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FUZZY MATHEMATICAL APPROACH TO DETECT MICRONUTRIENT DEFICIENCY DISORDERS BY USING MATLAB FUNCTIONS

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Abstract

Classical theory is still inadequate to properly handle the uncertainty of failure data. In real life situation the classical theory is insufficient to covers up the deficiency caused due to the uncertainty in sampling, collection of data and variation in data. Fuzzy logic covers up the deficiency caused due to the above factors and the grading in membership function. Present paper aims to applying the fuzzy methodology to a case study that was undertaken in two randomly selected community developed blocks of Uttar Pradesh. The major objective of the study was to analyze the iodine deficiency disorders in two areas of Uttar Pradesh, one endemic and one non-endemic and to compare prevalence of Goiter in the two areas of study.

Keywords: Fuzzy logic, Micronutrients, Fuzzification, Defuzzification, Matlab Software.

1. INTRODUCTION

Micronutrients are essential for the body to maintain its normal functions. Without them the body cannot function optimally and different health problem occur. If these micronutrients are missing during phases of rapid growth, the development of basic biological functions like intellect, and even life itself can be threatened. Micronutrients, that is**,** minerals and vitamins are deficient in the diets of all age groups, particularly in preschool children. Micronutrient deficiencies like iodine, iron and vitamin A are prevalent in many cases. Iodine is one of the essential micronutrients required for normal growth and development of the human brain and body.

This trace mineral is present in a minute amount, accounting for approximately 0.00004 percent of body weight. The body contains a total of 15 to 23 mg of iodine. Over 75 percent of this is present in thyroid gland. The rest is distributed in salivary, mammary and gastric glands and the kidneys. Within the circulation, iodine occurs either in the form of free iodine ions or as protein-bound iodine. Iodine plays an important role in the triodothyronine (T_3) and thyroxine (T_4). The joint expert committee of FAO/WHO set the maximum acceptable daily intake at 1000mg/day.The National Institute of Nutrition Hyderabad had carried out a systematic study to establish a database on iodine content of Indian foods. Based on dietary pattern and analysis of raw foods it is observed that the iodine content of various regional diets ranges from 170-300 µg/day. The iodine content of fish ranges between 28 and 55 µg /100g. Only certain types of fish which are occasionally seen in the sea-coast contain more iodine 175 µg /100g than fresh water fish. The iodine content of egg is about 50 µg /100g and concentrated more in the white portion.

Endemic goiter, the iodine-deficiency disease, occurs in those areas where the iodine content of the soil is low and insufficient iodine is obtained through food and water, unless any provision is made for supplying iodized salt. Lack of iodine leads to an increase in size and number of epithelial cells in the thyroid gland and thus enlarges the gland. Cretinism occurs in the infant when the pregnant woman is so severely depleted that she cannot supply iodine for the development of the fetus. Cretinism is characterized by a low basal metabolism, muscular flabbiness and weakness, dry skin, enlarged tongue, thick lips, arrest of skeletal development, and severe mental retardation.

Wide varieties of physical and neurological disorders associated with iodine deficiency are called "Iodine Deficiency Disorders" IDD. Iodine deficiency is recognised by WHO as the most preventable cause of brain damage in the world today. IDD affect about 15 percent of the world's population, 834 million having goiter and 16.5 million cretinism (WHO 1998). A recent ICMR study indicated the average prevalence of goiter among children (6-12 years) from 15 districts was 4.78%. The prevalence of grades I and II goiter was 4.66% and 0.12 % respectively. According to Ministry of Health and Family Welfare (2002) out of 310 districts surveyed for iodine deficiency disorders, 253 districts were found endemic. Up to 1990, prevalence among children (6-12 years) averaged 26%. The problem was most severe in the eastern regions (at 50 %) and the lowest in the south (at 6%).

2. CASE STUDY

We aim at applying fuzzy methodology to a case study performed by Dr. V.K. Srivastava et.al. from King George's Medical College, Lucknow, that was undertaken in two randomly selected community developed blocks of Uttar Pradesh. The major objective of the study was to analyze the iodine deficiency disorders in two areas of Uttar Pradesh, one endemic and one non-endemic and to compare prevalence of Goiter in the two areas of study. Necessary details of the study are given below:
(i). Type of study: Community based (ii). Location: Gonda District (iii) Type of population: Rural (iv). Type of sex: Male and female (v). Age range: All ages (vi). Study design: Group comparison (vii). Sample size: 6604(endemic); 5939(non-endemic) (viii). Technique: Clinic and biochemical (ix). Procedure: T_4, TSH levels by Radio immunoassay method (x) Method of Analysis: Mean, S.D., Test of significance.
The major outcome of the study is presented below in the two tables.

