A DECISION SUPPORT SYSTEM FOR FARM REGIONAL PLANNING

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Abstract: This paper presents a Decision Support System (DSS) for planning of farm regions in Greece. The DSS is based on the development possibilities of the agricultural sector in relation with the agricultural processing industries of the region and aims at the development of farm regions through a better utilization of available agricultural recourses and agricultural industries.

The DSS uses Linear and Goal Programming models and provides for different goals alternative production plans that optimize the use of available recourses. On the other hand, the alternative plans achieve a better utilization of the existent agricultural processing industries or propose their expansion by taking into account the supply and demand of agricultural products in the region.

The DSS is computerized and supported by a set of relational data bases. The corresponding software has been developed in Microsoft Windows platform, using Microsoft Visual Basic, Microsoft Access and LINDO.

For demonstration reasons, the paper includes an application of the proposed DSS in the region of Servia Kozanis in Northern Greece.

Key words: Decision support systems, farm regional planning.

1. INTRODUCTION

This paper describes in short a DSS developed in the context of a research project concerning the planning of farm regions, based on the development possibilities of the agricultural sector in relation with the agricultural processing industries in the region.

The corresponding research was divided into two parts. The paper follows the same structure. The first part presents in short the system scheduling, the data needed, the selection and development of required models, the development and the computerization of the DSS for planning of farm regions. The second part presents an application of the proposed DSS in the region of Servia Kozanis in Northern Greece for demonstration reasons.

Specifically, based on the existing planning of the primary agricultural sector and the agricultural processing industries of a region, the following methodology was followed:

- Review of the literature in the field of farm and land management, farm planning, optimal allocation of resources and development of farm regions,
- System scheduling, analysis of needs in hardware and software, plan of work,
- Collection of micro and macro, economic and technical data,
- Design of the development model of the region (Linear Programming model and Goal Programming model),
- DSS scheduling and development,
- Application of DSS in the region of Servia Kozanis in Northern Greece. DSS validation and verification.

2. SYSTEM SCHEDULING

The conceptual components of the DSS for planning of farm regions are a User Support Base, a Data Base and a Model Base (Barber 1976, Berlo 1993, Manos and Voros 1993, Manos et al. 2004, Vassiliadou et al. 2000).

The *Data Base* is divided into sub-bases, including information for a farm region such as:

Primary agricultural sector

- Available agricultural resources
  - ➢ Land
  - ➢ Livestock
  - ➢ Labor
  - ➢ Capital
  - ➢ Machinery
- Contribution of fix and variable costs in the total cost
- Agricultural enterprises and technical-economic coefficients
  - ➢ Agricultural enterprises
  - ➢ Required labor

> ➢ Required machinery
> ➢ Required variable costs
- Gross margin and profit of agricultural enterprises

Secondary sector – Agricultural processing industries of the region

- Agricultural processing industries of the region according to its category
- Investment costs
- Capacity
- Products' and raw materials' supply and demand

The _Model Base_ includes all the necessary and suitable models for achieving the following desired results:

- Calculation of economic results for each agricultural enterprise and for the entire farm region
- Optimization of the use of the available resources in each agricultural enterprise and in the entire farm region
- Optimization of economic results
- Sensitivity analysis of the various parameters (technical and economic) on the economic result, etc.

More specifically, the Model Base includes Operational Research models and specifically a Linear Programming and a Goal Programming model. It also includes some basic models used by the DSS for the calculation of technical coefficients and economic results. These results, which are stored in data files of the DSS Data Base, are:

- Economic results
  > ➢ Gross margin
  > ➢ Production expenditures
  > ➢ Profit, incomes
- Rate of utilization of resources
  > ➢ Rate of utilization of labor
  > ➢ Rate of utilization of machinery
- Rate of utilization of agricultural processing industries of the region

3. DATA

The DSS requires the collection of both micro economic – technical (source data) and macro economic (source and secondary data) that will feed its Data Base.

