

Innovative cotton management system: From field to cotton gin*

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Abstract

This paper presents an innovative cotton management system designed to enhance the marketability of cotton in Greece by preventing the mixing of different varieties during harvesting and ginning. The system involves grouping fields by cotton variety, using baling cotton pickers, and assigning each bale a unique identity with information on variety, weight, and moisture content. The study explores various routing algorithms to optimize the transportation of cotton, including the Traveling Salesman Problem (TSP) and its variations, ensuring efficient and cost-effective logistics. The proposed system provides cotton producers and cooperatives with the tools to manage their production and strengthen their bargaining power independently, marking a significant advancement in cotton management in Greece.

Keywords

Cotton, harvest, management system, standardization, transportation

1. Introduction

Cotton cultivation is one of the primary crops in Greece, occupying 45-50% of the country's irrigated arable land in recent years [1]. This reflects its competitive edge over other irrigated crops [2]. However, the increasing diversity of growing cotton varieties has led to product uniformity challenges [3]. During harvesting and ginning, different varieties often mix, complicating standardization. This variability hampers Greek cotton's competitiveness in the market, as bales frequently consist of mixed varieties and qualities, making it difficult to assign a distinct identity or fair compensation to producers. Another significant issue is that current harvesting and management practices do not allow for payment based on the quality of the final product. In Greece, cotton is typically harvested using pickers equipped with storage bins, which often leads to the blending of cotton from various plots before reaching the gins. This mixing of different varieties with varying qualities diminishes the final product's value and weakens producers' bargaining power or cooperative efforts to secure better prices.

This work seeks to present a new management system to tackle these issues. The proposed methodology involves initially grouping plots with the same cotton variety for harvesting with a baling cotton picker. Each bale will receive a unique identity, with the system documenting relevant information such as variety, weight, drop-off location, and moisture content. This data will be entered into an information system that utilizes specialized algorithms to optimize the grouping and scheduling of bales with similar quality characteristics for transport to the nearest gins. Using the system (an individual farmer or a cooperative scheme) will be able to independently strategize the marketing of their production, thereby strengthening their bargaining power to their advantage.

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The proposed system is being implemented for the first time in Greece, as it is the product of original research. Its novelty lies primarily in the different management philosophy of the harvested product and the use of specialized algorithms to optimize usage and standardize the product. For the proposed system, each bale of packaged cotton that comes out of the cotton picker has an identity and is accompanied by all the necessary identification information (weight, moisture content, variety, etc.). This system is entirely different from the conventional way of collecting cotton, where cotton of different varieties, different quality characteristics, and from different plots is mixed in the collection basket of the cotton picker or the transport platforms to the cotton gin.

2. Initial Data Collection

The first stage of the system is the collection of all agronomic and geomorphological data initially related to the harvest area. This data includes all the fields of the area in which cotton with the same variety is grown, the boundaries of the fields, their coordinates, the distance of each field from the nearest gin and the mapping of the existing road network through which the cotton bales will be transported in the gins (Figure 1).

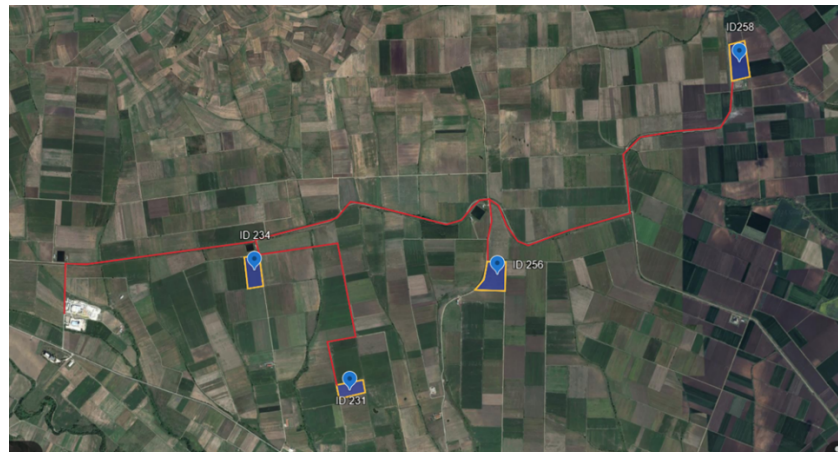


Figure 1: Mapping of indicative cotton fields and the road network from the fields to the gin.