Table 1: Age Wise and Sex Wise Prevalence of Goiter

Age(years)	**Sex**	**Area-I**		**Area-II**	
		Total Population	**Goiter +ve all grades (%)**	**Total Population**	**Goiter +ve all grades (%)**
0-4	M	345	6(1.7)	375	138(36.8)
	F	312	4(1.3)	285	139(48.8)
5-9	M	362	29(8.0)	372	216(58.1)
	F	319	33(10.3)	333	236(70.9)
10-14	M	324	36(11.1)	326	256(78.5)
	F	288	40(13.9)	262	220(83.9)
15-19	M	275	17(6.2)	286	169(59.0)
	F	247	19(7.7)	205	172(83.9)

Table 2: Age Wise Iodine Deficiency Disorders

Age Groups (Yrs)	Population					Population				
	Area - I	End-emic Creti-nism (%)	Hypothyroidism (%)	Cong. Anomal-ies (%)	Retard-ed Physical Growth (%)	Area-II	Ende-mic Cretinism (%)	Hypo-thyroi-dism (%)	Cong. Anomali-es (%)	Reta-rded Physi-cal Grow-th (%)
0-4	657	-	-	2(0.3)	12(1.8)	660	-	-	2(0.3)	12(1.8)
5-9	681	-	-	2(0.3)	16(2.3)	705	-	-	2(0.3)	30(4.2)
10-14	612	-	2(0.3)	2(0.3)	14(2.3)	588	-	-	3(0.5)	34(5.8)
15-19	522	-	-	-	12(2.3)	491	19(3.8)	4(0.8)	1(0.2)	24(4.9)

3. METHOD OF FUZZY ANALYSIS USED:

We now present an efficient algorithm for evaluating the systems by using fuzzy arithmetic operations. Assume that there are n criteria (i.e. C_1, C_2, C_3, -------- , C_n), and that there are m systems to be evaluated (i.e. S_1, S_2,---------S_m). Furthermore, assume that the weights are represented by a weighting vector W as,

$$\underset{\sim}{W} = (\tilde{W}_1, \tilde{W}_2, ----, \tilde{W}_m)$$

Where $\tilde{W}_1, \tilde{W}_2, ----, \tilde{W}_m$ are trapezoidal fuzzy numbers, whose values may be $\tilde{0}, \tilde{1}, \tilde{2}, ----, \tilde{9}$ defined as follows:

$$\tilde{0}=(0,0,0,0),\ \tilde{1}=(0,1,2,3),\ \tilde{2}=(1,2,3,4),\ \tilde{3}=(2,3,4,5),\ \tilde{4}=(3,4,5,6)$$

$$\tilde{5}=(4,5,6,7),\ \tilde{6}=(5,6,7,8),\ \tilde{7}=(6,7,8,9),\ \tilde{8}=(7,8,9,10),\ \tilde{9}=(8,9,10,11).$$

Further let $\tilde{V}_i$ denotes the weight of the criterion Ci, $1 \le i \le n$.

The computational procedure of the methodology is now presented as follows:

For each stage, we rank the degree of each system with respect to any integer numbers 1, 2, 3, etc. Summarize the rank score of each system with respect to the given stage, and each summarized rank score is represented by a trapezoidal fuzzy numbers. Now applying defuzzification to the trapezoidal fuzzy numbers, one gets the crisp numbers that gives the best choice of numbers for the analysis.

4. AGE WISE AND SEX WISE PREVALENCE OF GOITER FOR AREA I

First we will analyze age wise and sex wise prevalence of goiter from table1 by using the method to represent the system criteria in the form of trapezoidal fuzzy number. For all age groups of males and females, we will make trapezoidal fuzzy number around the goiter +ve cases for Area-I. Using Matlab functions and programming we get the following results:

(a) Male age group (0-4 years):

```
x=1:0.1:2.5;
y=trapmf(x, [1 1.4 2.0 2.3]);
Plot(x, y)
 xlabel('trapmf, P= [1 1.4 2.0 2.3]')
```

(b) Female age group (0-4 years):-

```
x=0:0.1:2.5;
y=trapmf(x, [0 1.1 1.6 1.9]);
Plot(x, y)
Xlabel ('tramp, P= [0 1.1 1.6 1.9]')
```

(c) Male age group (5-9 years):-

```
x=1:0.2:20;
y=trapmf(x,[1 5 11 15]);
Plot(x, y)
xlabel ('trapmf, P= [1 5 11 15]')
```

(d) Female age group (5-9 years):-

```
x=1:0.2:24;
y=trapmf(x, [1 6 14 20]);
Plot(x, y)
Xlabel ('trapmf, P= [1 6 14 20]')
```

(e) Male age group (10-14 years):-

```
x=1:0.2:24;
y=trapmf(x,[1 7 15 20]);
Plot(x, y)
xlabel ('trapmf, P= [1 7 15 20]')
```

