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Working Efficiency of Machinery in Cotton Residues Collection

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Abstract: The use of crop residues as an alternative and renewable energy source requires the development of integrated systems for harvesting, collection and provision in order to run the operations efficiently and cost-effectively. The focus of the present study was to investigate the working efficiency of the machinery involved in the process of cotton crop residues collection. Using geographical positioning systems the operational data from 40 fields were selected. The analysis of the data has shown that the field efficiencies were 0.69, 0.68, and 0.61, for the operations of mowing, raking, and baling, respectively.
Key words: Machinery efficiency, biomass, bioenergy, cotton residues

INTRODUCTION

Due to the increase of the global energy demand that is expected, the supply of carbon dioxide will be increase (Grahn et al., 2007). The strong dependence of the mankind on the fossil fuels has as result environmental, financial and political concerns in the world (Cherubini et al., 2010). In addition, the fact that the prices of the fossil fuel are increasing day by day, this will be a main problem of the population in the developed and developing world.

Biomass has become an important renewable energy resource to produce energy with low greenhouse gas and low acid gas emissions (Li and Liu, 2000). The term "biomass" refers to: "all renewable organic matter including plant material, whether grown on land or water; animal products and manure; food processing and forestry by-products; and urban wastes" (Stout, 1984). Biomass resources that can produce energy are the cultivation of the bioenergy crops, the woody perennial and the collection of the crop residues (Lal, 2005).

Especially, the utilization of the crop residues as raw material can produce alternative energy with positive affects in the environmental changes due to the zero balance of the gas emissions and enhancing energy security. Crop residues are the remains in the field after the harvest. The use of crop residues as raw material for bio-energy production has the advantage that does not involved in the competition between crops for food and energy crops (Junginger et al., 2008).

In Greece, one of the common crops is the cotton production. The cotton is sowed in the mid April until the begging of the May and it is harvested in the mid October until the mid November. After the collection of the seed and the fiber the parts of the plant that remain in the field are the stalks and the roots (Gemtos and Tsiricoglou , 1999). The farmers use to incorporate the residues of the stalks in order to improve the nutrition conditions of the soil especially the organic matter. Only few farmers leave the stalks uncut and after that they sow the winter cereals (Gemtos et al., 1997). The use of the cotton stalks residues for energy is easy to handle. The seasonal availability of the biomass is October until November.

Collection system efficiency

The efficiency of the system of the collection depends on logistics system, the transportation of the stalk residue bales, the storage type etc. The logistics system involves a number of agricultural production related activities. Unfortunately, in agriculture, in general, there is only a sparse tradition for using formalised planning tools for logistics processes management. Farm managers both generate and execute any plan made, and their decision-making process associated with the planning remains very much implicit and internal (Sørensen and Bochtis, 2010).

The information on the performance of the machinery involved in the cotton collection chain is crucial for machinery management decisions. Machinery performance studies have traditionally required the use of stopwatches with observations recorded on a clipboard (Grisso et al., 2002). These field studies were tedious, time consuming, and generally, with low accuracy leading to rough statistics that could not applied in specialised cases. The introduction of satellite-based monitoring systems in agricultural machinery has made data collection easier, and combined with appropriate geographical information systems (GIS) provide the basis for an in-depth analysis on tasks and operations parts compose the whole chain.

Gemtos and Tsiricoglou (1999) investigated, among others, the availability potential of cotton residues in Greece, the physical properties of cotton residue, as well as energy and economical issues. They estimated the moisture content of cotton residue to be about 40% for the stalks and 60% for roots. For a safely collection and storage of cotton it must stay in the field to achieve the reduction in moisture to 20%. This period for this process is usually three weeks. The availability of the cotton residues was estimated around 60% of the total residue potential. The conclusions of the investigation were that the whole work can be fulfilled by the existing equipment (mowers, balers, etc.).

The energy that carried out was 37.028 MJ/ha (equivalent to 971 / Diesel, given the HHV of Diesel as 44.08 MJ/kg and Diesel density ≈ 0.85 kg/l), while the harvesting operation was showed to be energy effective by a net energy of 35.571 MJ/ha. The amount of biomass was estimated for 2007 kg/ha.

