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A Decision Support System for Planning Agricultural Mechanization Centers

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ABSTRACT

A decision support system was developed and evaluated for planning agricultural mechanization centers based on MS Access Database using Visual Basic 6.0 package. Three modules: a) mechanization center requirements, b) farmer revenue and c) investor revenue were developed to determine the following output parameters: a) the required numbers and types of machines, b) the rent rate of various mechanized operations, c) the internal rate of return, d) the period of the invested capital return, and e) the net margin. The system was evaluated under three different service areas and three mechanization levels. The results show its influence on crop yields and revenues within actual crop rotation. The system could be used as a good indicator for helping farmers and investors to make appropriate decisions, under certain conditions, for establishing the proper farm mechanization centers.

1. INTRODUCTION

Agricultural mechanization stations play an essential role for developing agricultural production, because the agricultural machines represent the major capital input for most crop production systems. Therefore, establishment of an agricultural mechanization station is a highly complex problem. It requires careful determination and is deeply affected by many critical factors. These factors include weather uncertainties, timeliness and cost of operations; soil type and conditions; type of crop and crop rotations; labor and capital; and

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management practices. Thus, the decision-makers must have the necessary information and knowledge that help them to make sound management decisions.

Decision support systems are an emerging area of research. They combine database management systems and the branch of artificial intelligence known as knowledge representation. A decision support system should be able to provide appropriate information to decision makers in order for them to operate from a wider knowledge base than they do at present.

The transfer of knowledge from consultants and scientists to agricultural investors, extension workers and farmers represents a bottleneck for the development of agriculture on the national level (Rafea et al., 1993). Therefore, there is a need for high technology methods to transfer the knowledge of experts in certain domain to the general public of farmers or investors. Expert systems are considered as one of the important methods to transfer the knowledge of experts to policy makers and also support them to make appropriate decisions.

There are three levels of decision-making in business. These levels are operational, tactical and strategic. Operational decisions are based on maintaining records and organizing the day to day activities of work flow, tactical decisions address issues concerned with controlling the flow of work and are based on comparing results from operational decisions in the hope of improving work flow in the future and strategic decision-making on the other hand involve in long term planning for the future of the enterprise and may involve in purchasing of capital items (Leigh and Doherty, 1986; and Olson and Courtney, 1992).

The methodology of building an expert system is divided into two main parts. These were the knowledge engineering and software engineering. The two parts of the methodology are interacting through a spiral model (Blair, 1994; Rafea, et al.1993, 1994 and Abdelhamid, et al, 1997).

Sing and Colvin, 1991, designed and developed a decision support system for soil tilth assessment (DSSSTA) to calculate a numerical tilth index. It also estimates crop yield, reports tilth status of soil, and suggests possible measures for maintaining/improving the tilth and crop yield.

Farm smart 2000 was designed as a decision support system for managing crop production on the Western Canadian Prairies (Murray, 1998). The system provides support for most management aspects of crop production including variety selection, machinery selection, planting, crop rotations, fertility, all facts of weed management, disease management, residue management, harvesting, soil conservation, and economics, for the crops of wheat, canola, barley, peas, and flax.

In Egypt, several expert systems have been built up using the developed methodology by the researchers at the Central Laboratory for Agricultural Expert Systems (CLAES). These were the expert system for cucumber (Rafea et al., 1995), tomato (Shishtawi et al., 1995), orange (Salah et al., 1993), and lime (Mahmoud and Rafea 1997), and one expert system for wheat (Kamel et al., 1995) has been built using the Generic Task (GT) Methodology. Each expert system consists of a set of subsystems covering different areas of crop management including variety selection, planting, irrigation, fertilization, pest control and others. The impact of using these expert systems has been examined.

Awady, et al, 1997, developed a computer program (FARMEC) for selection of appropriate equipment for various farm operations and conditions through expert system files. The main field –operations studied files were plowing, seeding, spraying, and harvesting.