(f) Female age group (10-14 years):-

```
x=1:0.2:28;
y=trapmf(x, [1 10 18 24]);
Plot(x, y)
Xlabel ('trapmf, P= [1 10 18 24]')
```

(g) Male age group (15-19 years):-

```
x=0:0.2:18;
y=trapmf(x, [0 3 9 14]);
Plot(x, y)
Xlabel ('trapmf, P= [0 3 9 14]')
```

(h) Female age group (15-19 years):-

```
x=0:0.2:18;
y=trapmf(x, [0 4 11 16]);
Plot(x, y)
Xlabel ('trapmf, P= [0 4 11 16]')
```

5. DEFUZZIFICATION (AGE AND SEX WISE) FOR AREA-I

(a) Union and Defuzzification of all age groups of males: -

For defuzzification, we take the fuzzy union of the trapezoidal fuzzy numbers using from section 4 for all age groups of males of area I. The resulting trapezoidal number is then defuzzified. Using Matlab:

```
x=0:.2:25;
y=trapmf(x,[0 10 15 20]);
Plot(x, y)
Xlabel ('trapmf, P= [0 10 15 20]')
mf1 = trapmf(x,[1 1.4 2.0 2.3]);
mf2 = trapmf(x,[1 5 11 15]);
mf3 = trapmf(x,[1 7 15 20]);
mf4 = trapmf(x,[0 3 9 14]);
mf1 = max (max (0.5*mf2, 0.1*mf4), max (0.9*mf1, 0.1*mf3));
Plot(x, mf1,'LineWidth', 2);
Set (gca,'YLim', [-1 1],'YTick', [0 .5 1])
x1 = defuzz(x, mf1,'centroid')
h1 = line([x1 x1],[-0.2 1.2],'Color','k');
t1 = text (x1,-0.2,' centroid','FontWeight','bold');
X1 =7.5784
```

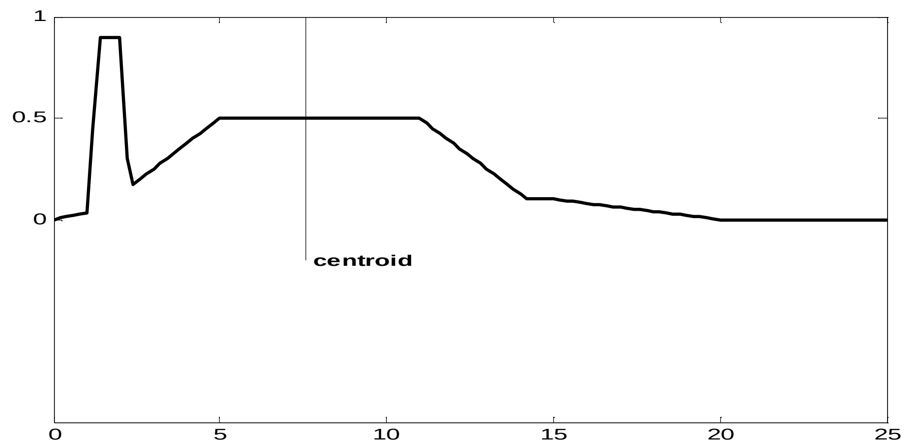

Figure 1:

This value yields the combined effect of prevalence of Goiter +ve on all age groups of males.

(b) Union and Defuzzification of all age groups of females: -

For defuzzification, we take the fuzzy union of the trapezoidal fuzzy numbers from section 4 for all age groups of females of area I. The resulting trapezoidal number is then defuzzified. Using Matlab:

```
x=0:.2:28;
y=trapmf(x, [0 12 18 28]);
plot(x,y)
Xlabel ('trapmf, P= [0 12 18 28]')
mf1 = trapmf(x,[1 1.1 1.6 1.9]);
mf2 = trapmf(x,[1 6 14 20]);
mf3 = trapmf(x,[1 10 18 24]);
mf4 = trapmf(x,[0 4 11 16]);
mf1= max (max (0.5*mf2, 0.1*mf4), max (0.9*mf1, 0.1*mf3));
Plot(x, mf1,'LineWidth', 2);
Set (gca,'YLim', [-1 1],'YTick', [0 .5 1])
X1 = defuzz(x, mf1,'centroid')
h1 = line ([x1 x1], [-0.2 1.2],'Color','k');
t1 = text (x1,-0.2,' centroid','FontWeight','bold');
X1 = 9.8413;
```

This value yields the combined effect of prevalence of Goiter +ve on all age groups of females.

