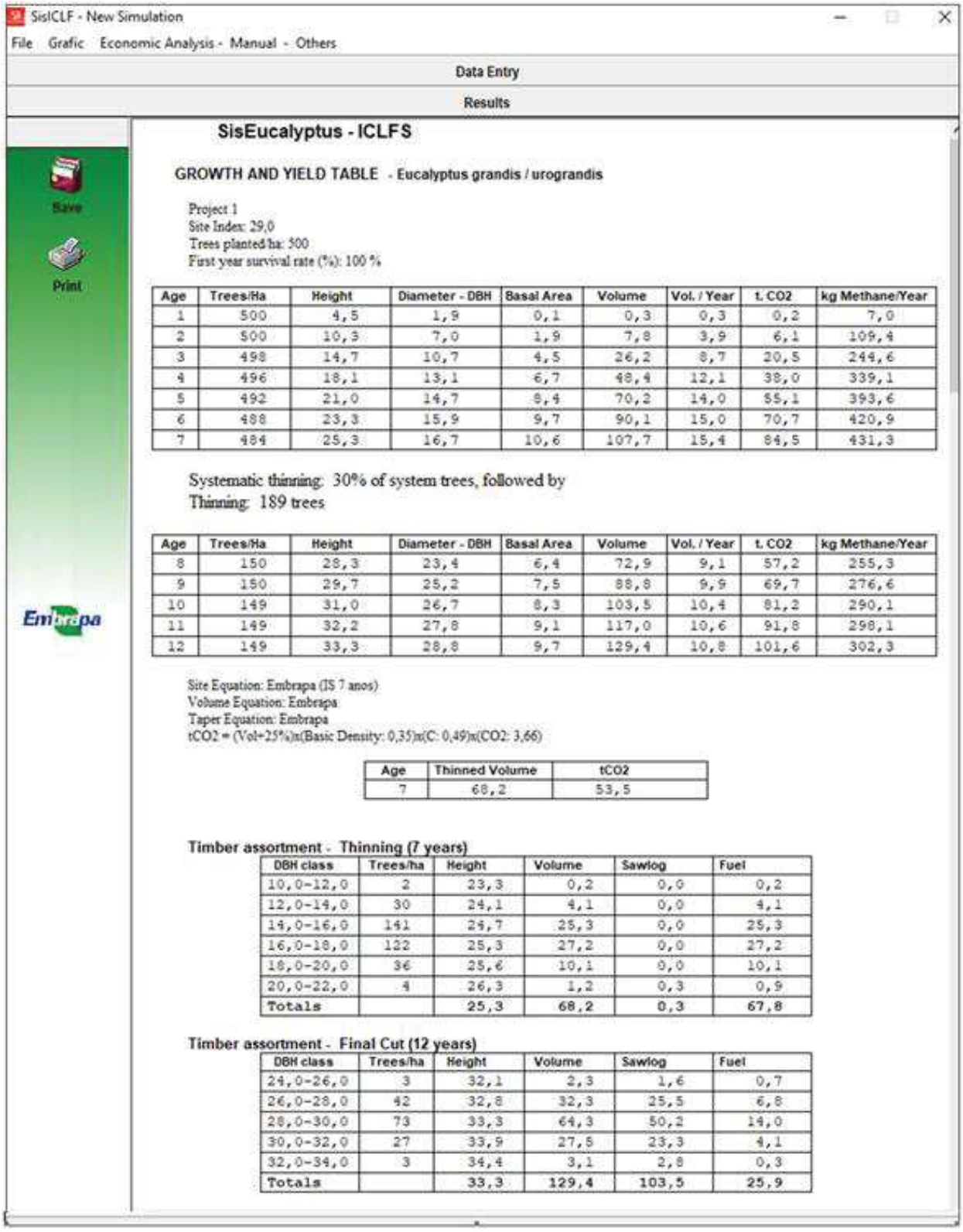


Figure 1. Simulation screen showing a summary of the information to be processed.

The parameter “Homogeneity index of the population”, which allows an input ranging from 1 to 10, can be based on statistical analyses (such as variance and coefficient of variance) or on empirical measurements. Clone plantations do not necessarily have a value of 10 because the parameter considers both genetic and site variability.

The growth and yield table and wood assortment tables by industrial use classes are shown in Figure 2.