The overall goal of this paper was to develop an expert system to support the decision-maker in establishing an agricultural mechanization station in a certain area. The specific objectives were studying the effect of mechanization levels and the effect of changing the service area on the machine requirements, cost, and net income of the farmer and the investor.

2. MODEL DEVELOPMENT

The model includes three modules as shown in figure (1).

2.1. Mechanization Unit Requirements Module

The main goal of this module is to determine the required number of machines to cover the needs of mechanization operations in a certain district or service area according to the level of mechanization desired by the investor or farmer.

According to the problem statement, each machine is used for accomplishing a certain number of operations that have to be done within a limited time interval, this interval is determined according to the currently cultivated crop, and the crop to be cultivated at the next cycle. This means that a machine could be needed for doing different operations for different plantations at the same time, while, it could be idle at other times as well.

In order to calculate the number of machines required to cover the needs of mechanization operations and still keeping machine idle time to the lowest level, we need to determine the time interval at which the largest number of machines of a certain type are needed, which we refer to by "critical interval".

The proposed algorithm determines the critical interval for each type of machines and accordingly determines the number of required machines. This module consists of input data, calculation of variables and output data.

2.1.1. Input Data

- The machines for each operation.
- Starting and ending dates of each operation.

These inputs are obtained from the database by using the machine code, which is an output of the "mechanization unit requirements" function, as a key.