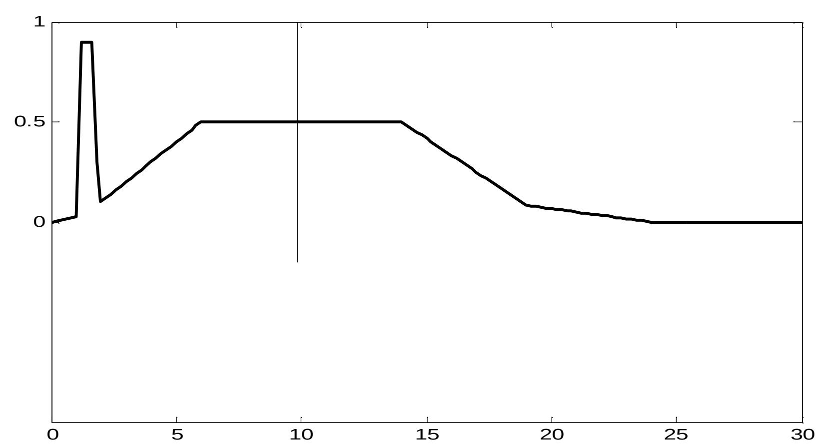

Figure 2:

6. DEFUZZIFICATION OF AGE WISE FOR AREA-I

(a) Defuzzification of Goiter +ive grades among males and females of age group (0-4 years) of area I:-

x=0:.1:3;
y=trapmf(x, [0 1 2 3]);
Plot(x, y)
xlabel('trapmf, P=[0 1 2 3]')
mf1 = trapmf(x,[1 1.4 2.0 2.3]);
mf3 = trapmf(x,[1 7 15 20]);
mf4 = trapmf(x,[0 3 9 14]);
*mf1 = max (max (0.5*mf2, 0.1*mf4), max (0.9*mf1, 0.1*mf3));*
Plot(x, mf1,'LineWidth', 2);
Set (gca,'YLim', [-1 1],'YTick', [0 .5 1])
X1 = defuzz(x, mf1,'centroid')
h1 = line ([x1 x1], [-0.2 1.2],'Color','k');
t1 = text (x1,-0.2,' centroid','FontWeight','bold');
x1 =7.5784

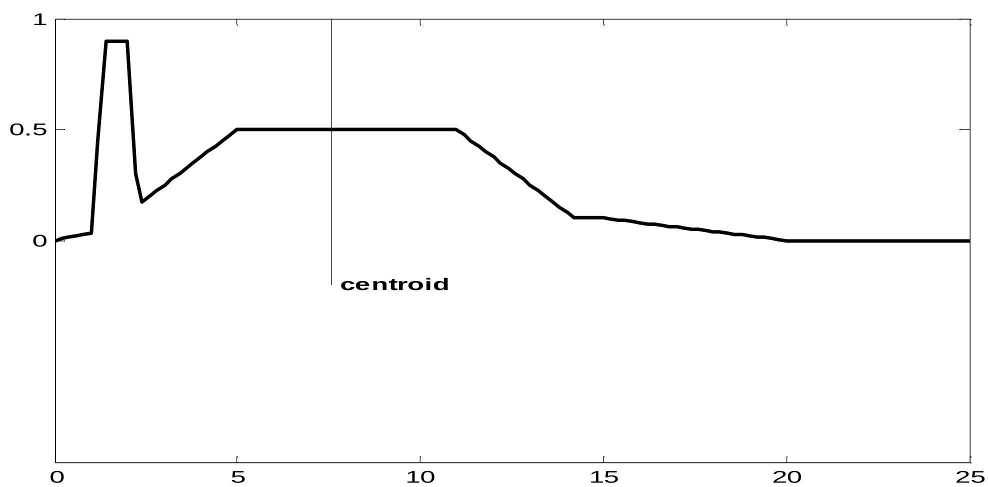

Figure 3:
This value yields the combined effect of prevalence of Goiter +ve on all age groups of males.

(b) Union and Defuzzification of all age groups of females: -
For defuzzification, we take the fuzzy union of the trapezoidal fuzzy numbers from section 4 for all age groups of females of area I. The resulting trapezoidal number is then defuzzified. Using Matlab:

x=0:.2:28;
y=trapmf(x, [0 12 18 28]);
Plot(x, y)
Xlabel ('trapmf, P= [0 12 18 28]')
mf1 = trapmf(x,[1 1.1 1.6 1.9]);
mf2 = trapmf(x,[1 6 14 20]);
mf3 = trapmf(x,[1 10 18 24]);
mf4 = trapmf(x,[0 4 11 16]);
*mf1= max (max (0.5*mf2, 0.1*mf4), max (0.9*mf1, 0.1*mf3));*
Plot(x, mf1,'LineWidth', 2);
Set (gca,'YLim', [-1 1],'YTick', [0 .5 1])
X1 = defuzz(x, mf1,'centroid')
h1 = line ([x1 x1], [-0.2 1.2],'Color','k');
t1 = text (x1,-0.2,' centroid','FontWeight','bold');
x1 = 9.8413;

This value yields the combined effect of prevalence of Goiter +ve on all age groups of females.

