A FUZZY DECISION SUPPORT SYSTEM EVALUATING QUALITATIVE ATTRIBUTES TOWARDS FOREST FIRE RISK ESTIMATION

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Abstract

This paper aims in the design and development of a Decision Support System performing forest fire risk estimation of forest departments in Greece. The system applies a Fuzzy Logic model that considers a variety of independent variables. This approach takes into consideration the center of gravity of every independent variable, in order to produce various scenarios, having the advantage of evaluating different kind of data. It can also evaluate the human experience in order to estimate the degree of forest fire risk, caused by each involved factor. In this way proper Fuzzy Sets are produced. Finally Partial Risk Indices are produced that express the degree of forest fire risk due to each involved parameter separately. Each department is assigned many Partial Risk Indices which are unified (under different perspectives) using Fuzzy conjunction operators (T-Norms). This is done towards the production of a Unified Forest Fire Risk Index for each area.

1. Introduction

Forest Fire Risk estimation is a major issue. This project deals with the construction of a fuzzy model, applied by a prototype Decision Support System (DSS) in order to evaluate the Degree of Forest Fire Risk (DFFR) for the Greek forest **departments**.

The *FFRDSS* (**F**orest **F**ire **R**isk **D**ecision **S**upport **S**ystem*)* aims in offering a more flexible and more sophisticated approach closer to the real world. Most of the forest fire risk estimation methods till now use statistical analysis to produce results

The *FFRDSS* applies Fuzzy Algebra and Fuzzy Set theory concepts that offer a flexible way of modelling, using proper Linguistics. Fuzzy Logic was introduced by Zadeh in 1965 (Kandel 1992). The use of Fuzzy numbers and Fuzzy Sets offered the scientists powerful tools for performing ranking tasks (Kandel 1992).

This study works towards two complementary parallel directions. The first direction involves the determination of the main $\underline{n}$ Risk Factors (RF) affecting the specific Risk problem. For each RF a Fuzzy Set is formed using different Fuzzy Set Membership functions. After the first task is completed we can come to a conclusion about which reasons make each area risky or not. But we do not have a clear view of its overall Forest Fire Risk. The main task though which is the determination of the unique Unified Risk Index (URI) that expresses an overall indication concerning the Forest Fire Risk of the Forest Department is still not accomplished. The URI is obtained by using the human experience to give values to each Risk Factor in order to express its importance to the URI. Furthermore by applying five different types of *Fuzzy Relations* which are called T-Norms and they operate conjunction between the Fuzzy Sets (and consequently between the Partial Risk Indices) under different perspectives the final URI is produced.

2. Materials and Methods

2.1 Research area

The research area where the DSS has been applied to estimate Forest Fire Risk is Greece. Data has been gathered from Greek public services who are responsible for meteorological and morphology data. This research is an initiative study in order to use all the possible data that can be gathered. In order to produce better results the information given by Forest departments had to be processed and the data tables to be altered and rebuilt so that they would be more understandable and useful. Data from every forest fire is used for this method and combined with human experience.

Table 1: 10 first results of semi-Triangular FMF of each one T-NORM

Forest department	Alg. Product	Forest department	Minimum
STAVROU	0,082217	LARISAS	0,621951
LAVRIOU	0,078987	STAVROU	0,579268
DEP. ARTAS	0,055232	KABALAS	0,555412
LARISAS	0,041577	THIBON	0,552846
THIBON	0,038553	PARNITHAS	0,539199
PARNITHAS	0,031551	LAVRIOU	0,484218
EGALEO	0,030420	DEP. CHANION	0,454051
KASANDRAS	0,029199	KOZNAIS	0,436891
GOUMENITSIS	0,028262	PATRON	0,432100
DEP. KEFALLINIAS	0,024493	LAGADA	0,429878
Forest department	**Drastic Product**	**Forest department**	**Einstein product**
LARISAS	0,621951	STAVROU	0,047387
STAVROU	0,579268	LAVRIOU	0,045264
PARNITHAS	0,539199	DEP. ARTAS	0,028057
LAVRIOU	0,484218	LARISAS	0,020303
DEP. CHANION	0,454051	THIBON	0,016836
PATRON	0,432100	PARNITHAS	0,015064
DEP IRAKLIOU	0,407409	KASANDRAS	0,013907
PIRGOU	0,402300	EGALEO	0,012591
DEP. KEFALLINIAS	0,360801	DEP. KEFALLINIAS	0,011464
DEP. KERKIRAS	0,335366	GOUMENITSIS	0,011412
Forest department	**Hamacher product**		
STAVROU	0,025148		
LAVRIOU	0,024233		
DEP. ARTAS	0,018198		
THIBON	0,014192		
LARISAS	0,014052		
EGALEO	0,011746		
GOUMENITSIS	0,011173		
PARNITHAS	0,010832		
KASANDRAS	0,010044		
KILKIS	0,008916		