Rentizelas et al. (2009) studied the storage problem of the cotton residues. They studied the logistic costs in three different scenarios:

- The covered no drying storage option; this type of storage does not prevent biomass material loss and therefore, a 0.5% material loss/month rate has been assumed
- The scenario that the biomass is dried by hot air injection
- The ambient storage scenario which is the scenario with the highest material loss rate

The first two scenarios were compared with the third one in terms of purchasing and the loading process cost, the transportation cost, and the storage and handling process cost. They concluded that the most cost-effective storage solutions the third scenario which leads to significant cost reduction of the biomass supply chain which exceeds by far the additional cost imposed by material losses and increased handling cost that characterise the simpler storage solutions applied.

Tasiopoulos and Tolis (2003) investigated the logistic cost of the processes of the collection, distribution, and warehousing within the cotton residues supply chain, considering two transportation scenarios. In the first scenario the farmers are participated in collection and transportation, while in the second one the supplied companies use their own machinery to carry out residues collection and transportation. In relation to the storage, they investigated three scenarios, namely, the biomass is stored and dried in closed warehouses, the balling storage, the pelleting storage. They concluded that the most cost-effective transportation strategy is where farmers engaged in the logistic network, while, as far as it regards the storage method, the baling scenario seems to be cost-effective under the condition that the recovering stacking method should follow the FIFO (first in first out) discipline.

In this study, the practical conditions of the residue collection process are investigated, in terms of the efficiency that the related operations are carried out.

MATERIALS and METHOD

A machinery system involved in the collection of cotton residues was monitored. The monitored operations include cutting, raking, balling, and loading. The experiment took place in the region of

Thessaly, Greece, during November since cotton is a crop that is harvested in the October. In the specific region the residues are used in the cement industry for the combined production of heating and ash. The cement industry in the region has developed a network of contractors for the collection of the crop residues.

The first process that took place in the collection chain was cutting. The cutter's effective operation width was 2.10m. After the cutting process, the residues are spread in all over the field. In order to collect the residues in pills and make the balling process more easy and efficiency, it is used a rake. The rake that was used in the specific monitored operations was a chopper –type rake with effective operating width 2.8 m. The process is to collect the residue into windrows in order the balling process to be more efficiency. The residues can be collected in rectangles or in round bales. The machine that it used was a round baler creating bales of 1.5 m diameter. The loading process was consisted from two machines the loader which was a forklift and a transport wagon able to carry 22 bales. The whole residue collection process was carried out in one month time. The collection of the cotton residue took place from the beginning of November until the end of November.

The monitoring was carried out by a number of GPS receivers mounted on the involved machines providing all the spatial-temporal information necessary for the system's efficiency evaluation after the data analysis. The data were received with 0.5 Hz frequency. The operations were monitored in 40 geographically dispersed fields of sizes varying between 0.6 ha and 13.6 ha.

RESULTS

Figure 1 shows the cutting operation in field 6. Figures 1, 2, 3, and 4 present the GPS recordings for the operations of cutting, raking, balling, and loading, respectively, in field 6.

The turning time, the processing time, the pre-processing time and the delays were calculated for the mower and the rake. In the case of the baler, the bale time was also calculated. Figures 5, 6, 7, and 8 present the results of the average time of the turning time, the processing time, the pre-processing time, the delays and the balling time for the baler, of the cotton residue collection process.