Macro economic data concerning the primary agricultural sector are the following:

Land: area according to its category (cultivated area, grassland, forest, and irrigated or dry area), production plants of a four – year term (production enterprises, hectares and age and variety of perennial plants as well).

Livestock: Livestock breeding of the region (variety of livestock population, age, number of stock – farms, the market value per capita.

Labor: Active population in the agricultural sector of the region.

Capital: Machinery according to its category (type, year and initial cost, horsepower HP) buildings by category (type, capacity, year and initial cost of construction) land reclamation works by category (type, year and initial cost of construction).

As far as the secondary sector and the agricultural processing industries are concerned, the following macro economic data are necessary:

Agricultural Processing Industries: Both the agricultural processing industries of the region and the general county according to its category (processed products, line production), investment costs, operational costs, capability (maximum capability by product, annual quantities of processed products, annual quantities of raw materials) and

Supply and demand of products, agricultural equipment and raw materials.

The micro economic and technical data must be gathered in accordance with the Ministry of Agriculture Book – keeping from an adequate sample of farms and their production enterprises, which represent the region's production plan. These micro economic and technical data are related with the following: Yields, product prices, necessary seeds – fertilizers – pesticides etc., necessary labor force and necessary machinery and all those necessary technical and economic data needed in order to estimate the gross margin, the variable cost and the gross profit of each production enterprise.

4. DESIGN AND DEVELOPMENT OF THE LINEAR MODEL

The DSS includes a Linear Programming model and a Goal Programming model which are used for the better utilization of available agricultural recourses and agricultural industries of a region (Barnard and Nix 1993, Bernardo et al. 1992, Hazell and Norton 1986, Jeffrey et al. 1992, Lee et al. 1995, Manos and Kitsopanidis 1988, Manos 1991, Manos and Gavezos 1995, Onta et al. 1991).

The Linear Programming model in matrix notation has the following form:

max $cx - dw$

subject to:

$Ax - Rw >=< b$

$x, w >= 0$

where:

x = the vector of both crop and livestock enterprises
w = the vector of resources activities
c = the vector of gross margins of both crop and livestock enterprises
d = the vector of variable costs of resources activities
A = the matrix of input - output coefficients of both crop and livestock enterprises
R = the matrix of input - output coefficients of activities of resources
b = the vector of the maximum available quantities or the minimum required quantities of production factors

The model has been designed and developed in order to include in the objective function all the necessary production enterprises and all the activities of resources such as family and seasonal labor, tractor, harvesting machinery and variable capital whereas their total variable cost is automatically subtracted from the optimum production plan's total gross profit.

The model formulation allows the input of all the constraints concerning land, total area or area by category and production enterprise, livestock breeding, labor, machinery, variable cost and the capacity of agricultural processing industries. This structure is in accordance with the relevant theoretical knowledge and the typical practice, concluding in an optimum – scientifically and technically – production plan, which is also feasible and has practical application.

The model determines the optimal allocation of resources and outcomes to the optimum production plan. It also provides the sensitivity analysis in the objective function coefficients and the maximum available or the minimum required quantities of the resources. It also provides an analysis of marginal productivity and marginal cost of agricultural factors.

This model also gives the opportunity of parametric analysis of the objective function or in the constraints, out-coming to alternative production plans.

Finally, this model is applicable on one hand, for its solution as a Mixed Integer Programming model in regard to factors' non-divisibility, such as livestock and machinery and on the other hand as a Goal Programming Model providing near optimum production plans.

4.1. Activities and constraints

The activities of the model are divided into two categories: The activities of agricultural enterprises and the activities of resources. The model may include up to 105 activities and specifically up to 53 annual and perennial crops, up to 6 livestock enterprises and up to 32 resources' activities.

