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Modeling and simulation of an improvement proposal through the method mechanized transplanting

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Abstract. Rice agriculture in Colombia has high costs and low profitability, compared to rice agriculture in leading countries that are supported in different ways by their governments worldwide. Part of these high costs is due to the deficient technification of the processes, the absence of standardized procedures and the farmers' lack of resources. This article develops modeling and simulation of the implementation of the indirect seeding method by mechanized transplanting; these results are obtained through the study and definition of technologies for the cultivation method, the description of the process, machinery, equipment, and inputs, which determined the necessary capacity of the production plant through modeling and simulation in software Flexsim. Rice cultivation is one of the main incomes of countries with high population density and poor economy, alternatives and improvement actions are of great importance for the growth of the sector. As a result, there is evidence of improved crop productivity, better water consumption efficiencies by physical analysis (comparison of traditional and technician water consumption) and the necessary capacity of a production plant from harvesting to final packaging.

1. Introduction

As the world population increases, the need for staple foods tends to rise, with rice being one of the most prominent for more than 95% of the population in developing countries, in turn, it also provides job opportunities to approximately 20 million farming households in the village [1]. Rice occupies the first place in demand, for which, the government supports through policies, both in aspects of cultivation, production, technological innovation, processing results and marketing policies [2]. One of the countries that has benefited in this agricultural sector is Indonesia, in this case, the strategy they have applied in narrow-land agriculture is to increase crop productivity by improving the genetic and production environment [3].

In Colombia, climate variability is considerable and affects the yield of basic crops and agricultural livelihoods [4], even so, the agricultural sector is present in the Colombian economy with 6.3%, considered among the seven crops with the highest economic development in the country, providing food security to the population [5]; for this reason, the government has promoted and supported the agricultural sector in economic, socio-cultural and innovation branches, for the evolution and development of production - quality, with the aim of ensuring the future food of the country, in turn, the improvement in the quality of life of farmers [6].

China, one of the world's leading rice producers, contributes about 28.1% of global rice production [7]. To promote sustainable rice production, in 2010, a new planting method called potholing mechanical transplanting (PSMT) was developed in China; focusing on advancing the proper planting of rice by more than 10 days, in addition, it protects the root system from damage suffered during mechanical transplanting and increases rice yield by at least 5% [8]. The mechanized transplanting planting system of rice cultivation brings excellent benefits to the agricultural sector, for example, in developing countries with small farms, low productivity and widespread poverty, mechanization is especially important to decrease the cost of production, improve farm efficiency, reduce drudgery, and improve crop productivity [9].

The department of Norte de Santander, Colombia, had 34.755 ha of rice sown between 2015 and 2016 [10], therefore, in this paper the proposal of improvement for rice agriculture by modeling and simulated in Norte de Santander, Colombia, is exposed; starting with the identification of the process, tools and inputs of the indirect sowing methodology by mechanized transplanting, to adapt them to the conventional sowing that is currently carried out, which consumes large amounts of water, the technification of this sowing reduces water consumption, allows control by maintaining the sowing in trays, reduces the use of insecticides, allows a homogeneous sowing in the mechanized transplanting. Subsequently, the analysis of the necessary capacity of the production plant is performed by means of Flexsim Software, being ideal for the simulation of logistic systems, helping users to establish and plan the simulation model of the process design [11], by modeling real periodic production systems and improvement scenarios [12]. With the conclusion that the mechanized model increases in this case by 35% the production of the company.

2. Methodology

Norte de Santander, Colombia was the location determined for the realization of the project, in a municipal company that has 7000 hectares of cultivation and production plant [13].

2.1. Rice cultivation

The increase in rice production can be developed by means of land concentration, high productivity of seeds, infrastructure, skilled labor, financial capital, institutional development, technology improvement and the development of the derived industry; in this case, technology improvement was chosen [14]; It is intended from the manual method, in which the seeds are thrown to the sowing area by the farmer to the mechanized sowing method.

The method of indirect sowing by mechanized transplanting was defined, being its principle the germination of seeds in a seedbed, weed-free site and under control. The seeds are sown in the pre-germinated seedbed after 24 hours in water and 24 hours in darkness. Once the seedbed has 25 to 30 days of germination or the seedlings have 5 to 7 leaves, the transplanting process proceeds with the following steps: pulling, transporting the seedlings to the defined site, and transplanting the seedling [15]. The advantages of this system are lower water consumption, less water and soil loss, less use of agrochemicals, less burning, lower production costs, and the use of biological controllers.

2.2. Capacity of the production plant

The current capacity of the production plant is generally greater than the cultivation capacity; it is this stage that generates bottlenecks in the processing of rice because it is not technician. The machinery in the production area has a utilization rate of less than 75%; the existing capacity is analyzed to determine if it is sufficient to implement the proposed mechanized cultivation, which is expected to increase by 35%.