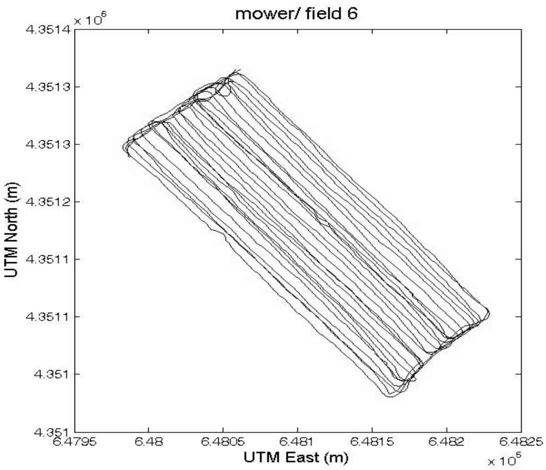

Figure 1. Mowing operation

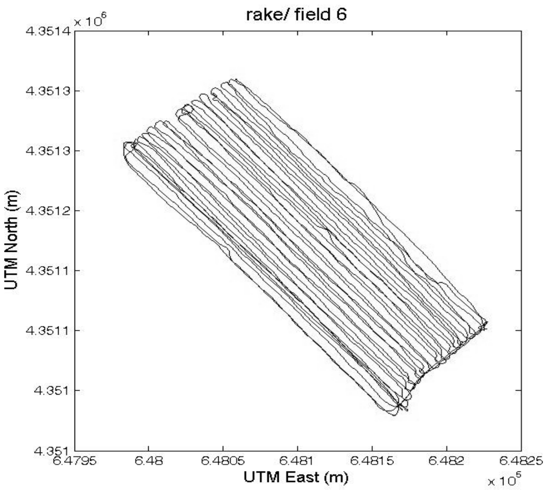

Figure 2. Raking operation

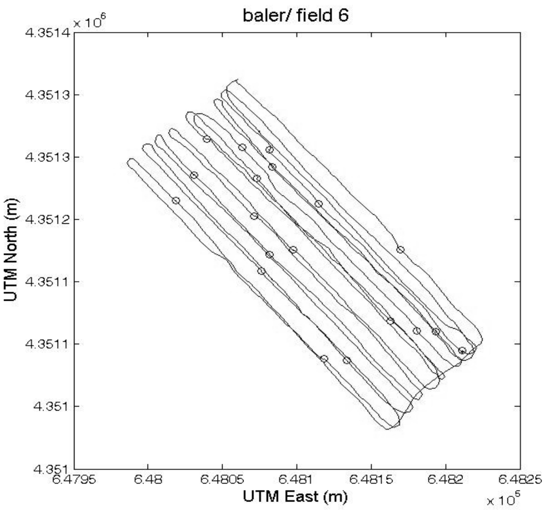

Figure 3. Balling operation

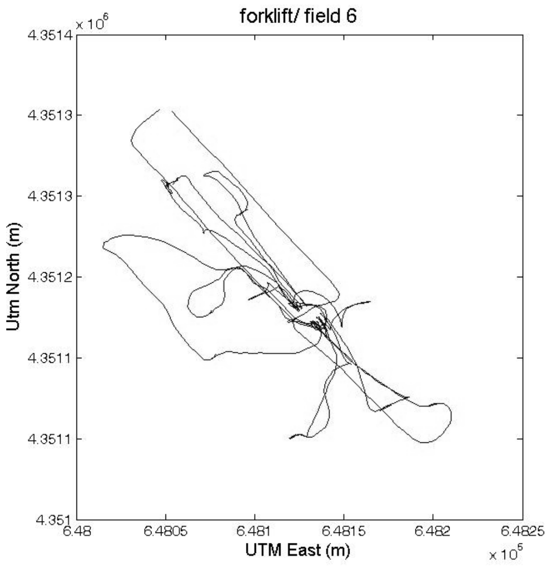

Figure 4. Loading operation (forklift)

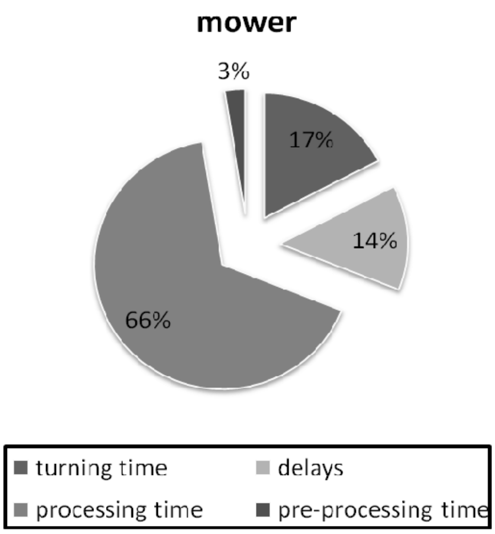

Figure 5. Mower time distribution

As it can be seen in figure 5 the average turning time for the mower was 17% of the average total time and the average time of the delays in the field was 14%. The 66% of the total time was the processing time. The processing time refers to the efficient time of the cutting. It is the time that the mower was moving in the field and cutting the cotton residues into rays. The 3% of the total operational time is the pre-processing time. The pre-processing time refers to case where in some fields, especially in the non-rectangular fields, the mower had to work in the headland area and then in the main field area.