Due to the lack of information from Greek public services the study concerns a past period of time. The information used is about the forest fire incidents of a period between 1983 and 1987. The results are stored each time on different tables so that the comparisons with reality are easier. The table above (Table 1) is a sample of the results given by using the semi-Triangular FMF and shows the first 10 results of each one of the five T-NORMS

2.2 The Partial Risk estimation model

The problem of Forest Fire risk estimation is quite composite due to the fact that several independent parameters of uneven contribution are involved. Another major difficulty is the fact that the DFFR is not directly measurable in a structured manner. Thus, a model has to be built to encapsulate the effect of each parameter separately and to produce a unified index that will serve as an overall Forest Fire risk indicator. This index will be a pure number from 0 to 1. Of course this modelling effort should be as flexible as possible, considering the problem under different perspectives.

Such modelling problems can be faced using two different algebraic modelling approaches. The one uses crisp Sets (Leondes, 1998) and it has the great disadvantage of using specific boundaries. Boolean logic is a logic of discrete variables whereas with Fuzzy Logic we can represent elastic and imprecise concepts as high risk, a long duration, a tall person, a large transaction volume (Cox, 2005). According to the crisp approach a forest department with an average of 25^{o}C temperature may be considered as "extremely hot" but another with 24.999 ^{o}C may be characterised simply as "hot area". Cases that belong to the boundaries are always a problem when crisp Sets are applied. The following function 1 defines a crisp Set. In crisp sets a function of this type is also called *characteristic function.*(Iliadis, 2005), (Iliadis, Spartalis, 2005)

$$\mu_s(X) = \begin{cases} 1, \text{if } X \in S \\ 0, \text{if } X \notin S \end{cases}$$

Function 1

On the other hand the approach proposed in this paper and in (Iliadis et. al. 2004) uses Fuzzy Sets (FS) which can be used to produce the rational and sensible clustering (Kandel, 1992). Fuzzy Logic (FL) is widely used in various fields of engineering, decision support and data analysis applications. A survey done in 1994 identified a total of 684 such applications in Europe (Kecman, 2001).

FL is a tool for modelling human knowledge and real world concepts. The world we are living in is not binary. For example in real life, people are not divided only into "good" and "bad" and there is a whole spectrum of colours between black and white. The modelling of the concept "Hot area" in terms of Average Temperature is both subjective and imprecise so it can be considered as a FS. It is clear that proper linguistics can be used to describe real world situations and that for each linguistic a corresponding FS can be defined. For FS there exists a degree of membership (DOM) $\mu(X)$ that is mapped on [0,1]. For example every forest department belongs to the FS "*Fire Risky* forest department" with a different degree of membership (Kandel, 1992). The functions that determine the DOM are called Fuzzy Membership functions (FMF). The FMF that have been applied in this research effort are the *Trapezoidal (TRAPMF), the Triangular (TRIAMF) and the Sigmoidal (SIMF).* Functions 2 and 3 represent the TRIAMF and the TRAPMF functions respectively (Kecman 2001) while function 4 the SIMF (Iliadis et al. 2005), (Iliadis et al., 2005)

$$\mu_s(X) = \begin{cases} 0 \text{ if } X < a \\ (X - a)/(c - a) \text{ if } X \in [a, c] \\ (b - X)/(b - c) \text{ if } X \in [c, b] \\ 0 \text{ if } X > b \end{cases}$$