2.1. Routing of the cotton harvesters and the trucks transporting the packed bales of cotton from the loading points to the gins

It is known that the cost of transporting the harvested product from the field to the sorting and standardization points can significantly affect the price of the final product and the reduction of the time of harvesting and transporting the product to the final collection points. This means that poor planning in the part of loading the product from the field to the gin most often creates problems both in the smooth supply of product to the gins and in feeding them with cotton of different varieties. Thus, the cotton platforms will have to operate for a longer time, often making more routes than they could ideally do. As a result, the cost of the companies that have undertaken this project increases significantly, while this cost increase is transferred to the final product.

For all the above reasons, it is obvious that both field cotton bale loaders and the trucks transporting the cotton from the field to the gin should carefully choose the route they should follow in order to reduce unnecessary trips. The main objective is for each truck or cotton bale loader to cover the target area in a way that saves time and cost, consuming as little fuel as possible while completing its mission. This is one of the reasons why the routing of cotton trucks from the field to the gin needs special study in recent years. The main approach to studying delivery truck routing is the Traveling Salesman Problem (TSP). This problem aims to calculate the optimal route by allowing the in-field cotton bale loaders to visit each point of interest in the field exactly once and return to its original location. Consequently, the in-field cotton bale loader is considered “the seller” and the

“visited cities” are the points in the field from which it will load cotton bales after being prompted by the management system. In the case of a truck with limited capacity that must visit specific areas, then the TSP problem is described as a Vehicle Routing Problem (VRP), or vehicle scheduling, as it has been applied to agricultural vehicles on the ground, both conventional and autonomous, as well as part of their high level of control.

TSP is a well-known combinatorial optimization problem which is classified as a non-deterministic polynomial time (NP) problem. This means that by increasing the number of points to be reached (fields with harvested bales of cotton or cotton bales in the same field), the execution time of any applied algorithm increases as a high-order polynomial. In these cases, the computations of optimal solutions require significant computational effort, even for 10 points. Figure 2 below illustrates a typical example graph of a TSP solution involving routing between 24 nodes.

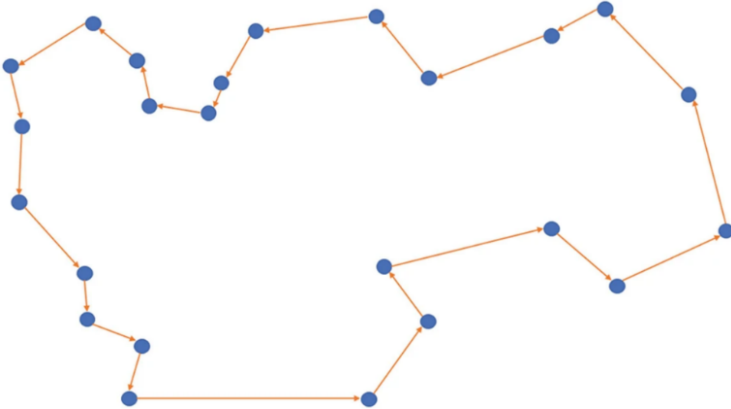


Figure 2: Solution to a 24-node (access point) TSP instance.

TSP is usually modelled as a weighted graph [4]. In graph theory, a graph is defined as a diagram consisting of points (nodes) and lines connecting pairs of points [5]. A typical graph consisting of four nodes is depicted in Figure 3. Specifically, approach points are expressed as the graph nodes (or vertices), graph edges denote the paths between the approach points, and the distance of the paths is represented by the weight of edges. This graph is described as undirected since the distance between all pairs of nodes is the same in both directions. In this case, this type of problem is referred to as a symmetric TSP. The cost of this graph is the distance travelled through the nodes of the graph. This problem is solved by finding the shortest path that starts and ends at the same vertex and visits each vertex exactly once.