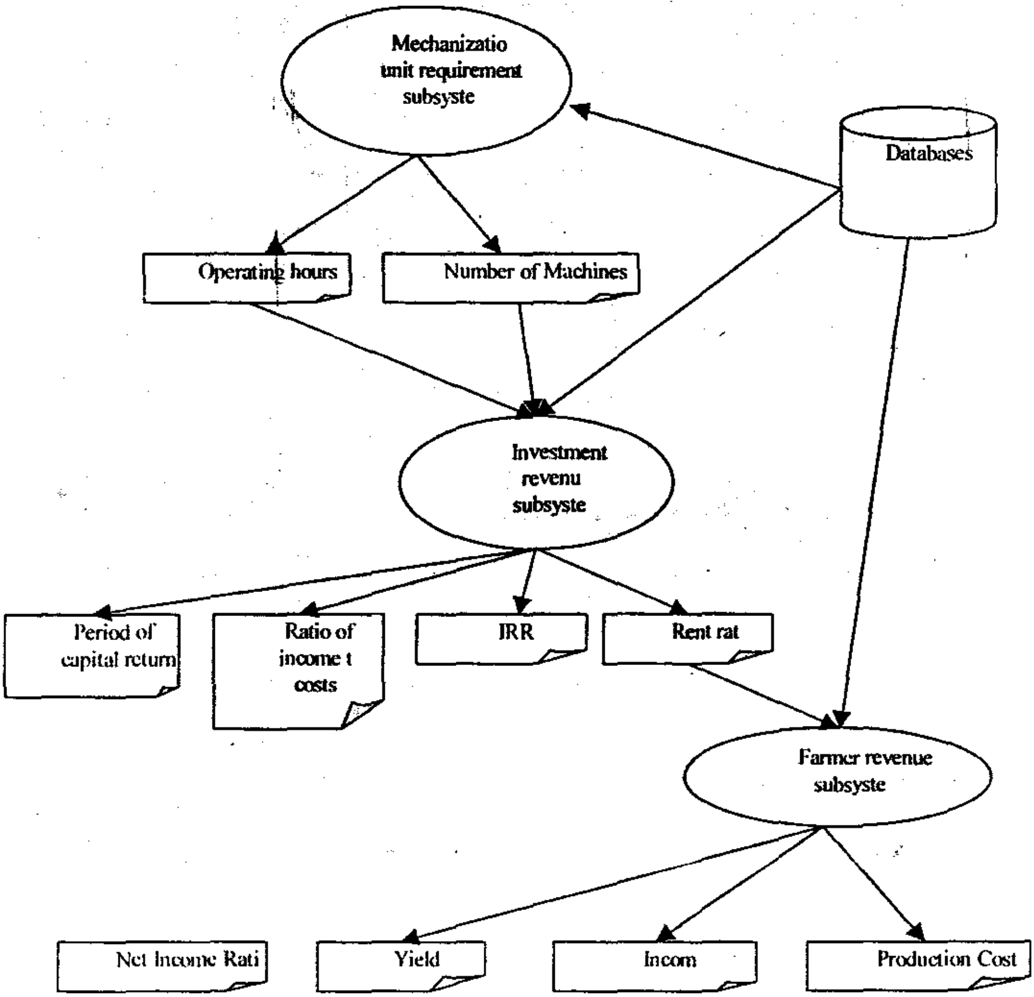


Figure (1): Overall structure of the proposed decision support system.

2.1.2. Calculation of Variables

The variables of the module were computed as the following:

- Convert starting and ending dates of each operation using an array of events signifying either the beginning of an operation or the end of an operation.
- Sort events chronologically.
- Generate intervals: intervals are generated from each two successive events. i.e. interval I generated from events (e) and events (e+1) if we have a list of events in the form [e,e+1,e+2,.,e+n] the intervals are generated as follows: {[e,e+1],[e+1,e+2], [e+2,e+3],□..., [e+n-1,e+n]}.

2.1.3. Output Data

- Maximum number of machines.
- Number of machines needed

2.2. Investment Revenue module

Investment revenue module calculates the rent of each machine, the Internal Return Rate (IRR), the margin to the costs, and the period of the capital return. This module consists of input data, calculation of variables and output data.

2.2.1. Input Data

- Number of machines needed.
- Machine name.
- Machine power.
- Machine price.
- Number of labors.
- Live time in hours.
- Fuel consumption.

These inputs are obtained from the database by using the machine code. which is an output of the "Calculation of rent" function.

2.2.2. Calculation of Variables

The variables of the module were computed as the following:

- Depreciation: = 0.9 * Machine price / Live time in hours L.E/hour

- Taxes & Insurance: = Machine price * X_1 L.E

- Interest $= 1.1 \frac{\text{Machine price}}{\text{Annual operating houers}} * \frac{\text{Interest } \% X_2}{2}$ L.E/h

- Total fixed cost: = (depreciation + interest) +(taxes + insurance) / working hours per year L.E/h

- Maintenance & repair: = depreciation * X_3 L.E/h

- Fuel cost:= machine power * specific fuel consumption* fuel price* 0.6 LE/h

- Lubricant cost: = fuel cost * 0.3 L.E/h

- Labors wages: = number of labors * hourly labor wage L.E/h

- Total Variable cost: = maintenance & repair + lubricant cost + fuel cost + labor wages L.E/h

- Total cost: = total fixed cost + total Variable cost L.E/h

- Administrative expensive: = total cost * X_4 L.E/h

- Renting cost/Hour: = (total cost + administrative expenses) * (1+ profit percentage X_5) L.E/h

Where: X_1 X_2 X_3 X_4 *and* X_5 were assumed to be 0.015, 11%, 0.6, 0.7, and 0.2 respectively. These figures are obtained from literature and out of experience.

2.2.3. Output Data

- The rent of each mechanized operation

- The Internal Rate of Return (IRR) as an economical parameter to evaluate the feasibility of establishing the center. IRR is defined as that interest rate which will provide for equalization of total costs to total benefits.

- The gross margin.
- The period of the capital refunding.
- Types and optimal number of machines.

2.3. Farmer Revenue Module

The objective of this Module is to determine the effect of using farm mechanization on the farmer income. This module consists of input data, calculation of variables and output data.

2.3.1. Input Data

- Rent of each machine.
- Machines required for each operation.
- Cost of each operation.
- Cost of production requirements (seeds, fertilizers, and pesticides)
- Cost of crop cultivation and irrigation.
- Crop production.
- Crop price.