Function 2

$$\mu_s(X) = \begin{cases} 0, & \text{if } X \le a \\ (X - a)/(m - a), & \text{if } X \in (a, m) \\ 1, & \text{if } X \in [m, n] \\ (b - X)/(b - n), & \text{if } X \in (n, b) \\ 0, & \text{if } X \ge b \end{cases}$$

Function 3

$$f(x, a, c) = \frac{1}{1 + e^{-a(x-c)}}$$

Function 4

The next figure 1, shows the definition of four Linguistics related to the Average Temperature of an area under study. It is obvious that a Forest Department can be characterised as "Cold area" with a DOM=0.7 and also as "Hot area" with a DOM=0.1. No specific and absolute boundaries are drawn. This real life situation is described in a most realistic way using the proper Linguistics (Kahlert and Frank, 1994).

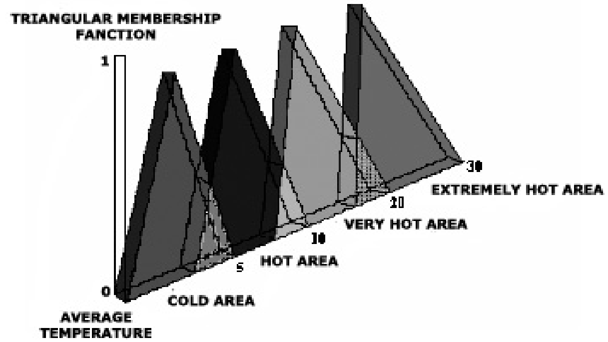


Figure 1: Definition of the Fuzzy set "Hot area" using Triangular Membership Function

The use of the TRIAMF offers only one peak, which means that only one area will have the highest risk value, whereas the TRAPMF can assign high risk to many areas. So our system acts as an actual consultant of the human expert, offering various dynamic views of the problem, rather than a single risk value.

It has been clarified so far that the model applies three different FMF in order to estimate the degree of membership of the <u>m</u> Forest Departments under examination, to each of the <u>n</u> corresponding Fuzzy Sets. In this way each watershed is assigned <u>n</u> real numbers (ranging from 0 to 1) that show its degree of Risk for each of the <u>n</u> Risk factors respectively. Each Forest Department can belong to all of the <u>n</u> corresponding Fuzzy Sets with a different degree of membership. Consequently the following two-dimensional Risk matrix 1 ($n \times m$) is formed for each FMF, containing the produced Risk indices. Totally three similar Matrices are formed.

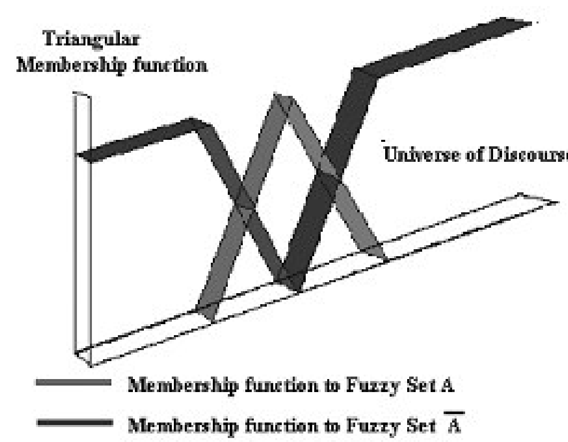


Figure 2: A fuzzy Set A and its complement Ā using *TRIAMF*

Matrix 1: Risk Degree Matrix

$$\mu(X_{ij}) = \begin{bmatrix} \mu_{11} & \mu_{12} & \ldots\ldots & \mu_{1n} \\ \mu_{21} & \mu_{22} & \ldots\ldots & \mu_{2n} \\ \ldots\ldots & \ldots\ldots & \ldots\ldots & \ldots\ldots \\ \mu_{m1} & \mu_{m2} & \ldots\ldots & \mu_{mn} \end{bmatrix}$$

where i = 1 to m and j = 1 to n

In this way the System assigns each Forest Department several Partial Risk Indices (PRI). So if the system evaluates the impact of five different parameters to the problem of Torrential risk, it produces five different PRI for each watershed. Each area can be very risky due to one factor and not risky at all due to another.

