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MODEL AND SUPPORT SYSTEM PROTOTYPE FOR SCHEDULING THE BEEHIVE EMPLACEMENT TO AGRICULTURAL AND FOREST MELLIFEROUS RESOURCES

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Abstract

The paper presents a model and a support system prototype for scheduling in time and space the beehive emplacement to different melliferous crops and different melliferous tree species. A general model specifies the data structures (inputs / outputs), the data processing for obtaining the beehive movement schedules, and different melliferous balances at territorial levels, based on the melliferous capability of the commune crops and forest bodies and the number of the existing beehives at commune level. The algorithm of the beehive movement schedules aims at the minimisation of the movement distances taking into consideration a large territory of the country. A reduced version of the scheduling model was implemented into a computerised support system prototype, "PaSPas-1.1". It refers to rapeseed crops and to robinia trees, and provides beehive movement schedules at commune level and forest body level, respectively, localised within eight districts ("judets") of South Romania.

Key words: *agricultural melliferous resources, forest melliferous resources, pastoral beekeeping planning, pastoral beekeeping planning model, planning support system.*

INTRODUCTION

In order to be sustainable and competitive, the beekeeping has to be “pastoral”. That means that the beekeepers move their beehives, beginning with the spring start and till the summer end, to different places of melliferous resources, correspondingly to their flowering, in order to have a continuous honey gathering at the maximum intensity.
This activity could be carried out only by an appropriate planning, based on the data regarding the melliferous resource locations, access resource distances, resource melliferous capacities (potential), resource flowering period, as well as based on the honey gathering needs for beehives in conditions of profitableness [3].
This paper presents a general model for scheduling in time and space the beehive emplacement to different melliferous crops and different melliferous tree species, and a prototype of a computerised planning support system (“PaSPas-1.1”), which implements a reduced version of the scheduling model (rapeseed and robinia tree resources from eight districts of South Romania). The prototype has however the main necessary functions.
Such a system is useful to the beekeepers’ associations for planning the efficient common use of the available melliferous resources within a large territory (one or more regions of the country).

MATERIAL AND METHOD

A first level analysis of the pastoral beekeeping activity (problem) was carried out and the type of the planning (scheduling) model and its requirements for functioning and computer implementation were established. A more detailed analysis of the information and objectives implied in the pastoral beekeeping planning led to the elaboration of the planning model (algorithms).

The main part of the model was implemented in a computerised planning support system (computer program), which was tested with real data concerning the existing bee-families, rapeseed crops and forest bodies of robinia trees located within the region of S-SE Muntenia (South of Romania), comprising eight districts: Calarasi (CL), Ialomita (IL), Ilfov (IF), Giurgiu (GR), Teleorman (TR), Olt (OT), Dolj (DJ), and Valcea (VL).

RESULTS AND DISCUSSIONS

1. On the problem of pastoral beekeeping planning

The pastoral beekeeping planning aims at scheduling the emplacement of a number of beehives corresponding to the melliferous potential of each melliferous resource (agricultural crop or tree species), having different objectives: all beehives to have enough melliferous resources for both their own food and for maximum possible trading honey, not to remain unutilized melliferous resources, minimizing the beehive transport costs, that is minimizing the moving distances and others [3].

Many characteristics of the problem of pastoral beekeeping planning [1, 2, 3, 6, 7] determine it to be considered a *"poorly-structured" problem* [4, 5]:

- *Data uncertainty:* fuzzy nature of spatial /geographical delineation of melliferous resources areas, fuzzy nature of biologic processes concerning the melliferous resources and beekeeping, qualitative /statistical nature of the parameters on melliferous resources and beekeeping, human errors in the data collecting, communication and storing, incomplete and unavailable data, data of different qualities and structures (obtained with different methodologies/definitions) etc.;
- *Knowledge uncertainty:* incomplete knowledge about the processes of land - plant - atmosphere - bee relation, uncertainty in establishing the right representative indicators for factors; qualitative knowledge; approximate methods/models for evaluation and decision (qualitative, statistical, heuristic, or deterministic with uncertain parameters and approximate submodels), etc.;
- *Uncertainty related to the management process:* decision-maker's subjectivism, uncertainty in establishing the evaluation criteria, errors in choosing and applying the models, delays in data availability, errors/delays in applying the decisions, etc.;
- *Problem complexity:* multi-criteria character of decisions, the great number and complexity of processes, state variables and inter-relations implied in the land - plant – atmosphere - bee system (e.g. factors/processes determining the flowering period of crops and trees, meteorological factor influence on nectar gathering etc.), risky/unknown phenomena, spatial variability of the melliferous resources characteristics, local knowledge necessity etc.

The problem analysis, including the above considerations, led to establishing some general requirements for a pastoral beekeeping planning system:

(i) In order that the system to be easily used by users, there are necessary:

- reduced requirements regarding input data to be provided by the user to the system, that is the input data to be available and easily to be obtained;
- reduced requirements on user knowledge needed to system use;
- simple user-system interface.

(ii) As a result of the "poorly-structured" character of the problem, the approach of the computerised implementation of a pastoral beekeeping planning system is necessary to be that of a "decision support system" type, respectively based on a strong interactivity with the user, which has to be included within the decision process. It is not advisable to have a completely automatic system that accomplishes the entire decision-making process [4, 5].

Consequently, the system has to be implemented as an open system, ensuring easiness in its development during its life, that is the system development has to be adaptive-evolving ("prototype" method):

- The prototype is a first variant of the requested system, which has its essential characteristics, at least in an incipient way. It is more rapidly and economically built, but in such a way to be easily modified.
- Then, step by step, the prototype is extended with new functions and improved during its utilization, as it is evaluated by users in real conditions.

The method is useful because of initial uncertainty on system detailed requirements. During its development, the system is adapted and personalised.

2. General model for pastoral beekeeping planning

Main input data

(i) *Production and gathering indices for each melliferous source type* (crop /tree-species):

- Honey Production Index (PI): the potentially gatherable honey quantity during a crop/tree-species flowering season (kg/ha);
- Honey Gathering Index (GI): the total honey quantity gathered by a bee-family (BF) during a crop/tree-species flowering season (kg/BF);
- Own Food Honey Gathering Index (OGI): the honey quantity gathered by a bee-family, that is used for its own food, during a crop/tree-species flowering season (kg/BF);
- Swarm Food Honey Gathering Index (SGI): the honey quantity gathered by a bee-family, that is used for its swarm food, during a crop/tree-species flowering season (kg/BF);
- Trading Honey Gathering Index (TGI): the honey quantity gathered by a bee-family during a crop/tree-species flowering season, that is collected for trading (kg/BF); TGI = GI - OGI - SGI.

(ii) *Input data for each "commune"* (basic administrative unit: commune /town /city): name, district ("judet"), absolute geographic coordinates X and Y of the commune centre/median, number of the existing bee-families, areas of the main melliferous crops (yearly updated).

(iii) *Input data for each forest-body*: name, district, forest direction, forest district, forest production unit, absolute geographic coordinates X and Y of the forest-body centre/median, number of the existing bee-families, areas of the main melliferous tree-species.