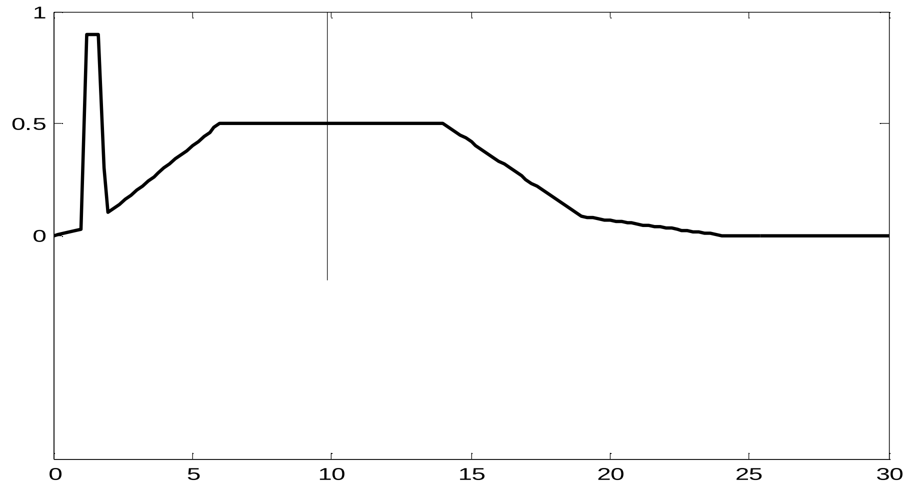

Figure 4:

(c) Defuzzification of Goiter +ive grades among males and females of age group (10-14 years):-

x=0:1:30;
y=trapmf(x, [0 10 20 30]);
Plot(x, y)
xlabel('trapmf, P=[0 10 20 30]')
mf1 = trapmf(x,[1 7 15 20]);
mf2 = trapmf(x,[1 10 18 24]);
*mf1 = max(0.5*mf2,max(0.9*mf1,0.1*mf2));*
Plot(x, mf1,'LineWidth', 2);
Set (gca,'YLim', [-1 1],'YTick', [0 .5 1])
X1 = defuzz(x, mf1,'centroid')
h1 = line ([x1 x1], [-0.2 1.2],'Color','k');
t1 = text (x1,-0.2,' centroid','FontWeight','bold');
X1 = 11.5806

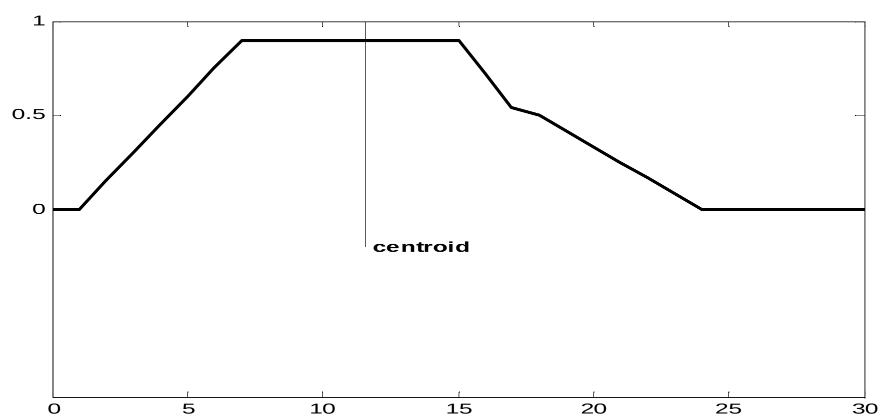

Figure 5:

This value yields the combined effect of prevalence of Goiter +ve on the age groups of 10-14, irrespective of the sex.

(d) Defuzzification of Goiter +ive grades among males and females of age group (15-19 years):-

x=0:1:20;
y=trapmf(x, [0 7 14 20]);

```
Plot(x, y)
xlabel('trapmf, P=[0 7 14 20]')
mf1 = trapmf(x,[0 3 9 14]);
mf2 = trapmf(x,[0 4 11 16]);
mf1 = max(0.5*mf2,max(0.9*mf1,0.1*mf2));
Plot(x, mf1,'LineWidth', 2);
Set (gca,'YLim', [-1 1],'YTick', [0 .5 1])
x1 = defuzz(x,mf1,'centroid')
h1 = line ([x1 x1], [-0.2 1.2],'Color','k');
t1 = text (x1,-0.2,' centroid','FontWeight','bold');
x1 =  6.9175
```