2.3 Risk factors involved

When making estimations about Forest Fires then two different Risk indicators have to be taken under consideration. The first one is about the speed with which the fire spreads and the second one is about the frequency of total fires in an area during a specific period of time. The factors that affect each risk indicator are numerous and most of them are difficult to measure or need to be measured for a long period of time. Also some of them are not easy to be represented in numbers. This project examines the Frequency risk indicator. The most important morphometric and climate characteristics that influence it are the temperature, the humidity, the vegetation (considering its density and its kind), the maximum altitude, the minimum altitude, the average altitude, the average slope of the area. There are also human factors that influence the frequency of fire incidents such as the population of a place, the number of tourists each year and the land value.

Table 2: T-Norms used in the project

1. *Minimum Approach* $URI = MIN(\mu_A(X), \mu_B(X), \ldots\ldots \mu_N(X))$
2. *Algebraic Product* $URI = \mu_A(X) * \mu_B(X) * \ldots\ldots\ldots * \mu_N(X)$
3. *Drastic Product* $URI = \begin{matrix} MIN(\mu_A(X), \mu_B(X), \ldots\ldots, \mu_N(X)).. \\ if..MAX(\mu_A(X), \mu_B(X), \ldots\ldots, \mu_N(X)) = 1 \end{matrix}$ otherwise URI = 0
4. *Einstein Product* URI= $\dfrac{\mu_A(X) * \mu_B(X) * \ldots \mu_N(X)}{2 - (\mu_A(X) + \mu_B(X) + \ldots \mu_N(X) - \mu_A(X) * \mu_B(X) * \ldots * \mu_N(X))}$
5. *Hamacher Product* URI= $\dfrac{\mu_A(X) * \mu_B(X) * \ldots \mu_N(X)}{(\mu_A(X) + \mu_B(X) + \ldots \mu_N(X) - \mu_A(X) * \mu_B(X) * \ldots * \mu_N(X))}$

The *FFRDSS* in order to produce the fire frequency risk takes into consideration the following five:

1. The Human factor which is represented as an integer from 1 to 5, with 5 being the most risky area due to its urban development to the size of its population or to its tourism.
2. The percentage of forest cover, not considering the kind of vegetation due to the lack of that kind information in Greece.
3. The average temperature of each Forest department.
4. The average humidity of each Forest department.
5. The average height of each Forest department.

Consequently, the following five FS have been formed, corresponding to the independent parameters. FS_1 = {High risky Forest Department due to human factor}, FS_2 = {High forested Forest Department}, FS_3 = {High temperature Forest Department}, FS_4 = {High humidity Forest Department} and FS_5 = {High altitude Forest department}. The four FMFs 2,3,4,5 have been used to determine the DOM of each Forest Department to each FS. All of the calculated DOM constitute the Partial Risk Indices vector.

2.4 The Risk Unification Model

The determination of the PRI is the first important step. The major step towards the final target is the unification of the PRI in order to produce the URI.

This means that specific Fuzzy conjunction operators have been applied towards the unification of the five FS. Thus according to (Kecman, 2001) the operation (FS_1 AND FS_2 AND FS_3 AND FS_4 AND FS_5) has been executed and the FS "Forest Fire Risky Forest Department" has been produced. Thus, the conjunction operation has been performed using all types of unification operations of Fuzzy Algebra (T-Norms). The highest value of the URI equals to one whereas the lowest equals to zero. Various T-Norms have been applied in order to unify the five FS. The above Table 2 presents the T-Norms that have been used for this purpose on this project.

Each of the T-Norms produces a Unified Risk Index, acting under a different perspective. For example the Min T-Norm considers the minimum DOM as the URI, whereas the Algebraic Product acts as an overall risk estimator and the Drastic Product considers the DOM of the Forest Department with the most extreme value as the URI. This can be very useful because each Unified Risk Index expresses a valid DTR under a different point of view.

