Fuzzy Logic Combined with Dempster-Shafer Theory for African Trypanosomiasis Spreading Prediction

Andino Maseleno, Md. Mahmud Hasan, Norjaidi Tuah, Fauzi and Muhammad Muslihudin

Abstract: This paper presents Fuzzy Logic and Dempster-Shafer belief theory to encounter the most important and unexpected enemies of the human been the epidemic diseases through the prediction of the risk of African Trypanosomiasis spreading. This work is estimated basic probability assignments using Fuzzy membership functions which capture vagueness. The advantage of this method is a new method to obtain basic probability assignment proposed based on the similarity measure between membership function. The result reveals that the system has successfully identified the risk of African Trypanosomiasis spreading. In areas which are in close proximity to Angola and Zambia, the risk of African Trypanosomiasis spreading obtained degree of belief 17.3% of very low, 19.6% of low, 18.6% of medium, 22.5% of high and 17.1% of very high. The risk of African Trypanosomiasis spreading in areas which include Angola, Botswana, Congo, Congo DRC, Malawi, Mozambique, Namibia, Tanzania, Zambia and Zimbabwe.

Key words: Fuzzy logic - Dempster-Shafer theory - The risk of disease spreading - African Trypanosomiasis

INTRODUCTION

There is an urgent need to develop better, more affordable systems for diseases that are devastating developing countries. Neglected tropical diseases kill an estimated 534,000 people worldwide every year [1]. World Health Organization reports that African Trypanosomiasis affects mostly poor populations living in remote rural areas of Africa that can be fatal if not properly treated. Sustainable elimination of African Trypanosomiasis as a public health problem is feasible and requires continuous efforts and innovative approaches. Population density and urbanization are two major factors affecting disease spreading. People who live in close proximity to one another spread diseases more quickly and easily [2]. Migration also affects the spread of encountering new diseases increases as humans move into previously uninhabited lands because of population growth, or as humans migrate into areas where they do not have resistance to certain diseases. Disease in a population increases with the density of that population. High densities makes it easier for parasites to find hosts and spread the disease. Population density is a measurement of the number of people in an area. It is an average number. Population density is calculated by dividing the number of people by area. Population density of an area may change over time. In recent decades, some cities have seen their urban centers lose population density, as residents spread farther out to suburbs and exurbs [3].

Population density affect the disease spreading within a population and other populations because a population that is very dense will generally see a faster spread of disease due to the larger amount of contact between individuals. In a population that is not very dense, close contact is much less likely to occur, thus halting the spread of the disease. Population density and growth are significant drivers for the emergence of different categories of infectious diseases [2]. Most diseases require that their host organisms come into close contact with another compatible organism in order to spread, meaning that denser populations of suitable hosts promote faster spread of a disease and that less-dense populations inhibit disease communication. Because disease prevention relies so heavily on contact between potential carriers, lower population densities have an increased chance of controlling disease spreading. Fuzzy Logic is based on the theory of Fuzzy sets [4], where an object's membership of a set is more gradual rather than just member or not a member. Fuzzy set theory
was guided by the assumption that classical sets were not natural, appropriate or useful notions in describing the real life problems, because every object encountered in this real physical world carries some degree of fuzziness. Fuzzy Logic uses the whole interval of real numbers between zero or False and one or True to develop a logic as a basis for rules of inference. The Dempster-Shafer theory originated from the concept of lower and upper probability induced by a multivalued mapping by Dempster [5, 6]. Following this work his student Glenn Shafer [7] further extended the theory in his book "A Mathematical Theory of Evidence" a more thorough explanation of belief functions. Dempster-Shafer mathematical theory of evidence is one of the important tool for decision making under uncertainty. In this research, a novel combination of Fuzzy Logic and Dempster-Shafer mathematical theory of evidence are applied to predict the risk of African Trypanosomiasis spreading. This research has considered population changes in an area to predict the risk of African Trypanosomiasis spreading. Population density in an area include very low, low, medium, high and very high.

Fuzzy Logic and Dempster-shafer Theory for African Trypanosomiasis Spreading Prediction: Implementation of the risk of African Trypanosomiasis spreading prediction in Africa. Africa is the world's second-largest and second-most-populous continent. At about 30.2 million km² including adjacent islands, it covers six percent of Earth's total surface area and 20.4% of its total land area [8]. The Africa's population is 1.1 billion in 2013, it accounts for about 15% of the world's human population [9]. Assume that the population density of five different conditions in which already known is available as shown in Table 1. Table 1 shows population density for inputs to predict the risk of African Trypanosomiasis spreading. Area1 is a population density in Angola and Area2 is a population density in Zambia.