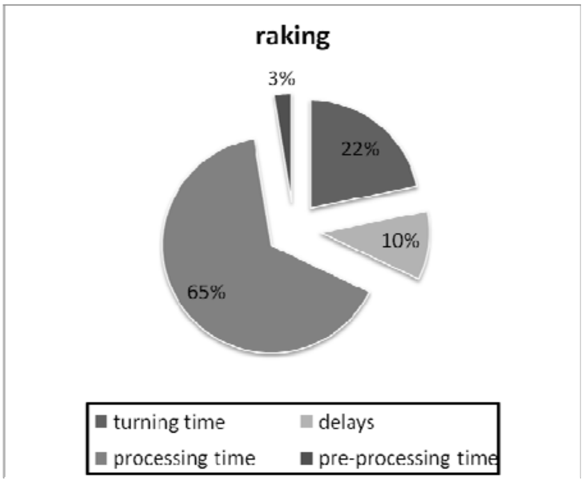

Figure 6. Rake time distribution

The average processing time for the rake was about 65% of the total time. The pre-processing time was about 3% of the total time. The pre-processing time is the time that the rake needs to take the right position in order to start the process. The average delay time was about 10% of the total time. The average turning time is 22% of the total time.

For the Baler the average delay time was the 17% of the total time. The turning time was 12% and the pre-processing time was the 2% of the total time. The processing time was 58% of the total time. The processing time of the baler is the time that the baler is moving on the rays in the field. The balling time is the time that the baler needs to create and to placed the bale in the field. During the balling time the baler is not moving. The balling time was the 11% of the total time.

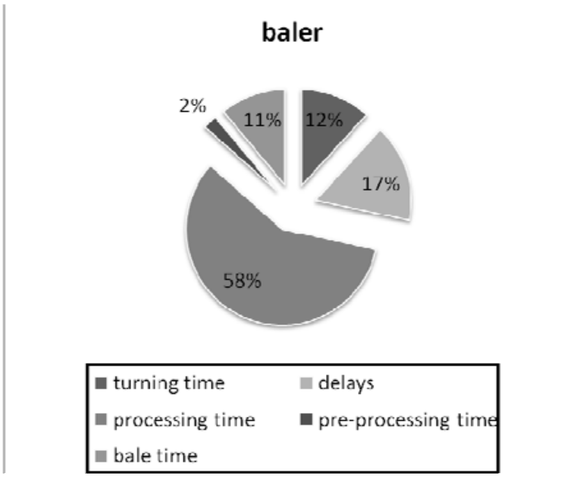

Figure 7. Bale time distribution

The balling time, the processing time and the pre-processing time consist the effiecient time of the baler. The efficient time is the time of the main work of the baler. It is the time that the baler collects the residues, creates the bale and places the bale on the field. The efficient time of the baler was the 71% of the total working time.

CONCLUSIONS

Cotton residues may present an alternative resource for environmentally-friendly energy production in the region of Thessaly, Greece. The utilisation of the cotton residues for energy it is depended on the way and the cost of collection.

The monitoring and time analysis of the machinery performance in the collection chain for cotton residues is the first step for the research in the implementation of industrialised methods on the operational management of the whole collection and distribution processes of this renewable resource of energy.

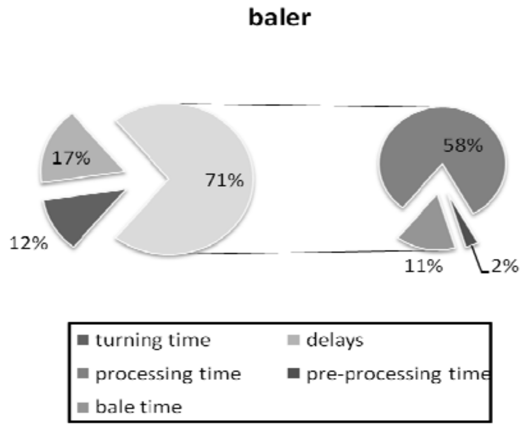

Figure 8. Baler efficient time

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