Data processing

(i) *Need and Availability of Melliferous Resources:*

- Trading and Total Honey quantities needed to be gathered, from each melliferous resource (crops/communes, tree-species/forest-bodies), for the existing bee-families at different levels (commune /district /country region); They are calculated based on honey gathering indices and the number of existing bee-families;
- Areas of each melliferous resource (crops/communes, tree-species/forest-bodies) needed for the existing bee-families at different levels (commune /district /country region); They are calculated based on honey production indices and the number of existing bee-families; It is considered that the bees gather 75% of the total potentially gatherable honey quantity during a crop/tree flowering season;
- Potentially gatherable Trading and Total Honey quantities from the existing melliferous resources (crops/communes, tree-species/forest-bodies) at different levels (commune /district /country region); They are calculated based on honey production indices and the areas of existing melliferous resources; It is considered that the bees gather 75% of the total potentially gatherable honey quantity during a crop/tree flowering season;
- Number of bee-families for which the necessary melliferous resources of each type (crops, tree-species) exist at different levels (commune /district /country region); They are calculated based on honey gathering indices and the total potentially gatherable honey quantities from the existing melliferous resources (crops/communes, tree-species/forest-bodies);

(ii) *Beehive emplacement scheduling to a given melliferous source type* (crop /tree-species):

- Location of the bee-families at the commune or forest-body level before their moving to the melliferous resources of the given type; For each commune and each forest-body, the number of bee-families from each home-commune, that are located within them, is specified; The locations result from the preceding emplacement, and for the first season they result from commune's input data (bee-family home-communes); The user may update the locations, according to the actual emplacement (in the case of the modifications of the schedules);
- Movement of the bee-families to the melliferous resources of the given type; For each commune and each forest-body, it is determined the number of bee-families from each home-commune, that are located within them, planned to be moved, if necessary, to an appropriate destination commune/forest-body having available resource; The moving distance is calculated, too; The melliferous resource are allocated in the increasing order of the sum of two distances: (1) the distance between the current location of the bee-families of a home-commune and the destination location, and (2) the distance between the destination location and the home-commune; In this way, it is aiming at minimising the moving distances without going too far away from the home-commune; The distances used in the scheduling algorithm are approximated by the distances "in air right line" between the centres/medians of the locations (communes /forest-bodies), calculated based on their X / Y coordinates;
- Location of the bee-families at the commune or forest-body level after their moving to the scheduled melliferous resources of the given type; For each commune and each forest-body, the number of bee-families from each home-commune, that are located within them after the movement, is specified;

(iii) *Melliferous parameters and balances at different levels* (commune /district /country region) *on different melliferous source types* (crop /tree-species):

- Surplus/deficit of the potentially gatherable trading and total honey quantities from the existing melliferous resources related to the number of the existing bee-families;
- Surplus/deficit of the number of the existing bee-families related to the potentially gatherable total honey quantities from the existing melliferous resources;
- The number of the existing bee-families scheduled to be moved to different existing melliferous resources;
- The potentially gatherable trading and total honey quantities planned to be obtained by the pastoral beekeeping from the existing bee-families.

(iv) *Other developments of the model:*

- Design and implementation of a GIS (geographical information system) version of the planning support system, containing the spatial layers of communes and forest-bodies, and the calculation of the distances used in the scheduling algorithm by applying the appropriate GIS function on the road layer;
- Design and implementation of a beekeeper database and the aggregation of some necessary data from that database;
- Obtaining different melliferous parameters and balances at the beekeeper level, too.