The constraints refer to the land, livestock, labor, machinery, number of the agricultural processing industries and variable costs. The model may include up to 123 constraints and specifically up to 53 land constraints for crops, up to 3 constraints for livestock, up to 7 constraints for processing industries, up to 33 constraints for agricultural machinery, up to 25 constraints for labor and 2 constraints for variable capital. Constraints have been set for each agricultural enterprise and for the entire region as well. The determination of the upper and the lowest limits is in accordance with the relevant theoretical knowledge and the technical – economic conditions (quota for tobacco, regions' rights for wheat, concession for beets, etc.). As far as labor is concerned constraints have been set for the one provided by the family members and the seasonal labor provided outside of the family. The same constraints have been set for tractors and the proposed production plan can use tractors outside of the region at any time of the year as long as the regions' tractors are inadequate. As long as the harvesting machinery is concerned their utilization is based on the maximum number of owned available machinery. As far as the activities of agricultural processing industries are concerned, the constraints are related with the maximum quantity of raw materials that can be processed. Additionally, for the milk processing industries one more constraint is used to determine the proportion between sheep's and goats' milk for the production of

the end product per unit. Finally there are two constraints that refer to the capital, one for the owed available capital and one for the borrowed capital.

The objective function of the Linear Programming is a linear function of all activities of agricultural enterprises and resources. The objective function represents the total gross profit of the production plan in the region of concern.

Total gross profit of the regions' production plan is maximized under the aforementioned constraints.

All data needed for the linear model are fed automatically by the Data Base of DSS. These are either primal data or data processed before by the models of the Model Base of DSS (see sections 2 and 5).

4.2. Optimum and alternative production plans

The DSS gives the optimum production plan and alternative production plans, makes sensitivity analysis and comparison, from the technical - economic point of view, between the existing and the proposed production plans. Specifically:

- Comparison between the existing and the proposed production plan
- Comparison of the rate of utilization of labor
- Comparison of the rate of utilization of machinery
- Comparison of the economic results
- Marginal analysis: marginal productivity and marginal costs of resources
- Sensitivity analysis of the optimum production plan
- Parametric analysis - achievement of alternative production plans

5. DSS'S COMPUTERIZATION

The DSS is fully computerized. The corresponding software has been developed in the platform of Microsoft Windows 98 using Microsoft Visual Basic, Microsoft Access and LINDO (release 6.01) for Windows (Schrage 1997). It is supported by a set of relational data bases permitting modern and quick operations by using Select Query Language (SQL).

The presentation of the outcoming results is based on DataBase Grids, where data are locked so as to prevent false input on behalf of the user. However, it is possible to change or add inputs wherever is necessary.

The user interface uses the multiple document information technique (MDI). This technique permits the users to keep open many Windows with different information making available the easy and quick control of work.

Printings are based on Crystal Reports interface that permit quick formatting of print outs (some screens of the DSS are given below).

THE MENU

The menu of DSS is divided into three sub menus: General Information, Files and Linear Model. Specifically the sub menus are:

Menu: General Information

This menu includes general information about the codification of all factors, farm enterprises, machinery, land reclamation works, population and products.

The following selections are available in the form of windows:
a) «Crop enterprises»
b) «Livestock enterprises»
c) «Categories of machinery»
d) «Categories of buildings and land improvements»
e) «Population data»
f) «Districts of the region under study»
g) «Products from crop enterprises»
h) «Products from livestock enterprises»
i) «Exit»

Menu: Files

This menu includes all the necessary technical and economic information for the region under study and its districts. These data are divided into different categories so that it is possible to both describe the existent situation and achieve optimal and alternative production plans.