On the basis of the description of input and output variables, this research has constructed 25 rules for the risk of African Trypanosomiasis spreading. The Fuzzy rules are nearly a series of if-then statements. These statements are derived by an expert to achieve optimum results. Following is the description of the rules of the risk of African Trypanosomiasis spreading: IF Area1 Density is [Very Low] AND Area2 Density is [Very High] THEN The Risk of African Trypanosomiasis Spreading should be [High].

Rule matrix suggest how the risk of African Trypanosomiasis spreading should be changed is shown in Figure 1.

Assume that Fuzzy ranges of population density of two areas in Africa to predict the risk of African Trypanosomiasis spreading is shown in Table 2.

There are two input variables which include Area1 and Area2 taken in this Fuzzy system. Area1 is a Fuzzy range of population density in Angola and Area2 is a Fuzzy range of population density in Zambia. These variables use different membership functions. Area1 functions which include Area1 very low, Area1 low, Area1 medium, Area1 high, Area1 very high. Area2 functions which include Area2 very low, Area2 low, Area2 medium, Area2 high, Area2 very high. Fuzzy ranges of population density of two areas in Africa to predict the risk of African Trypanosomiasis spreading can be defined as follows:

![Fig. 1: Rule matrix of the risk of African Trypanosomiasis spreading](image-url)
Table 1: Population density for inputs to predict the risk of African Trypanosomiasis spreading

<table>
<thead>
<tr>
<th>Condition</th>
<th>Area</th>
<th>Very Low</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
<th>Very High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Condition 1</td>
<td>Area1</td>
<td>11,500</td>
<td>13,500</td>
<td>16,500</td>
<td>18,000</td>
<td>21,000</td>
</tr>
<tr>
<td></td>
<td>Area2</td>
<td>9,000</td>
<td>11,500</td>
<td>12,500</td>
<td>12,750</td>
<td>14,500</td>
</tr>
<tr>
<td>Condition 2</td>
<td>Area1</td>
<td>12,000</td>
<td>14,000</td>
<td>15,000</td>
<td>17,000</td>
<td>21,000</td>
</tr>
<tr>
<td></td>
<td>Area2</td>
<td>9,500</td>
<td>9,000</td>
<td>11,000</td>
<td>12,750</td>
<td>14,500</td>
</tr>
<tr>
<td>Condition 3</td>
<td>Area1</td>
<td>12,000</td>
<td>14,000</td>
<td>15,000</td>
<td>17,000</td>
<td>20,000</td>
</tr>
<tr>
<td></td>
<td>Area2</td>
<td>9,000</td>
<td>11,500</td>
<td>12,500</td>
<td>12,750</td>
<td>14,500</td>
</tr>
<tr>
<td>Condition 4</td>
<td>Area1</td>
<td>11,000</td>
<td>13,000</td>
<td>16,000</td>
<td>18,500</td>
<td>21,500</td>
</tr>
<tr>
<td></td>
<td>Area2</td>
<td>9,500</td>
<td>12,500</td>
<td>13,500</td>
<td>17,000</td>
<td>15,500</td>
</tr>
<tr>
<td>Condition 5</td>
<td>Area1</td>
<td>12,000</td>
<td>11,000</td>
<td>14,000</td>
<td>18,000</td>
<td>21,000</td>
</tr>
<tr>
<td></td>
<td>Area2</td>
<td>9,000</td>
<td>11,500</td>
<td>12,500</td>
<td>12,750</td>
<td>14,500</td>
</tr>
</tbody>
</table>

Table 2: Fuzzy ranges of population density of two areas in Africa to predict the risk of African Trypanosomiasis spreading

<table>
<thead>
<tr>
<th>Area</th>
<th>Very Low</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
<th>Very High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area1</td>
<td>10,000</td>
<td>13,000</td>
<td>16,000</td>
<td>19,000</td>
<td>22,000</td>
</tr>
<tr>
<td>Area2</td>
<td>8,000</td>
<td>10,000</td>
<td>12,000</td>
<td>14,000</td>
<td>16,000</td>
</tr>
</tbody>
</table>