3 Support system prototype for pastoral beekeeping planning

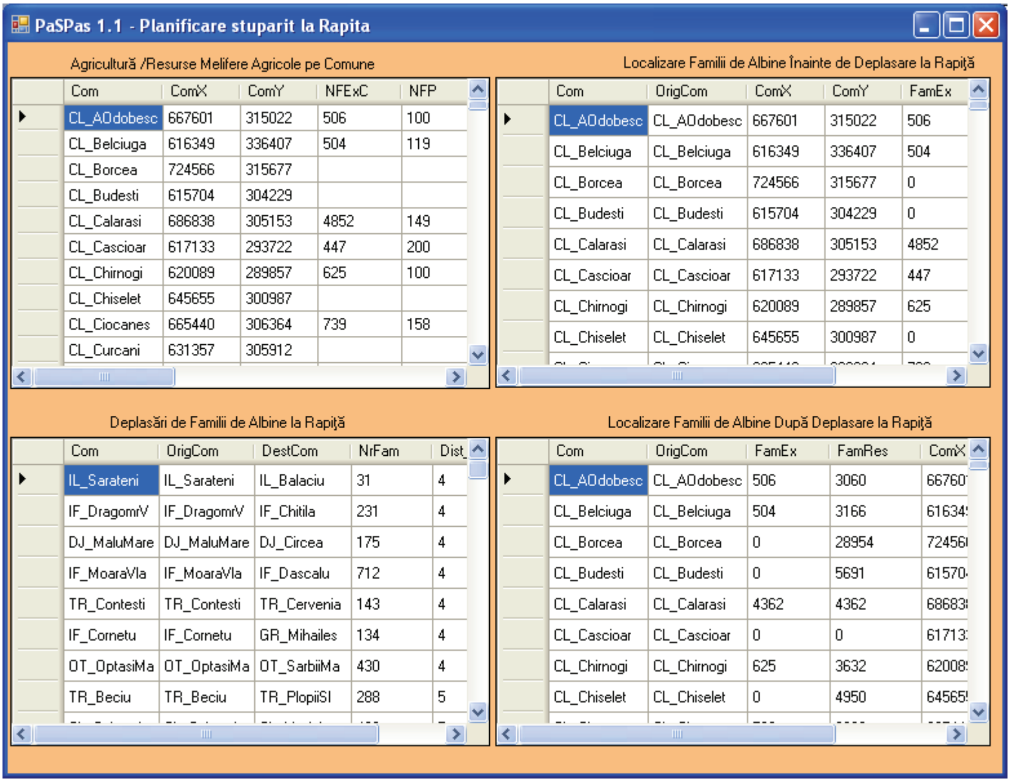
A support system prototype for pastoral beekeeping planning (PaSPas-1.1) was developed, which implements the planning for rapeseed crops and forest bodies of robinia trees located within the region of S-SE Muntenia.

The system prototype is structured in three subsystems: database, model and data processing subsystem and user interface. The data on 623 communes (communes /towns /cities) and 1494 forest-bodies are loaded in the system prototype database. The commune and forest-body centre/median coordinates were established by using the appropriate function of a commune GIS of Romania and, respectively of a forest resource GIS of South Romania.

The output window with beehive movement schedules to rapeseed crops of the PaSPas 1.1 system is showed in the Fig. 1.

In the left-top table of the window, there are showed the commune input data: district-code_commune-name (Com), commune

coordinates (ComX, ComY), number of the existing bee-families (NFExC) etc.
In the right-top table of the window, there are showed the location of the bee-families before beehive moving: the number of the existing bee-families (FamEx), their home (origin)-commune (OrigCom) etc.;



Com	ComX	ComY	NFExC	NFP
CL_AOdobesc	667601	315022	506	100
CL_Belciuga	616349	336407	504	119
CL_Borcea	724566	315677		
CL_Budesti	615704	304229		
CL_Calarasi	686838	305153	4852	149
CL_Cascioar	617133	293722	447	200
CL_Chirnogi	620089	289857	625	100
CL_Chiselet	645655	300987		
CL_Ciocanes	665440	306364	739	158
CL_Curcani	631357	305912		

Com	OrigCom	ComX	ComY	FamEx
CL_AOdobesc	CL_AOdobesc	667601	315022	506
CL_Belciuga	CL_Belciuga	616349	336407	504
CL_Borcea	CL_Borcea	724566	315677	0
CL_Budesti	CL_Budesti	615704	304229	0
CL_Calarasi	CL_Calarasi	686838	305153	4852
CL_Cascioar	CL_Cascioar	617133	293722	447
CL_Chirnogi	CL_Chirnogi	620089	289857	625
CL_Chiselet	CL_Chiselet	645655	300987	0