These inputs are obtained from the database by using machine codes, and crop code.

2.3.2. Calculation of Variables

This Module includes two components namely determining production cost and net income.

- Computing production cost

This function determines the total production cost for certain crops. It computes the cost of each operation, production requirements (seeds, fertilizers, and pesticides), crop cultivating and irrigation.

- Computing net margin.

This function determines the net income for certain crops according to the difference between the total production cost and crop production price.

2.3.3. Output Data

Net margin

3. APPLICATION OF THE DECISION SUPPORT SYSTE -A CASE STUDY

3.1. Investor Revenue

The decision support program was run to study the effect of changing the size of cropping area (2000, 3000, and 4000 feddan) and mechanization levels (level No.1 seedbed preparation, level No.2 seedbed preparation + planting, and level No.3 seedbed preparation + planting + harvesting) on the required numbers and types of machines, the rent rate of various mechanized operations, the internal rate of return, and the period of the invested capital return.

3.1.1. Effect of the size of cropping area on the number of tractors and machines required for mechanization level No.1.

Data in Table (1) represents the current and required numbers of tractors and machines for mechanization level No.1 under different sizes of cropping. It shows that the current and required number of tractors and machines increased with an increase in the cropping area. The required number of 65 HP (48.5 kW) tractors increased by 33% and 77% as the cropping area increased from 2000 to 3000 and from 2000 to 4000 feddans, respectively. Also, the required number of 90 HP (67 kW) tractors increased by 40% and 120% as the cropping area increased from 2000 to 3000 and from 2000 to 4000 feddans, respectively.

Similar trends of the current and required numbers of other machines were obtained as 65 HP (48.5 kW) tractor except for the following differences:

- There was no change in the current number of laser leveller units at various levels of cropping area.
- There was no need for any trailed land leveller at 2000 and 3000 cropping area.
- The required number of manure broadcasting units increased by 25% and 73% as the cropping area increased from 2000 to 3000 and from 2000 to 4000 feddans, respectively.
- The required number of rotary plows and 90 HP (67 kW) tractors increased by 100% and 120% respectively, as the cropping area increased from 2000 to 4000 faddans.

Table 1. Effect the cropping area on the number of tractors and machines required for mechanization level No.1.

Cropping area	2000 Feddans		3000 Feddans		4000 Feddans	
Machine	Current	Required	Current	Required	Current	Required
65 HP(48.5 kW) Western Tractor	12	9	19	12	25	16
Chisel plow (7 tines)	5	9	8	12	10	17
Rotary plow 180 cm width	2	5	3	7	4	10
90 HP(67 kW) Western Tractor	3	5	5	7	6	11
Manure broadcasting unit	1	4	2	5	3	7
Trailed land leveler 3 m.	3	0	5	0	6	1
Laser leveler unit	0	1	0	2	0	3

3.1.2 Effect of the size of cropping area on the required mechanization center areas and costs of shelter and shelter surround under different mechanization levels.

Data in Table (2) indicates the required area of mechanization center. the shelter area, shelter cost and the shelter surround cost at different levels of cropping area under mechanization level No1. It shows that the required mechanization center area, area of the shelter, cost of the shelter and shelter surround cost increased with increasing the size of the cropping area.

The change in the cropping area from 2000 to 3000 feddans caused an increase in the area of mechanization center, shelter area, and shelter cost by 34%. On the other hand, the shelter surround cost increased by only 15.8% at the same conditions. Similarly, as the cropping area changed from 3000 to 4000 feddans, the mechanization center area, shelter area, and shelter cost increased by 43.8% , while the shelter surround cost increased by 20% only.