2.5 Factors' importance

While trying to produce the URI another detail has to be taken under consideration. Each of the five factors given in the data table does not influence the risk indicator in the same way. Some of them influence it in a greater way while some others in a smaller way. For example an area might be of a high risk because of its high average temperature and its morphometric characteristics but very low risk due its luck of tourism, while another one might be extremely low risky because of the temperature and the morphometric characteristics but have a great number of tourists every year. When trying to compare these two areas it would be easy to say that the one with the touristic activity is of higher risk. The problem becomes more difficult when taking into consideration the population of an area and its touristic value. Places with considerable tourism or a great amount of habitats have to be categorized. This project tries for the first time to evaluate this relationship between the factors and the final unified risk indicator. In order to do such a thing the partial risk indicator x for each of the five factors has to be replaced with the following function 5.

$$f(x,a) = x^{1/w}$$

Function 5

Where x is the number between 0 and 1 produced by any of the three FMFs and w is a proper real weight between 0.00001 and 1 which is provided each time by the user. In order to provide more realistic results this stage takes advantage of the human's experience.

The greater value for variable w given to each one of the five factors the greater its influence will be to the final URI. The user is free to give a different w value for each of the factors in order to produce various scenarios. After examining the final results with reality and the total amount of fire instances every year for each of the Forest Departments the user can come to a conclusion about the way each of those five factors influence the frequency of fire instances and which one is the most or the least important.

2.6 Final results

Data was gathered from Greek Forest Departments and it was given in separate annual tables. Each year's data table was used separately and produced its own partial risk indices and unified DFFR index. This resulted in the annual classification of the Greek Forest Departments. The DSS was made to produce one unified DFFR for every department, so the results of this classification were collected, inserted in a new database and recalculated by using the average value for every risk factor separately. After this each Forest Department was assigned only one unified DFFR.

3. The software

A Decision Support System (DSS) has been developed using the relational database Microsoft Access and it is compatible with version 2002 and later. The Access environment was used due to the fact that the reasoning of the System is quite straightforward and there are no complicated or special Rules involved in it, whereas the data are the main key concept leading the System to the goal. Consequently it is a data driven DSS.

All data have been stored in properly designed Tables that follow the principles of the first three Normal forms (Date, 1990). The functions of the Mathematical model have been performed using single and multiple Queries written in the Structured Query Language (SQL). The system uses a very friendly Graphical user interface and its results are obtained in a straightforward manner. The input and the output are being performed by simply using Access forms and Command Buttons.

The potential user does not need any special experience in Computers to run the System and he does not have any access to the protected core of the System. On the other hand the user has to know the basics of forest fires and also to be able to evaluate the weight value of each new factor that he uses.