**Area1 of African Trypanosomiasis:** Area$_{1_{\text{very low}}}$ is used to define the variable very low. The weight is calculated by the following formula:

$$
\mu(\text{Area1}_{\text{very low}}[x]) = \begin{cases} 
1, & x \leq 10,000 \\
\frac{13,000-x}{13,000-10,000}, & 10,000 \leq x < 13,000 \\
0, & x \geq 13,000 
\end{cases}
$$  \quad (1)

Area$_{1_{\text{low}}}$ is used to define the variable low. The weight is calculated by the following formula:

$$
\mu(\text{Area1}_{\text{low}}[x]) = \begin{cases} 
0, & x \leq 10,000 \\
\frac{x-10,000}{13,000-10,000}, & 10,000 \leq x \leq 13,000 \\
\frac{16,000-x}{16,000-13,000}, & 13,000 \leq x \leq 16,000 
\end{cases}
$$  \quad (2)

Area$_{1_{\text{medium}}}$ is used to define the variable medium. The weight is calculated by the following formula:

$$
\mu(\text{Area1}_{\text{medium}}[x]) = \begin{cases} 
0, & x \leq 13,000 \text{ or } x \geq 16,000 \\
\frac{x-13,000}{16,000-13,000}, & 13,000 \leq x \leq 16,000 \\
\frac{19,000-x}{19,000-16,000}, & 16,000 \leq x \leq 19,000 
\end{cases}
$$  \quad (3)

Area$_{1_{\text{high}}}$ is used to define the variable high. The weight is calculated by the following formula:

$$
\mu(\text{Area1}_{\text{high}}[x]) = \begin{cases} 
0, & x \leq 16,000 \text{ or } x \geq 22,000 \\
\frac{x-16,000}{19,000-16,000}, & 16,000 \leq x \leq 19,000 \\
\frac{22,000-x}{22,000-19,000}, & 19,000 \leq x \leq 22,000 
\end{cases}
$$  \quad (4)

Area$_{1_{\text{very high}}}$ is used to define the variable very high. The weight is calculated by the following formula:
Area2 of African Trypanosomiasis: Area2\textsubscript{very low} is used to define the variable very low. The weight is calculated by the following formula:

\[
\mu(Area2_{\text{very low}}[x]) = \begin{cases} 
0, & x \leq 19,000 \\
\frac{x-19,000}{22,000-19,000}, & 19,000 \leq x \leq 22,000 \\
1, & x \geq 22,000
\end{cases} \quad (5)
\]

Area2\textsubscript{low} is used to define the variable low. The weight is calculated by the following formula:

\[
\mu(Area2_{\text{low}}[y]) = \begin{cases} 
1, & y \leq 8,000 \\
\frac{8,000-y}{10,000-8,000}, & 8,000 \leq y \leq 10,000 \\
0, & y \geq 10,000
\end{cases} \quad (6)
\]

Area2\textsubscript{medium} is used to define the variable medium. The weight is calculated by the following formula:

\[
\mu(Area2_{\text{medium}}[y]) = \begin{cases} 
0, & y \leq 10,000 \text{ or } y \geq 12,000 \\
\frac{12,000-y}{14,000-12,000}, & 12,000 \leq y \leq 14,000 \\
\frac{14,000-y}{16,000-14,000}, & 14,000 \leq y \leq 16,000
\end{cases} \quad (7)
\]

Area2\textsubscript{high} is used to define the variable high. The weight is calculated by the following formula:

\[
\mu(Area2_{\text{high}}[y]) = \begin{cases} 
0, & y \leq 12,000 \text{ or } y \geq 16,000 \\
\frac{16,000-y}{18,000-16,000}, & 16,000 \leq y \leq 18,000 \\
\frac{18,000-y}{20,000-18,000}, & 18,000 \leq y \leq 20,000 \\
1, & y \geq 20,000
\end{cases} \quad (8)
\]

Area2\textsubscript{very high} is used to define the variable very high. The weight is calculated by the following formula:

\[
\mu(Area2_{\text{very high}}[y]) = \begin{cases} 
0, & y \leq 14,000 \\
\frac{14,000-y}{16,000-14,000}, & 14,000 \leq y \leq 16,000 \\
1, & y \geq 16,000
\end{cases} \quad (9)
\]

The weighting factors of the rules of the risk of African Trypanosomiasis spreading are calculated as follows:

If Area1 Density is [Very Low] AND Area2 Density is [Very High] THEN The Risk of African Trypanosomiasis Spreading should be [High]

\[
\alpha_i = \mu(A1DVL) \cap \mu(A2DVH), \quad \alpha_i = \min(\mu(A1DVL)[11,500] \cap \mu(A2DVH)[14,500])
\]

\[
\alpha_i = \min (0.50, 0.25), \quad \alpha_i = 0.25, \quad \{\text{RSH}\} = 0.25
\]

The result of African Trypanosomiasis Fuzzy rules between Area1 versus Area2 are shown in Figure 2.
Table 3: Membership values to predict the risk of African Trypanosomiasis spreading

<table>
<thead>
<tr>
<th>Area</th>
<th>Very Low</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
<th>Very High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area1</td>
<td>0.50</td>
<td>0.833</td>
<td>0.833</td>
<td>0.666</td>
<td>0.666</td>
</tr>
<tr>
<td>Area2</td>
<td>0.50</td>
<td>0.25</td>
<td>0.75</td>
<td>0.375</td>
<td>0.25</td>
</tr>
</tbody>
</table>

Fig. 2: The result of African Trypanosomiasis Fuzzy rules between Area1 versus Area2

The similarity between Fuzzy membership function to get basic probability assignment can be calculated as shown below.

\[ \text{RSVL} = \frac{\alpha_{11} + \alpha_{16} + \alpha_{21} + \alpha_{23}}{4} = 0.4375 \]
\[ \text{RSL} = \frac{\alpha_{6} + \alpha_{12} + \alpha_{17} + \alpha_{18} + \alpha_{24}}{5} = 0.425 \]
\[ \text{RSM} = \frac{\alpha_{2} + \alpha_{7} + \alpha_{8} + \alpha_{13} + \alpha_{19} + \alpha_{22}}{6} = 0.4166 \]
\[ \text{RSH} = \frac{\alpha_{1} + \alpha_{3} + \alpha_{14} + \alpha_{20} + \alpha_{25}}{5} = 0.3832 \]
\[ \text{RSVH} = \frac{\alpha_{4} + \alpha_{5} + \alpha_{9} + \alpha_{10} + \alpha_{15}}{5} = 0.3832 \]

The risk of African Trypanosomiasis spreading should be medium, the risk of African Trypanosomiasis spreading should be high and the risk of African Trypanosomiasis spreading should be very high. The following will be shown prediction process of the risk of African Trypanosomiasis spreading.

- The risk of African Trypanosomiasis spreading should be Very Low (RSVL)
  \[ m_1 \{ \text{RSVL} \} = 0.4375, m_1 \{ \emptyset \} = 1 - 0.4375 = 0.5625 \]
- The risk of African Trypanosomiasis spreading should be Low (RSL).
  \[ m_2 \{ \text{RSL} \} = 0.425, m_2 \{ \emptyset \} = 1 - 0.425 = 0.575 \]

The calculation of the combined \( m_1 \) and \( m_2 \) is shown in Table 4. Each cell of the table contains the intersection of the corresponding propositions from \( m_1 \) and \( m_2 \) along with the product of their individual belief.

The first two bpas \( m_1 \) and \( m_2 \) are calculated to yield a new bpa \( m \), by a combination rule as follows:
The risk of African Trypanosomiasis spreading should be Medium (RSM).

\[ m_{RSM} = 0.4166, \quad m_{\emptyset} = 1 - 0.4166 = 0.5834 \]

The calculation of the combined \( m_3 \) and \( m_4 \) is shown in Table 5. Each cell of the table contains the intersection of the corresponding propositions from \( m_3 \) and \( m_4 \) along with the product of their individual belief.

The second two bpas \( m_5 \) and \( m_6 \) are calculated to yield a new bpa \( m_7 \) by a combination rule as follows:

\[ m_7 \{ RSVL \} = \frac{0.2515}{1 - 0.1065} = 0.3089, \quad m_7 \{ RSL \} = \frac{0.2390}{1 - 0.1065} = 0.2936 \]

\[ m_7 \{ \emptyset \} = \frac{0.3234}{1 - 0.1859} = 0.3972 \]

The risk of African Trypanosomiasis spreading should be High (RSH)

\[ m_6 \{ RSH \} = 0.3832, \quad m_6 \{ \emptyset \} = 1 - 0.3832 = 0.6168 \]

The calculation of the combined \( m_5 \) and \( m_6 \) is shown in Table 6. Each cell of the table contains the intersection of the corresponding propositions from \( m_5 \) and \( m_6 \) along with the product of their individual belief.