The following selections are available:
a) «Land of crop enterprises»
b) «Livestock capital»
c) «Available machinery»
d) «Available buildings and land improvements»
e) «Available human labor»
f) «Available mechanical labor»
g) «Requirements of crop enterprises in human and mechanical labor»
h) «Requirements of livestock enterprises in human and mechanical labor»
i) «Variable capital of crop enterprises»
j) «Variable capital of livestock enterprises»
k) «Economic data of crop enterprises»
l) «Economic data of livestock enterprises»
m) «Gross return for each district»
n) «Synthesis of fixed and variable capital»
o) «Production expenses and coefficients»
p) «Returns, profits and incomes»
q) «Exit»

Menu: Linear Model

This category includes all operations about the design, formulation, development and evaluation of linear models as well as the presentation of the final economic results.

The following selections are available:
a)   «Formulation of linear program»
b)   «Close the linear program»
c)   «Development of optimum production plans»
d)   «Evaluation of production plans»
e)   «Comparison of results of existent and optimum plan»
f)   «Comparison of profits, returns and incomes of existent and optimum plan»

It is noted that the linear model is open as regards the number of constraints and variables in the sense that the user may add or subtract variables and constraints according to the needs that he meets.

6. DSS APPLICATION

In this section we present an application of the given DSS in practice. Specifically, the DSS was applied to farm planning of the region of Servia Kozanis in Northern Greece. The region consists of one Municipality (Servia) and four Communities (Platanorema, Avles, Goules and Kranidia) with a total population of 6,678 people. The cultivated area of the whole region is 38.522 stremmas (1 hectare = 10 stremmas).

The production plan of the region includes annual and perennial crops such as wheat, barley, maize, tobacco, sugar beets, vegetables, vineyards, plum tress, apple trees, peaches, nuts, cherries and almond trees. There are 448 farms in the whole region which means an average farm size of 86 stremmas. There are also reared 26,288 sheep and goats and 571 cows. The available labor of the whole region is 755 man units.

The invested capital in the primary agricultural sector of the region is about 24 million euro, 65.3% of which is fixed (buildings, machinery, perennial crops, land improvements) and 34.7% variable (seeds, fertilizers and medicine, seasonal human and mechanical labor, machinery oil, variable capital for animals). The fixed capital does not include the value of the land. The gross return in the total region is about 12.4 million euro, which is due by 58.4% to plant production and 41.6% to animal production. The main sources of this return are tobacco (15.0%), maize (14.3%), wheat hard (6.1%), potatoes (4.7%), peaches (2.5%), sugar beets (2.7%), sheep (22.7%), goats (9.5%) and cows (9.4%) (Table 1).

For the processing of the produced agricultural products in the region there are various small and medium size industries and mainly for milk, peaches, apples, cherries and potatoes. The capacity and the needs of them are considered in the linear model.

The data base and sub bases of the DSS were fed by primal and secondary data collected by the associates of the Department of Agricultural Economics and the Development Agency of Western Macedonia (ANKO S.A.). The DSS automatically processed all the data and produced all technical and economic coefficients (in about 40 tables) described in sections 2, 3 and 5 above. All results are presented by district (in our case Servia, Platanorevma, Avles, Goules and Kranidia) and in total. Among them the data needed to feed the linear model are included.

Table 1: Existent and optimum production plan for the whole region

Enterprises	Existent	Optimum
Plant production	**Area (stremmas)**	
Vineyards (for wine)	533	625
Almond trees	71	95
Maize	10,081	10,081
Plum trees	62	92
Sugar beets	1,216	240
Tobacco	1,465	1,153
Water melons	268	268
Walnut trees	100	128
Barley	1.260	99
Lucern	4.262	6,185
Apples	232	279
Potatoes	552	35
Leeks	0	250
Peaches	474	567
Rye	430	364
Wheat hard and then Eggplants	0	250
Wheat soft	2,745	3,880
Wheat hard non-irrigated	4,497	6,136
Wheat hard irrigated	6,688	0
Beans	45	0
Fallow	3,541	0
Total	34,981	30,726
Crops for feedstuffs		
Maize	0	65
Wheat hard	0	1,229
Barley	0	5,885
Lucern	0	614
Total	0	7,795
Animal production	**Number of heads**	
Sheep (feedstuffs bought)	15,308	14,649
Sheep(feedstuffs self-produced)	0	659
Goats (feedstuffs bought)	10,980	0
Goats (feedstuffs self-produced)	0	10,980
Cows (feedstuffs bought)	571	571
Cows (feedstuffs self-produced)	0	0

In continuation the linear model was applied. As we mentioned above, this model is included in the model base of the DSS and automatically is fed by the data base

and sub bases. In the case of the whole region the linear model included 105 variables and 123 constraints.