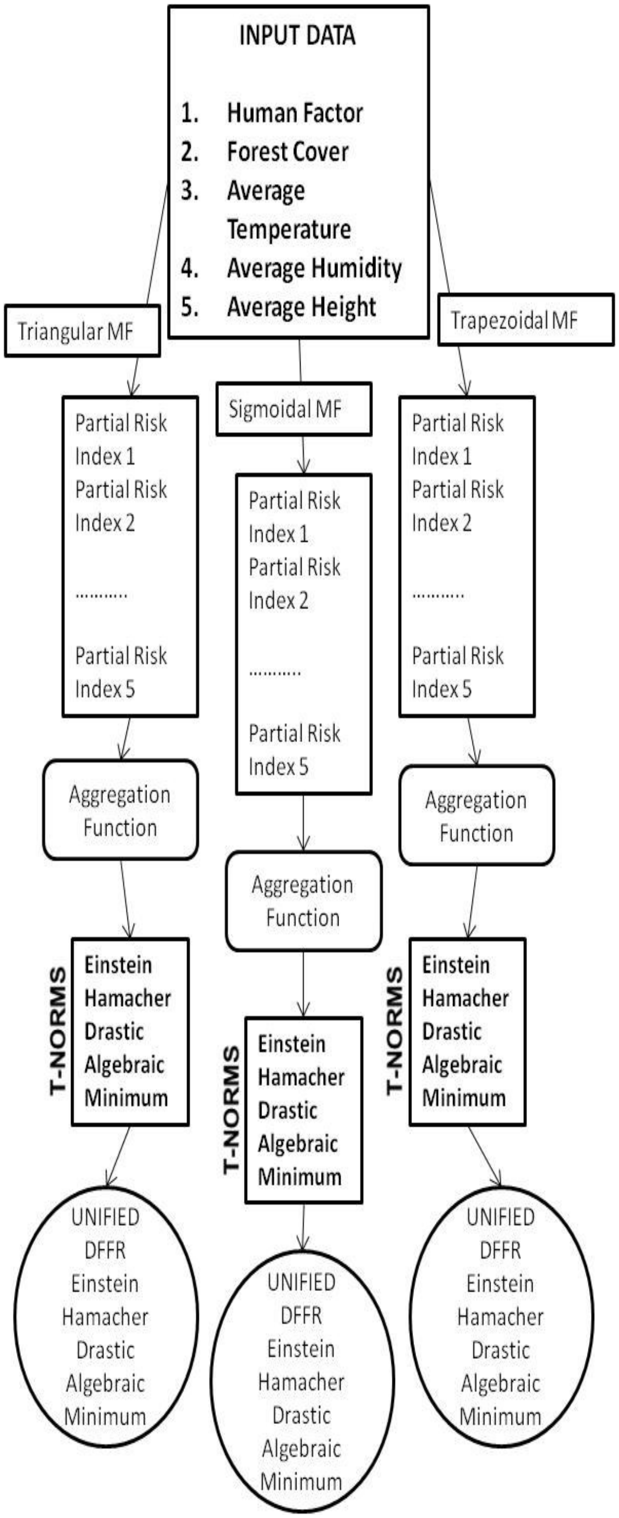
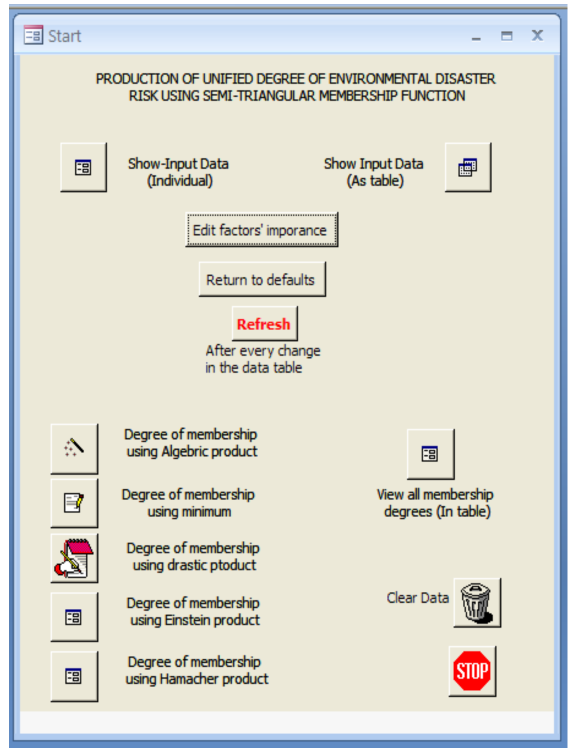


Figure 3. The structure and the logical functionality of the FFRDSS



Screen 1: A screen from the System's Interface

4 RESULTS AND DISCUSSION

.4.1 Results

Obviously the total number of results cannot be presented in a paper. The results depend on the values given by the user on the importance table that will give the final results after the aggregation function. A great number of tests have been made in order to find the best combination of values to use on the importance table.

The first step is to extract results without taking into consideration the importance of each factor to the final Forest Fire Risk. Each factor was given the same weight value w=1 in the aggregation function. The results were inaccurate in the meaning of not being able to come close to the real classification of Risky Forest Departments. This step is represented in the next table (Table 3).