Table 2. Areas and costs of the mechanization center as influenced by the size of cropping area at mechanization level No.1

Cropping Area	2000 Feddan	3000 Feddan	4000 Feddan
Area of Mechanization center,(m^2)	409.00	548.00	788.00
Shelter area , (m^2)	245.40	328.80	472.80
Shelter cost, (L.E)	49,080	65,760	94,560
Shelter surround cost, (L.E)	8,089	9,364	11,229

Table 3 shows that the change in the mechanization level from level No.1 to level No.2, increased the area of mechanization center, shelter area, and shelter cost by 62%. However, the shelter surround cost increased by 27% at 3000 feddans cropping area. Also, changing mechanization level from level No.1 to level No.3 resulted in increasing the area of the mechanization center, shelter area, and shelter cost by 314%. However, the shelter surround cost increased by 103% at the same size of cropping area (3000 feddan).These large areas and high cost required for mechanization level No.3, may be attributed to the large size , high values harvesting and baling machines needed in this level.

Table 3. Areas and costs of the mechanization center as influenced by the mechanization levels under 3000 feddan cropping area.

Mechanization Level	Seedbed (level No.1)	Seedbed +Planting (level No.2)	Seedbed + Planting +Harvesting (level No.3)
Area of Mechanization center,(m^2)	548.00	890.00	2267.00
Shelter area ,(m^2)	328.80	534.00	1360.20
Shelter cost, (L.E)	65,760.00	106,800.00	272,040.00
Shelter surround cost, (L.E)	9,364.00	11,933.00	19,045.00

3.1.3 Effect of cropping area and mechanization level on the investor revenue:

Data in Table (4) represents the effect of cropping area on the invested capital requirements, internal rate of return, and the period of invested capital refunding (at 10% interested rate and at 50% net margin rate) under mechanization level No1. It could be observed that, the invested capital requirements increased by 38% and 45% as the size of the cropping area changed from 2000 to 3000 feddans, and from 3000 to 4000 feddans, respectively. On the other hand, there were no appreciable changes in the internal rate of return and the period of invested capital refunding as the size of cropping area increased from 2000 to 4000 feddan.

Table4. Effect of cropping area on the investor revenue under mechanization level No.1:

Cropping Area	2000 Feddans	3000 Feddans	4000 Feddans
Invested capital required, (L.E)	1,091.169	1,507,124	2,182,289
The internal rate of return (%)	12.63	12.90	11.03
The period of invested capital refunding (year)	7.50	7.40	7.96

Table 5, shows the effect of mechanization level on the invested capital requirements, the internal rate of return and the period of invested capital refunding of a service center for 3000 feddan cropping area. The data revealed that, the invested capital requirements increased by 83.5% and 164% as the mechanization level changed from level No.1 to level No.2 and from level No.2 to level No.3, respectively. There were no appreciable changes in the internal rate of return as the mechanization level changed from level No.1 to level No.2. However, the highest value of the internal rate of return (9.31%) was obtained with the third level of mechanization under 3000 feddans cropping area. The change in the mechanization level did not produce any change in the period of invested capital refunding at the same conditions. These results may be attributed to the seasonal nature of farm work as well as most of the farm machineries are used during relatively short periods of the year.

Table 5. Effect of mechanization levels on the investor revenue under 3000 feddans cropping area.

Mechanization level	Seedbed (level No.1)	Seedbed +Planting (level No.2)	Seedbed + Planting +Harvesting (level No.3)
Invested capital required, (L.E)	1,507,124	2,765,733	7,308,085
The internal rate of return (%)	7.82	7.89	9.31
The period of invested capital refunding (year)	9.31	9.08	8.23

3.2. Farmer Revenue

The decision support program was run to study the effect of changing the mechanization levels on the gross margin for the farmer using the data of three different crops (wheat, cotton, and rice) under 3000 feddans cropping area and at 50% net return rate.