The solution of the model gave an optimum crops plan with a better reallocation of production resources (land, labor, machinery and variable capital). The rates of employment for human and mechanical labor present important improvements. The optimum plan achieves 4.9% higher gross return than the existent one, 5.0% lower production expenses, 18.9% higher agricultural income and 24.0% higher return to labor. The optimum plan also achieves 11.1% return to capital against 3.4% of the existent plan (Table 2).

Table 2: Economic results of existent and optimum plan for the whole region

Profits/ returns	Existent plan	Optimum plan	Increase / decrease (%)
Gross return	12,395,778	12,999,025	4.9
Production expenses	12,679,644	12,040,351	-5.0
Profit / loss	-283,866	958,673	437.7
% of gross return	-2.29%	58.53%	60.8
% of production expenses	-2.24%	141.11%	60.8
Stremmas	38,522	38,522	
per stremma	-7,4	24,9	437.7
Return to land	794,052	2,145,705	170.2
per stremma	20.6	55.7	170.2
Return to labor	5,734,062	7,107,776	24.0
per day	22,4	27,1	21.3
Return to capital	3.39%	54.26%	50.9
Agricultural income	7,624,785	9,069,546	18.9
No of farms	448	448	
Agricultural income per farm	17,020	20,245	18.9

The DSS was also used to estimate the marginal productivity of agricultural resources as well as to make sensitivity analysis (both for activities and resources) and check the stability of the optimum plan (See screen below).

Moreover the DSS was used for parametric investigations of resources availability that becomes automatically by the Parametric Linear model. This model e.g. was used to examine the impacts of availability of annual or monthly labor on its productivity (Figure 1) and on agricultural income. It is also used to investigate the impacts on livestock breeding from an increase of capacity of corresponding milk processing industry.

Finally, the DSS was used to simulate different scenarios by Goal Programming. The model has the possibility to achieve specific goals, e.g. to find alternative production plans which achieve predetermined levels of gross margin near the optimum one.
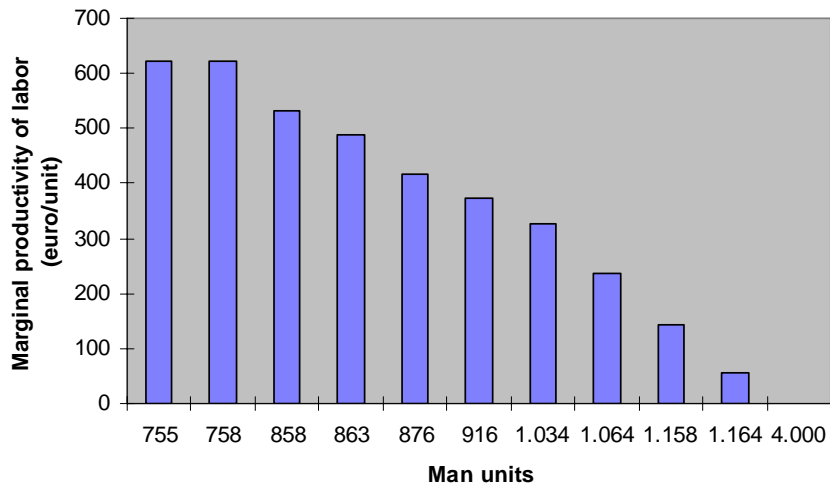
Figure 1: Variations of labor productivity

7. CONCLUSIONS

Disposing all conceptual and necessary components, the DSS presented above is a suitable tool for farm regional planning. It is a computerized simple and friendly tool for the decision makers of farm regions helping them in finding the optimum allocation of the available resources and better utilization of agro-processing industry. Extra advantages of the proposed DSS help the decision makers in doing parametric investigations and simulating different scenarios.