2.3. Software

FlexSim Software was used to visualize the project in operation for cultivation and the capacity of the production plant, being the leading software in simulation of discrete, continuous, and mixed events. It is the tool available in the market for modeling, analyzing and visualizing processes. The software allows to simulate the behavior of the process flow with the load that is demanded to the process at a given time and thus conclude if it can operate as desired.

3. Results

3.1. Proposal for cultivation
The Dapog system was related in this project as it is an easy method to grow rice by means of seedling boxes with rice seeds to be planted in the transplanting machine [16]. Figure 1 shows the proposal, which consists of the pregerminator, tray filler and transplanting machine.

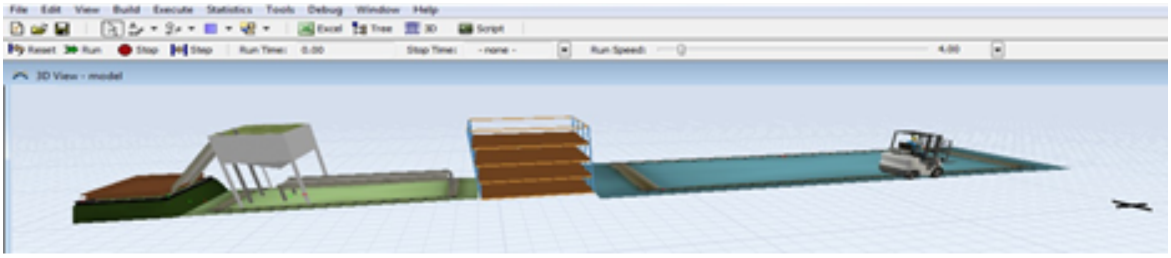

Figure 1. Proposal for cultivation.

3.2. Production process
A modeling as identical as possible to the actual production plant was made, inserting equipment and approximate images; subsequently, all the necessary components were added so that the process could operate, as illustrated in Figure 2, the static drying process, its maximum content in the drying batteries and the order of the material output.

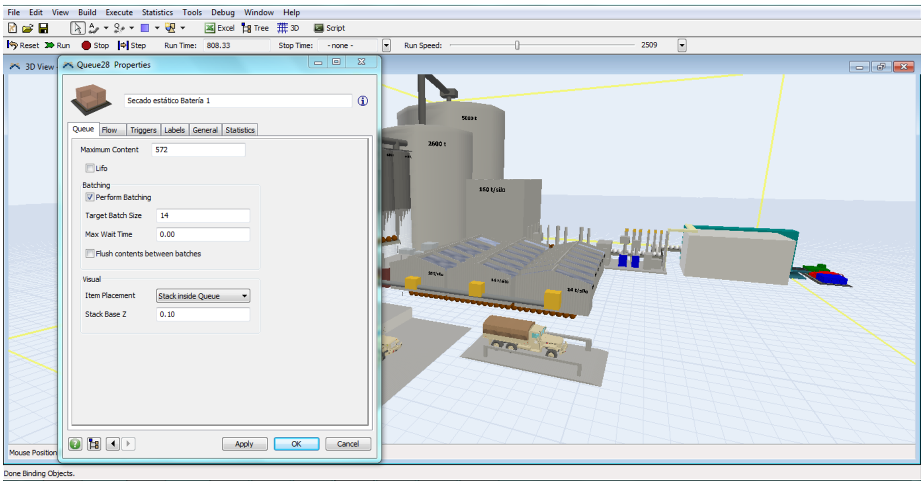

Figure 2. Queue variable for static drying.

The order in which the material is processed is set in Flow, as shown in Figure 3. In addition to the previous variables, the software allows the incorporation of all the others; triggers: color is changed when the product has one at the input and requires another color at the output; general: change physical characteristics of the machinery, such as color, size, and location, among others. An example of colors is shown in the packaging section, where a separator was used for the type of product according to the packaging, as shown in Figure 4.

To be able to observe part of the process, conveyor belts were placed and not piping, which is what is used in the plant. Each object has its own specific variables for its function, which in general are the same for all of them, some with, according to their function. For the Layout that allows to give curvature to a pipe, that is, it defines that it looks straight or curved, the image of a conveyor belt was captured, according to Figure 5, also for this object, for example, the Conveyor option is available in which the information about speed, content, among others, is placed, that is, all the real specifications to carry out the simulation.