SisICLF - New Simulation

File Grafic Economic Analysis - Manual - Others

Data Entry

Results

Save

Print

Embrapa

SisEucalyptus - ICLFS

GROWTH AND YIELD TABLE - Eucalyptus grandis / urograndis

Project 1
Site Index: 29,0
Trees planted/ha: 500
First year survival rate (%): 100 %

Age	Trees/Ha	Height	Diameter - DBH	Basal Area	Volume	Vol. / Year	t. CO2	kg Methane/Year
1	500	4,5	1,9	0,1	0,3	0,3	0,2	7,0
2	500	10,3	7,0	1,9	7,8	3,9	6,1	109,4
3	498	14,7	10,7	4,5	26,2	8,7	20,5	244,6
4	496	18,1	13,1	6,7	48,4	12,1	38,0	339,1
5	492	21,0	14,7	8,4	70,2	14,0	55,1	393,6
6	488	23,3	15,9	9,7	90,1	15,0	70,7	420,9
7	484	25,3	16,7	10,6	107,7	15,4	84,5	431,3

Systematic thinning: 30% of system trees, followed by
Thinning: 189 trees

Age	Trees/Ha	Height	Diameter - DBH	Basal Area	Volume	Vol. / Year	t. CO2	kg Methane/Year
8	150	28,3	23,4	6,4	72,9	9,1	57,2	255,3
9	150	29,7	25,2	7,5	88,8	9,9	69,7	276,6
10	149	31,0	26,7	8,3	103,5	10,4	81,2	290,1
11	149	32,2	27,8	9,1	117,0	10,6	91,8	298,1
12	149	33,3	28,8	9,7	129,4	10,8	101,6	302,3

Site Equation: Embrapa (IS 7 anos)
Volume Equation: Embrapa
Taper Equation: Embrapa
tCO2 = (Vol+25%)x(Basic Density: 0,35)x(C: 0,49)x(CO2: 3,66)

Age	Thinned Volume	tCO2
7	68,2	53,5

Timber assortment - Thinning (7 years)

DBH class	Trees/ha	Height	Volume	Sawlog	Fuel
10,0-12,0	2	23,3	0,2	0,0	0,2
12,0-14,0	30	24,1	4,1	0,0	4,1
14,0-16,0	141	24,7	25,3	0,0	25,3
16,0-18,0	122	25,3	27,2	0,0	27,2
18,0-20,0	36	25,6	10,1	0,0	10,1
20,0-22,0	4	26,3	1,2	0,3	0,9
Totals		**25,3**	**68,2**	**0,3**	**67,8**

Timber assortment - Final Cut (12 years)

DBH class	Trees/ha	Height	Volume	Sawlog	Fuel
24,0-26,0	3	32,1	2,3	1,6	0,7
26,0-28,0	42	32,8	32,3	25,5	6,8
28,0-30,0	73	33,3	64,3	50,2	14,0
30,0-32,0	27	33,9	27,5	23,3	4,1
32,0-34,0	3	34,4	3,1	2,8	0,3
Totals		**33,3**	**129,4**	**103,5**	**25,9**

Figure 2. The growth and yield table generated by the software.

The software supports decision making related to when, how, and how much to thin, and when to conduct the final harvest. Based on inventory data, the software allows the user to simulate all tree component management options in ICLFs, forecast present and future production, conduct economic analyses, and decide on the best alternatives to manage their plantation.

Thinning alows for a reduction in the number of trees per area, thus providing trees with more space to grow. One method of thinning involves the preservation of the best trees, eliminating those that are suppressed, bifurcated, or broken and those with symptoms of disease or extensive damage from pests. Well-planned and well-executed thinning increases the likelihood of obtaining a high-quality final product. It also increases the economic profitability of the population and allows the producer to receive some economic return before the final harvest. The methods that can be used for simulated thinning of a population include: **Systematic** – when trees are removed using a chosen, fixed regime, depending on the available stand. For example, the removal of an entire row of trees, with other rows of trees remaining intact; **Selective** – in this case, the smallest trees in the population are removed (low thinning). Both the diameter as well as the height can be used as a variable in choosing the trees for removal; **Mixed** – this method integrates both types described above first by conducting a systematic thinning and subsequently a selective thinning in the remaining tree rows.

CONCLUSIONS

SisILCF generates prognosis charts and graphs for growth and yield of trees, indicates how much wood will be produced at any age, tests any management regime that the user wishes to apply, and calculates the carbon (methane and CO_2 equivalent) stored by the trees. The program also generates wood assortment tables by industrial use class, such as laminate, sawlog, and fuel, according to log diameters and lengths identified by the user. SisILCF enables the simulation of different thinning regimes, generating an assortment table for each. The software is available for download on Embrapa Forestry's website (www.embrapa.br/florestas).

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