The proposed DSS stores source and secondary data, processes them and calculates all technical and economic coefficients of the region by different categories, by sub region and in total. At a second stage, the DSS achieves the optimum crops plan of the region and the optimum utilization of available agricultural resources taking in account the development possibilities of the agricultural sector, the supply and demand of the agricultural products and the capacity of agro-processing industry of the region.

Moreover, the decision makers can investigate the impacts on optimum plan and income from the variations of available resources and/ or crops and resource prices. In addition, the decision makers can achieve alternative near optimum plans with predetermined levels of total gross margins. These characteristics of the DSS are due to the Parametric and Goal Programming models that are embodied in the DSS.

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Files   Linear Model   General Information

Crop enterprises
Livestock enterprises
Categories of machinery
Categories of buildings and land improvements
Population data
Districts of the region
Products from crop enterprises
Products from livestock enterprises
Inquiries

PILOT MODEL

Files   Linear Model   General Information

Land of crop enterprises
Livestock capital
Available machinery
Available buildings and land improvements
Available human labor
Available mechanical labor
Requirements of crop enterprises in human and mechanical labor
Requirements of livestock enterprises in human and mechanical labor
Variable capital of crop enterprises
Variable capital of livestock enterprises
Economic data of crop enterprises
Economic data of livestock enterprises
Gross return for each district
Synthesis of fixed and variable capital
Production expenses and coefficients
Returns, profits and incomes

Exit

VARIABLES	PRESENT VALUE	PERMISSIBLE INCREASE	PERMISSIBLE DECREASE
Corn Outside Network, irrigated, Normal Cultivation	7018199219	12819695312	1728450195
Corn Inside Network, Irrigated, Normal Cultivation	7018199219	67907296875	5239700195
Wheat Hard Outside Network, Dry, Normal Cultivation	3763400391	5239699707	INFINITY
Wheat Hard Inside Network, Dry, Normal Cultivation	3763400391	22635765625	2138399903
Wheat Hard Outside Network, Irrigated, Normal Cultivation	1810000000	7378100096	INFINITY
Wheat Hard Inside Network, Irrigated, Normal Cultivation	1810000000	2138399902	INFINITY
Barley Outside Network, Dry, Normal Cultivation	2590000000	10767450195	INFINITY
Barley Inside Network, Dry, Normal Cultivation	2590000000	5527750000	INFINITY
Rye Outside Network, Dry, Normal Cultivation	2586000000	42446796875	INFINITY
Rye Inside Network, Dry, Normal Cultivation	2586000000	37207093750	INFINITY
Wheat Soft Outside Network, Dry, Normal Cultivation	1356500000	1728450195	INFINITY

CROP ENTERPRISES	EXISTENT PLAN (St)	OPTIMUM PLAN (St)
LUCERN IRRIGATED	533	533
VINEYARDS DRY	0	92
RYE DRY	71	71
ALMOND TREES IRRIGATED	0	24
MAIZE IRRIGATED	10081	8651
MAIZE & SPINACH IRRIGATED	250	0
PEARS IRRIGATED	630	7.76
PLUMS DRY	0	30
PLUMS IRRIGATED	62	62
OLIVES DRY	0	605
SUGAR BEETS IRRIGATED	1240	739.27
TOBACCO IRRIGATED	1153	1153
WATER MELONS IRRIGATED	268	268
POTATOES IRRIGATED	100	100
WALNUTS IRRIGATED	0	27.5
CHERRIES IRRIGATED	0	17.22
BARLEY DRY	3265	0
CABBAGES IRRIGATED	0	0