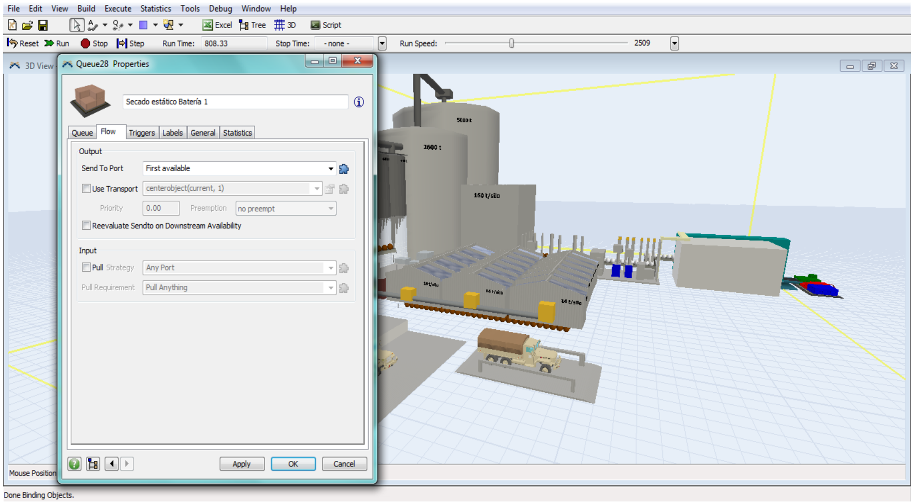

Figure 3. Material output.

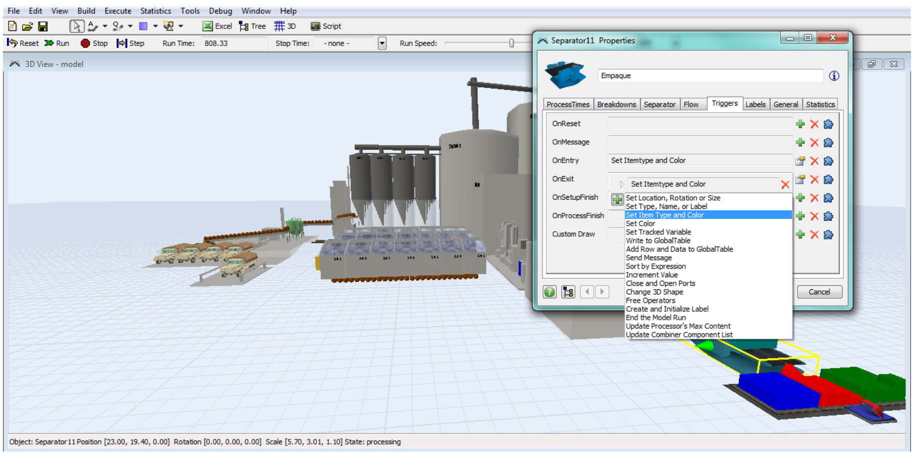

Figure 4. Color separator.

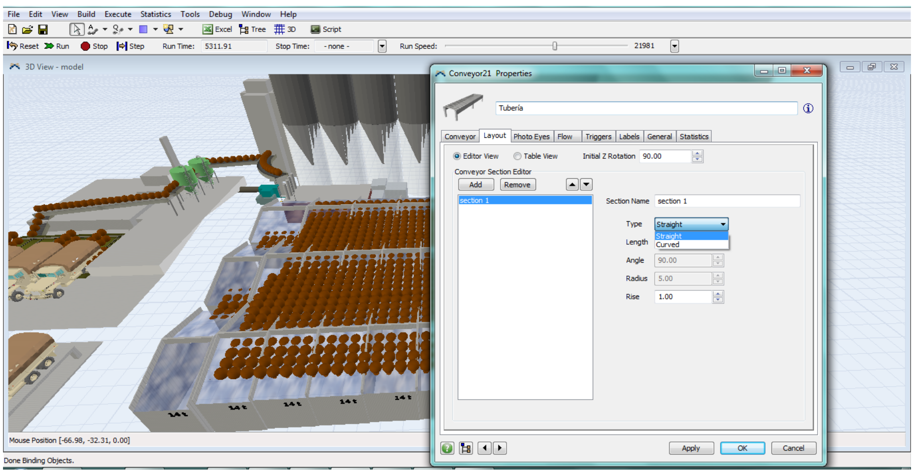

Figure 5. Curved or straight tube.

Figure 6 shows the amount of product entering and leaving, the amount leaving is lower, considering the moisture loss of the grain; it is highlighted that inaccurate moisture content measurements cause additional drying value and crop loss if paddy rice is harvested wetter than necessary [17].