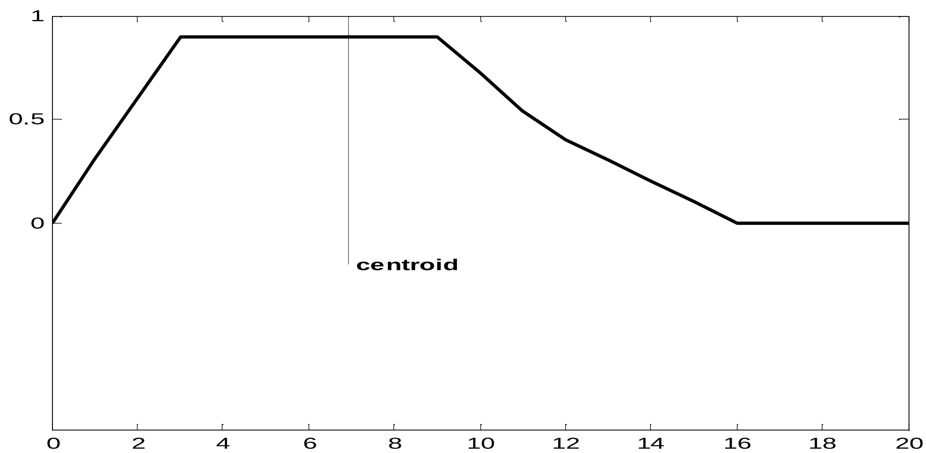

Figure 6:
This value yields the combined effect of prevalence of Goiter +ve on the age groups of 15-19, irrespective of the sex.

7. AGE WISE AND SEX WISE PREVALENCE OF GOITER FOR AREA II

Now we will analyze age wise and sex wise prevalence of goiter from table 1 by using the method to represent the system criteria in the form of trapezoidal fuzzy number. We will make trapezoidal fuzzy number around the goiter +ve cases for Area-II.

(a) Male age group (0-4 years):-

```
x=4:1:72;
y=trapmf(x, [4 26 48 68]);
Plot(x, y)
Xlabel ('trapmf, P= [4 26 48 68]')
```

(b) Female age group (0-4 years):-

```
x=6:1:86;
y=trapmf(x, [6 38 58 80]);
Plot(x, y)
Xlabel ('trapmf, P= [6 38 58 80]')
```

(c) Male age group (5-9 years):-

```
x=8:1:96;
y=trapmf(x, [8 48 68 90]);
Plot(x, y)
Xlabel ('trapmf, P= [8 48 68 90]')
```

(d) Female age group (5-9 years):-

```
x=10:1:106;
y=trapmf(x, [10 62 80 98]);
Plot(x, y)
Xlabel ('trapmf, P= [10 62 80 98]')
```

(e) Male age group (10-14 years):-
x=12:1:120;
y=trapmf(x, [12 68 88 110]);
Plot(x, y)
Xlabel ('trapmf, P= [12 68 88 110]')
(f) Female age group (10-14 years):-
x=14:1:120;
y=trapmf(x, [14 74 94 114]);
Plot(x, y)
Xlabel ('trapmf, P= [14 74 94 114]')
(g) Male age group (15-19 years):-
x=8:1:100;
y=trapmf(x, [8 50 70 90]);
Plot(x, y)
Xlabel ('trapmf, P= [8 50 70 90]')
(h) Female age group (15-19 years):-
x=14:1:120;
y=trapmf(x, [14 74 94 114]);
Plot(x, y)
Xlabel ('trapmf, P= [14 74 94 114]')

8 DEFUZZIFICATION (AGE AND SEX WISE) FOR AREA-II

(a) Union and Defuzzification of all age groups of males:
For defuzzification, we take the fuzzy union of the trapezoidal numbers for all age groups of males of area II from section 7. The resulting trapezoidal number is then defuzzified using Matlab:
x=0:1:120;
y=trapmf(x, [0 20 80 120]);
Plot(x, y)
xlabel('trapmf, P=[0 20 80 120]')
mf1 = trapmf(x,[4 26 48 68]);
mf2 = trapmf(x,[8 48 68 90]);
mf3 = trapmf(x,[12 68 88 110]);
mf4 = trapmf(x,[8 50 70 90]);
*mf1= max(max(0.5*mf2,0.1*mf4),max(0.9*mf1,0.1*mf3));*
plot(x,mf1,'LineWidth',2);
set(gca,'YLim',[-1 1],'YTick',[0 .5 1])
x1 = defuzz(x,mf1,'centroid')
h1 = line([x1 x1],[-0.2 1.2],'Color','k');
t1 = text (x1,-0.2,' centroid','FontWeight','bold');
x1 = 43.8486