Com	OrigCom	DestCom	NrFam	Dist
IL_Sarateni	IL_Sarateni	IL_Balaciu	31	4
IF_DragomirV	IF_DragomirV	IF_Chitila	231	4
DJ_MaluMare	DJ_MaluMare	DJ_Circea	175	4
IF_MoaraVla	IF_MoaraVla	IF_Dascalu	712	4
TR_Contesti	TR_Contesti	TR_Cervenia	143	4
IF_Cornetu	IF_Cornetu	GR_Mihailes	134	4
OT_OptasiMa	OT_OptasiMa	OT_SarbiiMa	430	4
TR_Beciu	TR_Beciu	TR_PlopiiSl	288	5

Com	OrigCom	FamEx	FamRes	ComX
CL_AOdobesc	CL_AOdobesc	506	3060	66760
CL_Belciuga	CL_Belciuga	504	3166	61634
CL_Borcea	CL_Borcea	0	28954	72456
CL_Budesti	CL_Budesti	0	5691	61570
CL_Calarasi	CL_Calarasi	4362	4362	68683
CL_Cascioar	CL_Cascioar	0	0	61713
CL_Chirnogi	CL_Chirnogi	625	3632	62008
CL_Chiselet	CL_Chiselet	0	4950	64565

Fig. 1. PaSPas 1.1 – Output window for Rapeseed (Beehive movement Schedules to Rapeseed crops)

The data (bee-family location) may be modified, if necessary; because the rapeseed crop flowering is the first gathering season, “Com” is just “OrigCom”.
In the left-bottom table of the window, there are showed the beehive moving scheduled for the rapeseed crops. For example, in the first table row 31 bee-families (NrFam), originated in Sarateni_Ialomita (OrigCom) are scheduled to be moved four km (Dist) from the present location, Sarateni_Ialomita (Com), to the destination location, Balaciu_Ialomita (DestCom).
In the right-bottom table of the window, there are showed the location of the bee-families after the scheduled beehive moving. For example, within the city of Calarasi, initially having 4852 existing bee-families (FamEx in the right-top table), and after the scheduled beehive moving left 4362 bee-families (FamEx in the right-bottom table), because the rapeseed crop area in Calarasi is enough only for 4362 bee-families (FamRes in the right-bottom table). That bee-family location may be modified according to the field situation (if the beehive did not move according to the schedule) and become the input location for the next season scheduling (e.g. robinia-tree).

CONCLUSIONS

The beekeepers’ associations need a computerised pastoral beekeeping planning support system for scheduling the efficient common use of the available melliferous resources within a large region of country.

The main characteristics of the pastoral beekeeping planning problem (uncertainties concerning the data, knowledge and management, multi-criteria character of decisions, problem overall complexity et al.) determine it to be considered a "poorly-structured" problem.

Consequently, some requirements for a pastoral beekeeping planning system are needed: reduced requirements regarding the input data (available and easily to be obtained) and the user knowledge needed to system use; the system implementation approach is necessary to be that of a "decision support system" type, respectively based on a strong interactivity with the user, which has to be included within the decision process.

The pastoral beekeeping planning model elaborated corresponds to these requirements, ensuring an optimal allocation, in each gathering season, of the necessary melliferous resources for the existing bee-families, in the conditions of minimising the beehive moving distances.

The planning model could be improved primarily by the elaboration of a GIS-based version, comprising the spatial layers of communes and forest-bodies, and the calculation of the distances used in the scheduling algorithm by applying the appropriate GIS function on the road layer.

It is advantageously that a pastoral beekeeping planning support system to be implemented as an open system, by using the "prototype" method (adaptive-evolving development and implementation of the system): the prototype is a first variant of the requested system, which has its essential characteristics, at least in an incipient way; it is more rapidly and economically built, but in such a way to be easily modified; then, step by step, the prototype is extended with new functions and improved during its utilization, as it is evaluated by users in real conditions.

The method is useful because of initial uncertainties on system detailed requirements.

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