3.2.1 Effect of the mechanization level for different crops on farmer revenue:

3.2.1.1. Wheat Crop

Figure 2 shows the total income, total costs and the gross margin on the farmer with the different mechanization levels using wheat crop under 3000 feddans cropping area. In a comparison among the three mechanization levels used under the model and the current level (traditional practice), the following results were obtained:

- The total income increased by 15%, 35 %, and 50 % compared with current level, for the level No.1, level No.2, and level No.3, receptively.

- There was no significant difference in the total cost between the level No.1 and the level No.2. However, the total cost with the level No.3 increased by 25% compared with the current level.
- The gross margin on the farmer level increased by 22.7 %, 54 %. and 64 % compared with current level for the level No.1, level No.2, and level No.3, receptively.

3.2.1.2 Cotton Crop

Results of the cotton crop (Figure 3) showed similar trends in the total income, total costs and the gross margin on the farmer as that with the wheat crop except for following differences:

- The total cost increased by 11.6 %, 11%, and 60% compared with current level for the level No.1, level No.2, and level No.3, receptively.
- The gross margin on the farmer increased by 15.8%, 40%, and 47.7% compared with current level for the level No.1, level No.2, and level No.3, receptively.

3.2.1.3 Rice Crop

Results of the rice crop (Figure 4) showed similar trends in the total income, total costs and the gross margin on the farmer as that with the wheat crop except for the following differences:

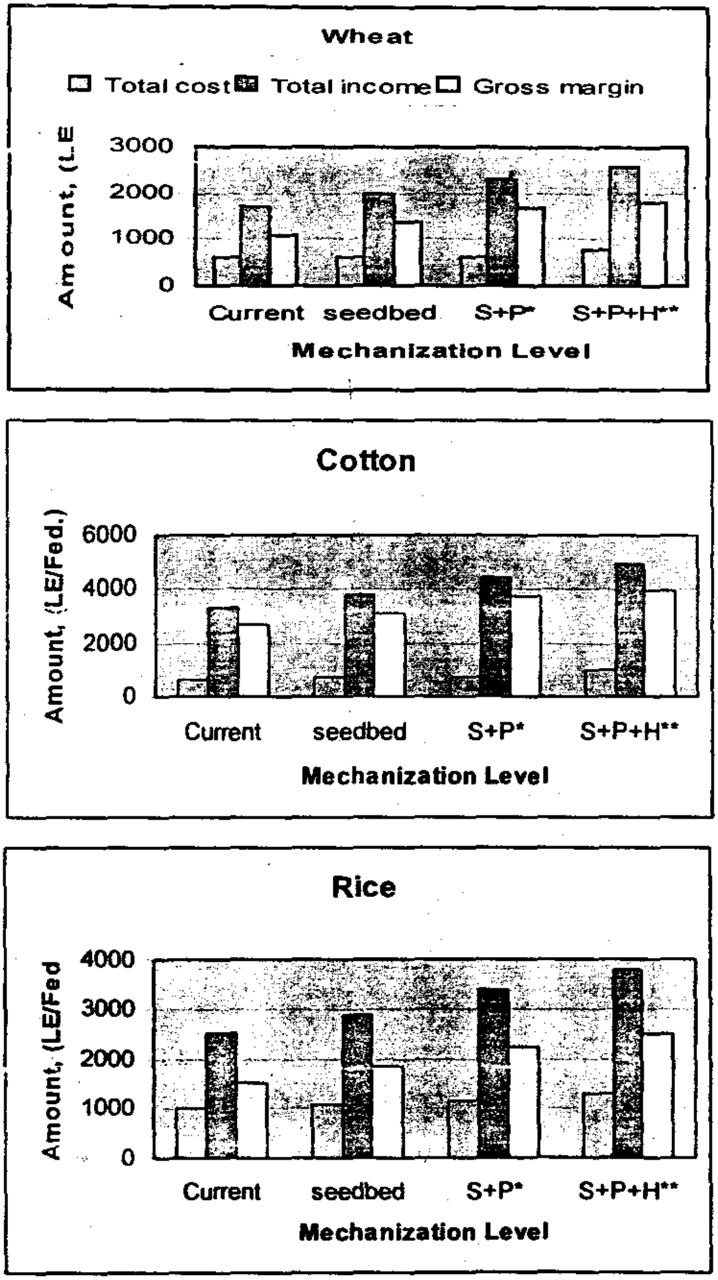
- The total cost increased by 7%, 15.8%, and 30% compared with current level for the level No.1, level No.2, and level No.3. receptively.
- The gross margin on the farmer increased by 20%, 47.6%, and 63% compared with current level for the level No.1, level No.2, and level No.3, receptively.