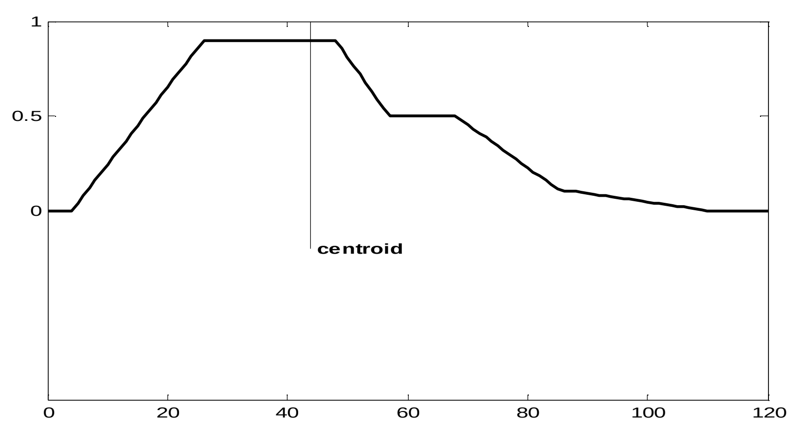

Figure 7:
This value yields the combined effect of prevalence of Goiter +ve on all age groups of males.

b) Union and Defuzzification of all age groups of females: -

For defuzzification, we take the fuzzy union of the trapezoidal numbers for all age groups of females of area II from section 7. The resulting trapezoidal number is then defuzzified. Using Matlab:

```
x=0:1:120;
y=trapmf(x,[0 20 80 120]);
Plot(x, y)
xlabel('trapmf, P=[0 20 80 120]')
mf1 = trapmf(x,[6 38 58 80]);
mf2 = trapmf(x,[10 62 80 98]);
mf3 = trapmf(x,[14 74 94 114]);
mf4 = trapmf(x,[14 74 94 114]);
mf1= max(max(0.5*mf2,0.1*mf4),max(0.9*mf1,0.1*mf3));
Plot(x, mf1,'LineWidth', 2);
set(gca,'YLim',[-1 1],'YTick',[0 .5 1])
X1 = defuzz(x,mf1,'centroid')
h1 = line([x1 x1],[-0.2 1.2],'Color','k');
t1 = text(x1,-0.2,' centroid','FontWeight','bold');
x1 =51.4122
```

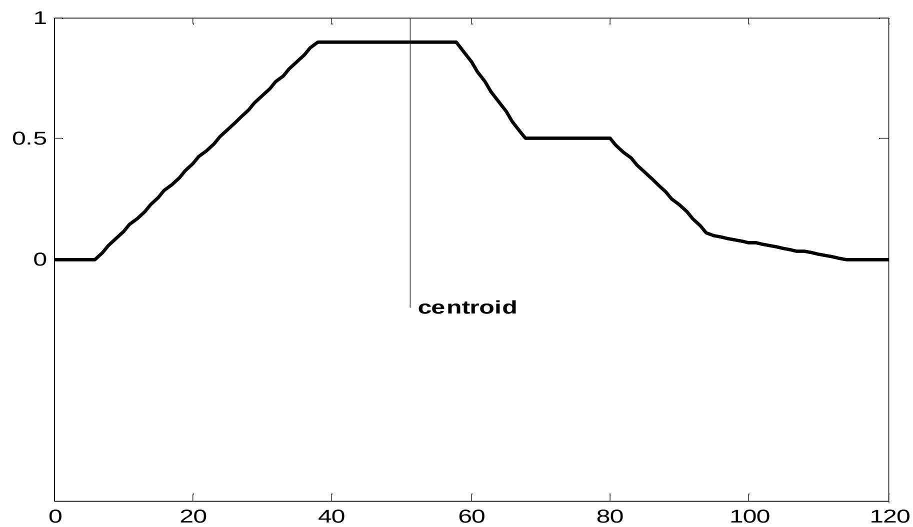

Figure 8:

This value yields the combined effect of prevalence of Goiter +ve on all age groups of 0 females.

9. DEFUZZIFICATION (AGE WISE) FOR AREA-II:

(a) Defuzzification of Goiter +ive grades among males and females of age group (0-4 years) of area II: *x=0:1:90;*

```
y=trapmf(x, [0 30 60 90]);
plot(x,y)
xlabel('trapmf, P=[0 30 60 90]')
mf1 = trapmf(x,[4 26 48 60]);
mf2 = trapmf(x,[6 38 58 80]);
mf1 = max(0.5*mf2,max(0.9*mf1,0.1*mf2));
Plot(x, mf1,'LineWidth', 2);
set(gca,'YLim',[-1 1],'YTick',[0 .5 1])
X1 = defuzz(x, mf1,'centroid')
h1 = line([x1 x1],[-0.2 1.2],'Color','k');
t1 = text(x1,-0.2,' centroid','FontWeight','bold');
X1 =   38.6499
```