It is obvious that the various T-NORMS used by the model work well with each other and produce similar results. The compatibility between them is good, but the compatibility with the real distribution of the Forest Departments considering the annual average number of forest fires is not good enough. Forest

Table 3. Assuming each of the factors has the same influence to the final DFFR (w=1 for all five factors)

Semi - Triangular FMF		
algebraic product	minimum	drastic product
PENTELIS	PENTELIS	PENTELIS
LAVRIOU	THIVON	LAVRIOU
THIVON	LARISAS	A.D. SAMOU
A.D. DODEKANISOU	PIRAIA	PARNITHAS
A.D. XIOU	LAVRIOU	STAVROU
A.D. XANION	TRIKALON	A.D. XANION
MEGARON	KAVALAS	A.D. IRAKLEIOU
PIRAIA	IOANNINON	A.D. KERKIRAS
PARNITHAS	CHALKIDAS	A.D. DODEKANISOU
A.D. SAMOU	BOLOU	A.D. LESBOU
Einstein product	Hamacher product	
PENTELIS	PENTELIS	
LAVRIOU	LAVRIOU	
THIVON	THIVON	
A.D. DODEKANISOU	A.D. DODEKANISOU	
A.D. XIOU	A.D. XIOU	
A.D. XANION	A.D. XANION	
MEGARON	MEGARON	
PARNITHAS	PIRAIA	
PIRAIA	PARNITHAS	
A.D. SAMOU	A.D. SAMOU	

Department "PENTELIS" is 31st in reality, "LAVRIOU" is at place 62nd, "A.D. DODEKANISOU" is 31st, "THIVON" is 20th and "A.D. XANION" is 5th. It is a fact it is almost impossible to predict the exact risk order of any Forest Department, because the factors that influence the results are much unpredictable. In spite of that when a Department is shown in the nth position out of 104 Departments in the result table it should be in the n±10 position in reality. Having that in mind the compatibility of the system to the reality is a bit lower than 29%. These results show, obviously, that assuming that each of the five factors used in this project has the same influence to the final Unified Forest Fire Risk does not produce the right results.

In order to find a satisfactory model which will produce good enough results various hypothetical cases had to be made. Using common sense it is obvious that from the five factors used to produce the results, the one that influences the most the number of fire incidents in an area is the human factor. By keeping a high value of w=1 for that factor and by giving lower values to the other 4 factors the results come much closer to reality. Using the next "set a" (table 4) of values, shown in table 4, for the aggregation function the results acquire a compatibility of about 45%.

Table 4. "Set a"

Factor	Variable w
Human Factor	1,0
Forest Cover	0,4
Avg. Temperature	0,3
Avg. Humidity	0,8
Avg. Height	0,2

It becomes clear that by using different sets of values for variable w in the aggregation function the system produces different DFFR indexes. In order to be effective the system needs the human experience. Using the "set b" (table 5) of values on table 5 the system produced the best compatibility of about 55% to reality.

Table 5. "Set b"

Factor	Variable w
Human Factor	1,0
Forest Cover	0,4
Avg. Temperature	0,1
Avg. Humidity	0,3
Avg. Height	0,5

4.2 Discussion on the aggregation operators

The comparative test has not been performed to prove the efficiency of *FFRDSS* but to examine under which FMF and T-Norms it comes closest to reality. The fact that it considers several dynamic and static risk factors and that it can be expanded to use as many parameters as the user wants (as long as respective data exist) makes it a valuable tool. *FFRDSS* also, depending on the T-Norm used, either considers the risk factors evenly in order to produce an average risk index (in the cases of the Hamacher or Einstein Products), or it assigns a very high or a very low risk index to Forest Department having extreme values in one or more factors (in the case of the Drastic Product), or it considers mostly the minimum values (in the case of the Minimum T-Norm). But the most important parameter of this DSS is that it can take advantage of the user's experience. By using the aggregation function to give different 'importance values' the user can manipulate his data the way he likes. Every factor that influences the Unified DFFR has its own participation to it whether it is a great one or a little one. The user can freely change this influence with *FFRDSS*. When taking into consideration a new factor for the first time, the user is free to estimate its influence to the final DFFR using his experience, so this DSS is not limited only to the factors of this paper.

This means that our model looks at the problem under various different perspectives. So by using this decision support system one can estimate the most risky areas in a dynamic way. An example is a case of an area (a Forest department distinct in our case) that in the last few years has developed either its tourism or has grown its population. Even if its forests are burned partly and the vegetation coverage is decreased this place will be at higher risk due to the other two factors.