The third two bpas \( m_7 \) and \( m_8 \) are calculated to yield a new bpa \( m_9 \) by a combination rule as follows:

\[ m_9 \{ RSVL \} = \frac{0.1802}{1 - (0.1287 + 0.1223)} = 0.2405, \quad m_9 \{ RSL \} = \frac{0.1713}{1 - (0.1287 + 0.1223)} = 0.2287 \]

\[ m_9 \{ \emptyset \} = \frac{0.1655}{1 - (0.1287 + 0.1223)} = 0.2209 \]

\[ m_7 \{ RSM \} = \frac{0.2317}{1 - (0.1287 + 0.1223)} = 0.3093 \]

The risk of African Trypanosomiasis spreading should be Very High (RSVH)

\[ m_9 \{ RSVL \} = 0.3832, \quad m_9 \{ \emptyset \} = 1 - 0.3832 = 0.6168 \]

The calculation of the combined \( m_7 \) and \( m_9 \) is shown in Table 7. Each cell of the table contains the intersection of the corresponding propositions from \( m_7 \) and \( m_9 \) along with the product of their individual belief.
Table 4: The first combination of the risk of African Trypanosomiasis spreading

<table>
<thead>
<tr>
<th>$m_\alpha([RS1])$</th>
<th>0.4375</th>
</tr>
</thead>
<tbody>
<tr>
<td>$m_\beta([\emptyset])$</td>
<td>0.5623</td>
</tr>
<tr>
<td>$m_\gamma$</td>
<td>0.2390</td>
</tr>
</tbody>
</table>

Table 5: The second combination of the risk of African Trypanosomiasis spreading

<table>
<thead>
<tr>
<th>$m_\alpha([RS1])$</th>
<th>0.3089</th>
</tr>
</thead>
<tbody>
<tr>
<td>$m_\beta([\emptyset])$</td>
<td>0.2936</td>
</tr>
<tr>
<td>$m_\gamma([\emptyset])$</td>
<td>0.3972</td>
</tr>
</tbody>
</table>

Table 6: The third combination of the risk of African Trypanosomiasis spreading

<table>
<thead>
<tr>
<th>$m_\alpha([RS1])$</th>
<th>0.2405</th>
</tr>
</thead>
<tbody>
<tr>
<td>$m_\beta([\emptyset])$</td>
<td>0.2287</td>
</tr>
<tr>
<td>$m_\gamma([\emptyset])$</td>
<td>0.3093</td>
</tr>
</tbody>
</table>

Table 7: The fourth combination of the risk of African Trypanosomiasis spreading

<table>
<thead>
<tr>
<th>$m_\alpha([RS1])$</th>
<th>0.2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>$m_\beta([\emptyset])$</td>
<td>0.1918</td>
</tr>
<tr>
<td>$m_\gamma([\emptyset])$</td>
<td>0.2593</td>
</tr>
</tbody>
</table>

The fourth two bpas $m_\alpha$ and $m_\beta$ are calculated to yield a new bpa $m_\gamma$ by a combination rule as follows:

\[
m_\gamma[RSVH] = \frac{1}{1 - (0.772 + 0.735 + 0.0709 + 0.0617)} = 0.1385
\]

Finally, in Angola and Zambia, the risk of African Trypanosomiasis spreading is very low. It means the risk of African Trypanosomiasis spreading is very rare but cannot be excluded. The final ranking of the degree of belief is $0.173 > 0.165 > 0.159 > 0.138 = 0.138$. The final ranking of African Trypanosomiasis spreading is Very Low > Low > Medium > High = Very High. Figure 3 shows the risk of African Trypanosomiasis spreading. The risk of African Trypanosomiasis spreading in areas which include Angola, Botswana, Congo, Congo DRC, Malawi, Mozambique, Namibia, Tanzania, Zambia and Zimbabwe. Figure 3 shows the risk of African Trypanosomiasis spreading.
RESULTS AND DISCUSSION

Figure 4, Figure 5, Figure 6 and Figure 7 are shown graphics of the risk of African Trypanosomiasis spreading prediction in areas which are in close proximity to Angola and Zambia. Figure 4 shows condition 1 of the risk of African Trypanosomiasis spreading is very low. It means the risk of African Trypanosomiasis spreading is rare but cannot be excluded. The final ranking of the degree of belief is 0.173 > 0.165 > 0.159 > 0.138 = 0.138. It can be seen from Figure 4 that the final ranking of African Trypanosomiasis spreading is Very Low > Low > Medium > High = Very High.