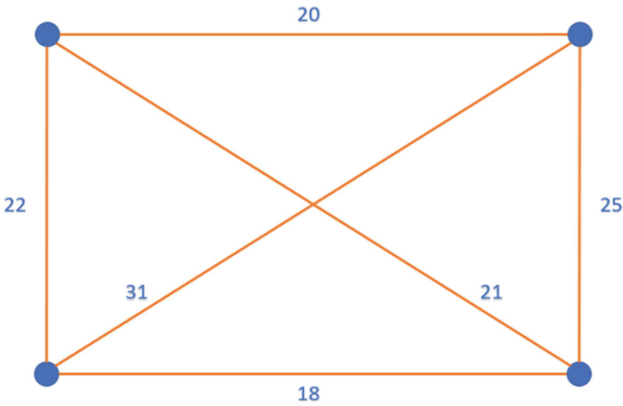


Figure 3: Standard four-node graph.

3. Algorithms for Solving the TSP

To solve routing problems characterized as TSP, the following two groups of algorithms are mainly used:

- Algorithms for exact solutions: Approaches of this type guarantee optimal solutions. However, they only work fast for graphs with a relatively small number of nodes.
- Algorithms for sub-optimal solutions: These approaches produce optimal or near-optimal solutions in reasonable computational times, even for a large number of nodes.

In some TSP cases with several million nodes, the algorithms can lead to very satisfactory near-optimal solutions [6]. Figure 4 presents the approaches to solving the TSP discussed.

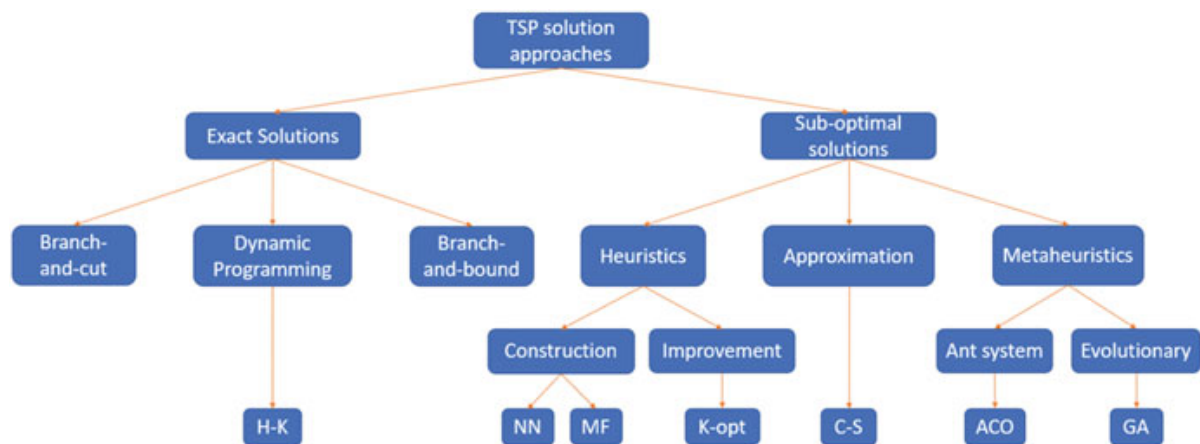


Figure 4: Different approaches to solving TSP cases.

4. Routing Tests of the Cotton Bale Loading Machine within the Field in a Simulated Environment

This section presents some routing scenarios of the cotton bale loading machine within the field (points approach). The performance of these approaches is tested under different conditions. Specifically, two fields of different geometry were used. The characteristics of these fields are shown in Table 1 below. The area of each field, as well as the number of positions where the cotton bales are located that need to be loaded in each case are different.

Table 1

Field characteristics

Field	Number of Positions (bales)	Field Area (ha)
1	50	7,52
2	100	9,5

The following algorithms were used for routing:

- Single TSP (sTSP): A single version of the problem where a single vehicle must visit all positions and return to its starting position.
- Multiple TSP (mTSP) (without fixed depot): Multiple versions of the problem where many vehicles must visit all positions without having a predefined depot.

Multiple TSP, single (fixed) depot (mTSPsD): Multiple versions of the problem, multiple fixed start/end points.

4.1. Single TSP (sTSP)

As previously mentioned, the route of the loading machine starts from the starting position. Then, the machine approaches the nearest point to the starting position. This process is repeated until all points are approached exactly once, and the machine returns to the starting point.