4. SUMARRY & CONCLUSION

Based on the results of this study, the developed decision support system for planning agricultural mechanization centers is capable to carry out the following:

- Determining the numbers, types, cost and rent rate of the machines needed for an appropriate farm mechanization service center, for a given area in a given region and certain cropping pattern, using one of three recommended levels of mechanization.
- Determining the area and the cost of the farm mechanization service center based on the size of cropping area served and the level of mechanization required.
- Determining the invested capital requirements, the internal rate of return, and the period of invested capital refunding at any selected interest and net margin rates for a given cropping area and mechanization level.
- Determining the total income, total costs and the gross margin for wheat, cotton, and rice crops as farmer's revenue under given cropping area and certain mechanization level.

Finally, the decision support system could be used as a good indicator for helping farmers and investors to make appropriate decisions, under certain conditions, for establishing the proper farm mechanization centers.



*(* S+P = seedbed +planting   ** S+P+H = seedbed +planting +harvesting)*

Figure (2): Effect of mechanization level on the total income, total cost, and gross margin for different crops

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الملخص العربي

نظام دعم اتخاذ القرار لبناء محطات ميكنة زراعية

د/ محمد يوسف الأنصاري* د/ السيد الأزهري** د/ سليمان إدريس**

تم تطوير وتقييم نظام دعم اتخاذ القرار لتكوين محطات ميكنة زراعية بناءا على MS Access Database وباستخدام Visual Basic 6.0 . package ويتكون النظام من ثلاثة مدخلات Modules وهي: متطلبات محطة الميكنة ، العائد على المزارع ، والعائد على المستثمر. وتم استخدام المدخلات السابقة في تقدير كلا من المخرجات التالية: عدد ونوعية الآلات المطلوب شراؤها ، معدل الإيجار لعمليات الميكنة المختلفة ، معدل العائد الداخلي ، فترة استرداد رأس المال ، صافي العائد على كلا من المزارع

والمستثمر. كما تم تقييم النظام تحت ثلاثة مستويات مختلفة من مساحة الخدمة للمحطة وأيضا تحت ثلاثة مستويات من الميكنة. وقد أوضحت النتائج زيادة العائد على كل من المزارع والمستثمر وكذلك الإنتاج الكلي للمحاصيل تحت أي نظام دورة زراعية يتم تطبيقه.فمثلا اظهر النظام ان معدل العائد الداخلي على الاستثمار في وحدة خدمة آلية لإعداد مرقد البذرة والتسوية بالليزر كان 12.6 ، 12.9 ، 11.32% عند زمام خدمة 2000 ، 3000 ، 4000 فدان على الترتيب. كما اظهر آن زيادة أرباح المزارع من اتباع الميكنة بالمستوى الثالث (ميكنة إعداد مرقد البذرة+الزراعة+الحصاد) للقمح والقطن والأرز كان 64% ، 47.7% ،63% على الترتيب مقارنة بالمستوى الحالي للميكنة. ومن ثم، فإن النظام يمكن استخدامه لمساعدة كل من المزارع والمستثمر وصانع القرار على اتخاذ الرأي الصائب لإنشاء محطة الميكنة الزراعية المناسبة لظروف المنطقة المنشئة بها.

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**باحث بالمعمل المركزي للنظم الزراعية الخبيرة.