Figure 5 shows condition 2 of the risk of African Trypanosomiasis spreading is low. It means the risk of African Trypanosomiasis spreading is rare but does occur. The final ranking of the degree of belief is 0.196 > 0.146 > 0.143 > 0.127 > 0.113. It can be seen from Figure 5 that the final ranking of African Trypanosomiasis spreading is Low > Medium > Very High > High = Very Low.

Figure 6 shows condition 3 of the risk of African Trypanosomiasis spreading is medium. It means the risk of African Trypanosomiasis spreading occurs regularly. The final ranking of the degree of belief is 0.186 > 0.16 > 0.151 > 0.118 > 0.109. It can be seen from Figure 6 that the final ranking of African Trypanosomiasis spreading is Medium > Low > Very Low > Very High > High.

Figure 7 shows condition 4 of the risk of African Trypanosomiasis spreading is high. It means the risk of African Trypanosomiasis spreading occurs very often. The final ranking of the degree of belief is 0.225 > 0.195 > 0.095 > 0.083 > 0.04. It can be seen from Figure 7 that the final ranking of African Trypanosomiasis spreading is High > Very High > Medium > Low > Very Low.

Figure 8 shows condition 5 of the risk of African Trypanosomiasis spreading is very high. It means the risk of African Trypanosomiasis spreading occurs almost certainly. The final ranking of the degree of belief is 0.171 > 0.170 > 0.137 > 0.124 > 0.121. It can be seen from Figure 8 that the final ranking of African Trypanosomiasis spreading is Very High > High > Medium > Low > Very Low.

Using the population density of five different conditions, the degree of belief of each condition are different in the risk of African Trypanosomiasis spreading prediction. Figure 9 shows the risk of African Trypanosomiasis spreading for each condition. The risk of African Trypanosomiasis spreading of condition 1 is very low obtained degree of belief 17.3%, the risk of
Fig. 4: Condition 1 of African Trypanosomiasis spreading prediction

African Trypanosomiasis spreading of condition 2 is low obtained degree of belief 19.6%, the risk of African Trypanosomiasis spreading of condition 3 is medium obtained degree of belief 18.6%, the risk of African Trypanosomiasis spreading of condition 4 is high obtained degree of belief 22.5%, the risk of African Trypanosomiasis spreading of condition 5 is very high obtained degree of belief 17.1%.
CONCLUSION

In this study, a novel combination of Fuzzy Logic and Dempster-Shafer mathematical theory of evidence are applied to predict the risk of African Trypanosomiasis spreading. The risk of African Trypanosomiasis spreading is not classified according to higher population density which is equal to higher risk. This research has considered population changes in an area to predict the risk of African Trypanosomiasis spreading. Population
density in an area can be very low, low, medium, high and very high. Early prediction of the risk of African Trypanosomiasis spreading is important in interrupting the transmission cycle of the parasite and progress of the disease to the late stage. Therefore, cost effective, simple, rapid, robust and reliable methods, are urgently needed. There is also an urgent need for accurate tools for prediction of the risk of African Trypanosomiasis spreading, a new initiative for the development of new diagnostic tests to support the control of African Trypanosomiasis.

This system is the provision of timely and effective information that allows individuals exposed to hazard to take action to avoid or reduce their risk and prepare for effective response. Vagueness, impreciseness and uncertainty are fundamental and indispensable aspects of knowledge, so as in many practical problems, the experts face vagueness in feature vectors and uncertainty in decision-making. Essentially, a symptom is an uncertain indication of a phenomenon as it may or may not occur with it. In other words, uncertainty characterizes a relation between symptoms and phenomena. On the other hand, the feature vectors are usually vague. Hence, uncertainty regards the relation between symptoms and phenomena, whereas vagueness represents impreciseness in the feature vectors. The Dempster-Shafer theory of evidence was developed to model uncertainties. It has the advantage of allocating belief to subsets of the universal set and a combination rule that is able to combine multi-source evidence. This is an exceptional virtue for making decisions when multi-source information is available.

REFERENCES