This means that the *FFRDSS* locates the Forest Departments that are risky due to extreme values of one or more factors, and it also points the areas that have a high risk value due to the combination of the values of all the considered parameters. It is obvious that because of this system's philosophy the levels of compatibility to the reality could be as much higher as the number of factors used and the users own experience. It is an approach that tries to take advantage of almost any factor that could be translated to a number.

In our case the data provided concern only a few years. Also the lack of information about the dominant tree species in every Forest Department, which is a great factor considering the frequency of fire incidents, results in a moderate compatibility of the system to the real ranking of the forest departments based on the annual number of forest fires. We can argue that the compatibility is quite high, considering the fact that our data cover only a three year period.

From this point of view and due to the limitations that we have already mentioned this study can be considered as a preliminary one. It will evolve in the near future as more forest fire data will be available. The greater and the more accurate data is given to the system the more accurate its results will be. The difficulty appears when the user has to decide the effectiveness of each factor to the Unified DFFR. For that reason future upgrades of this DSS will concentrate on making it capable of choosing on its own which combination of FMFs and T-Norms to use, depending on the area studied and the data given, and also to be able to provide the user specific universal weight values for the most common forest fire factors.

4.3 Analysis of risky areas

Below (In Table 6) are given some examples of Forest Departments that are risky or non risky for one or more factors and are chosen to be analyzed according to their characteristics that make them risky for all methodologies.

Table 6. Examples

Forest Department	Applied T-Norms	Morphometric and Human factors of Forest Departments
A.D. KEFALLINIAS	AP-DP-Ham-Eins-Min	Very high risk due to human factor 5, high risk due to average temperature 23,77oC, low risk due to average humidity 52,41%, moderate risk due to average altitude 260, high risk due to average vagetation coverage value 1,71
A.D. ZAKINTHOU	AP-DP-Ham-Eins-Min	Moderate risk due to human factor 3, high risk due to average temperature 23,42oC, low risk due to average humidity 59,15%, moderate risk due to average altitude 277, moderate risk due to average vagetation coverage value 1,19
MESSOLOGIOU	AP-DP-Ham-Eins-Min	Moderate risk due to human factor 3, high risk due to average temperature 25,34oC, moderate risk due to average humidity 41,73%, moderate risk due to average altitude 244, high risk due to average vagetation coverage value 1,43
AMALIADAS	AP-DP-Ham-Eins-Min	Moderate risk due to human factor 3, high risk due to average temperature 27,78oC, moderate risk due to average humidity 40,63%, high risk due to average altitude 162, moderate risk due to average vagetation coverage value 1,26

5. Conclusions

The System produces similar characterisations in the cases of the Trapezoidal and Triangular MF and different in cases of Sigmoid MF. So there seem to be two different clusters of Risky areas. The first is the cluster of the Triangular-Trapezoidal MF and the second is the cluster of the Sigmoid MF. The final determination of the most suitable and accurate cluster will become through the years as the research goes on, comparing to the actual risky forest departments. A large amount of more accurate data is essential in order to produce realistic results. Despite that there are always many unpredictable factors when trying to calculate the risk for the frequency of fire incidents in an area. This is a fact that makes this system just a tool to help organize and distribute manpower and vehicles in order to help the fast and easy fire detection and extinguishment.

A very important aspect of the System is that it has been designed to use as many parameters as possible. So it can be easily adjusted to incorporate more than five independent parameters if data is available. This fact makes the DSS very flexible.

Our first future priority is to gather more annual data on forest fires considering more parameters and to test the systems again using them.

As explained in the previous chapter, the percentage of agreement of the *FFRDSS* to the reality is interesting but it is not a measure of the *FFRDSS*'s validity. It is a System that views the problem of Forest Fire Risk under different angles. The optimal MF and T-Norm for each area should be determined after years of testing and experience. A second future extension of the DSS can be its integration with a GIS system that will output the results to a geographical Database (Bunch and Dudycha, 2004), (Portoghese,2005),(Regli, 2004) probably operating in the web (Salewicz., 2004).

6. References

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