This approach creates routes with some suboptimal movements, as depicted in Figure 5, which shows the loading machine routes generated by the NN algorithm for fields 1 and 2 with 50 and 100 positions, respectively. Overall, this algorithm produces fairly good results despite its simplicity. The red points indicate the start (S) and end (E) of each route.

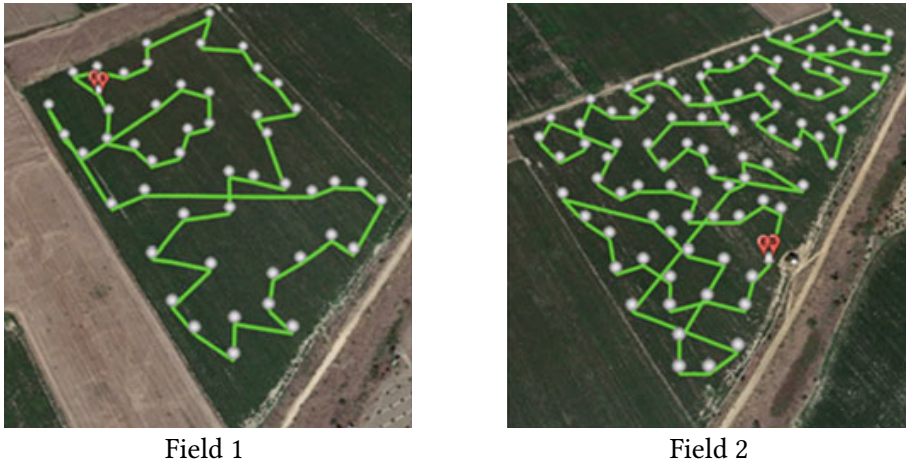


Figure 5: Routes of the cotton bale loading machine in the two fields obtained with a single TSP (sTSP). Red markings indicate the start/end point of each route.

4.2. Multiple TSP (mTSP)

There is a significant possibility that a loading machine may not complete the entire route due to some limitations. Therefore, the overall route can be divided into smaller routes with fewer visit points. This approach was implemented using a variation of the previous algorithm, which uses the number of loading machines as an input parameter. The near-optimal routes created for the three field cases described above are shown in Figure 6. The results for the first field correspond to smaller routes compared to the sTSP algorithm. Specifically, the distances covered using the mTSP algorithm were approximately 4.8% shorter than those using sTSP for field 1. Additionally, the computation time for implementing the mTSP algorithm was almost seven times longer for field 1. Conversely, for field 2, the mTSP algorithm resulted in 25.6% longer distance and six times increased computation time.



Field 1



Field 2

Figure 6: Routes generated by multiple TSP (mTSP). Each colored line represents the route of each loading machine, and red markings indicate the start/end point of each route.

4.3. Multiple TSP, Single (Fixed) Depots (mTSPsD)

An extension of the previous algorithm is the use of a predefined depot for all loading machines. This technique appears suitable for tasks where only one loading machine is used. Additionally, the route of each loading machine is limited to visiting a minimum number of points to balance the workload during their missions. The generated routes are presented in Figure 7. The computation times are approximately equal to those of the previous approach for all fields. As a result, these times are somewhat longer due to the additional parameters that were introduced. The covered distances were about 11.9% greater for Field 1, while the distance for Field 2 was 13.1% shorter compared to the mTSP algorithm.



Field 1



Field 2

Figure 7: Routes generated by multiple TSPs, Single (fixed) Depot (mTSPsD). Each colored line represents the route of each loading machine and the red marking indicates the predetermined depot of each route.

5. Conclusions

The proposed cotton management system addresses key challenges in Greek cotton production by preventing the mixing of different varieties during harvesting and ginning. By assigning unique identities to each bale and optimizing transportation through advanced algorithms, the system enhances product standardization and quality. This approach not only improves supply chain efficiency but also empowers farmers to market their cotton based on quality, increasing their market

power and profitability. The system represents a significant advancement in cotton management, offering a scalable solution to boost competitiveness and sustainability in the industry.

Acknowledgements

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Declaration on Generative AI

The author(s) have not employed any Generative AI tools.

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