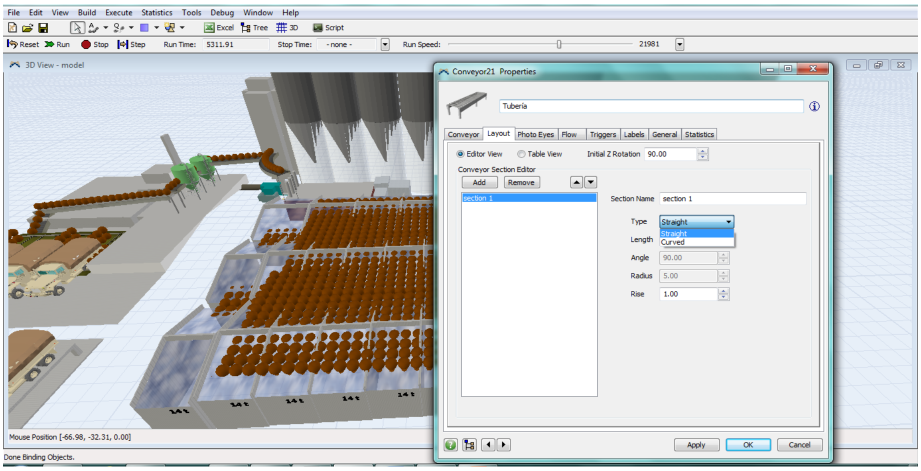

Figure 6. Input and output volume.

According to what has been mentioned, the information of the process was incorporated, and it was verified that the capacity of the production plant can satisfy the expected increase. This means that, in terms of productivity, the plant located in Norte de Santander, Colombia, is underutilized, i.e., with the projections of increased crop production with the proposed improvement method, it would have sufficient capacity to be able to process the increase in raw material that will arrive once the cultivation method is changed. In terms of the planting model selected as the appropriate alternative for increasing rice crop productivity, it was observed in the simulation that the time required for cultivation decreased and that with this method, more orderly plantations are obtained with greater possibility of control.

For any process, in this case rice cultivation, it is important to know how the system will behave at a global level, as shown in Figure 7, from cultivation, harvesting, preparation and packaging of the final product. With this type of simulation alternatives, planning and testing of variables and changes can be carried out, which will help to make decisions based on observations derived from a simulation and not just a trial and error, with the resulting cost reduction.

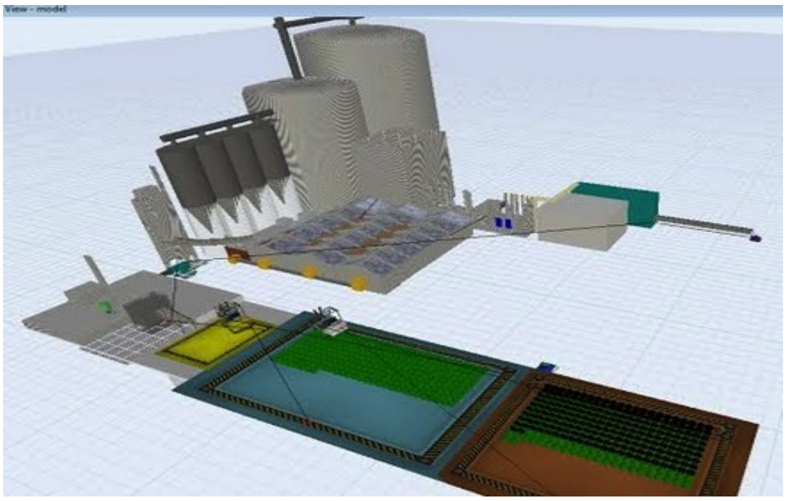

Figure 7. General simulation scheme.

4. Conclusions

Rice cultivation can be optimized from soil preparation, planting method, irrigation, fertilization, pest and disease control; changing the manual planting methodology for a mechanized methodology combined with the implementation of documented and standardized cultural practices, optimizing the use of resources and environmental impact, also increasing productivity per hectare cultivated, with high quality indexes; being these benefits obtained by the proposed methodology of indirect planting by mechanized transplanting. With the application of the proposed methodology, a decrease in water loss of 90% to 100% is obtained for rice cultivation, soil loss of 60%, water consumption of 61% per hectare per harvest and an increase in production of 35% per hectare planted. The change in planting methodology and its irrigation from daily to water storage in the trays, reduced, mainly by changing the hose, flow, and water pressure, using less personnel and cost. The significant increase in rice crop production is a latent need of the rice industry, considering the precariousness and different difficulties during its cultivation cycle until the final production process.

According to the technical study, the production plant for rice processing was designed for quantities much higher than what is currently processed, so the plant is being underutilized by an average of 75%, which is a waste of machinery and resources. According to the simulation carried out, it was found that the production plant can operate as desired without creating any bottleneck, i.e., the new load required for the process can be processed with a 35% increase in crop yield. It was thus determined that the crop is the bottleneck in the process and that the technification of this process allows benefits for the company in terms of cost reduction, reduction of downtime in production machinery, increase in production and increase in productivity, in addition to the benefits that occur in the crop at the level of workers by reducing the use of chemicals and at the same time improving the quality of the raw material. According to the above, this procedure can be implemented in different rice crops worldwide, mechanizing and standardizing conventional procedures; in this way, it supports food security, in addition to the positive economic and social impact for farmers.

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