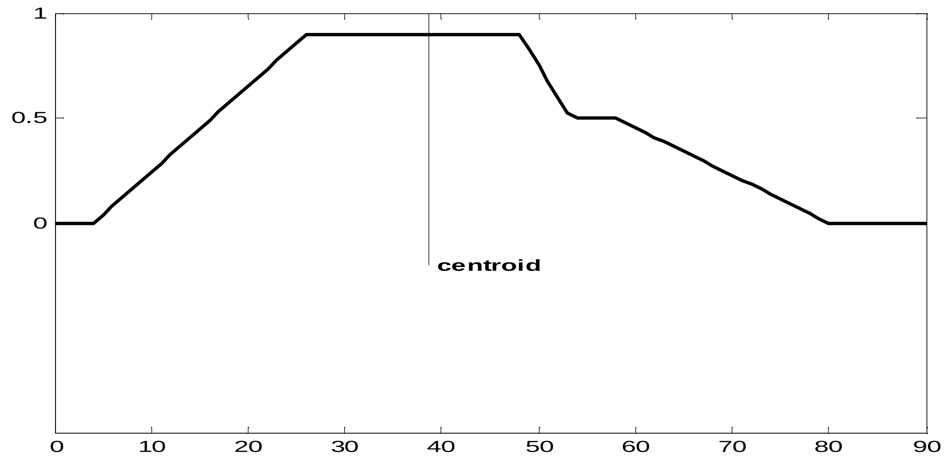

Figure 9:
This value yields the combined effect of prevalence of Goiter +ve on the age groups of 0-4 irrespective of the sex.

(b) Defuzzification of Goiter +ive grades among males and females of age group (5-9 years) of area II:-

x=0:1:120;
y=trapmf(x, [0 40 80 120]);
Plot(x, y)
xlabel('trapmf, P=[0 40 80 120]')
mf1 = trapmf(x,[8 48 68 90]);
mf2 = trapmf(x,[10 62 80 98]);
*mf1 = max(0.5*mf2,max(0.9*mf1,0.1*mf2));*
Plot(x, mf1,'LineWidth', 2);
set(gca,'YLim',[-1 1],'YTick',[0 .5 1])
x1 = defuzz(x,mf1,'centroid')
h1 = line ([x1 x1],[-0.2 1.2],'Color','k');
t1 = text (x1,-0.2,' centroid','FontWeight','bold');
X1 = 54.4506

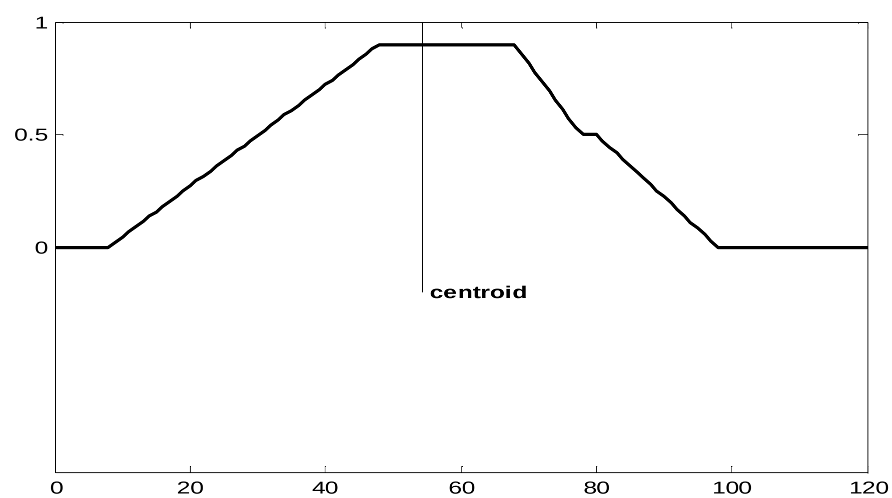

Figure 10:
This value yields the combined effect of prevalence of Goiter +ve on the age groups of 5-9, irrespective of the sex.

(c) Defuzzification of Goiter +ive grades among males and females of age group (10-14 years) of area II:-

x=0:1:120;
y=trapmf(x, [0 40 80 120]);
Plot(x, y)
xlabel('trapmf, P=[0 40 80 120]')
mf1 = trapmf(x,[12 68 88 110]);
mf2 = trapmf(x,[14 74 94 114]);
*mf1 = max(0.5*mf2,max(0.9*mf1,0.1*mf2));*
Plot(x, mf1,'LineWidth', 2);
set (gca,'YLim',[-1 1],'YTick',[0 .5 1])
x1 = defuzz(x,mf1,'centroid')
h1 = line ([x1 x1], [-0.2 1.2],'Color','k');
t1 = text(x1,-0.2,' centroid','FontWeight','bold');
X1 =   68.0273

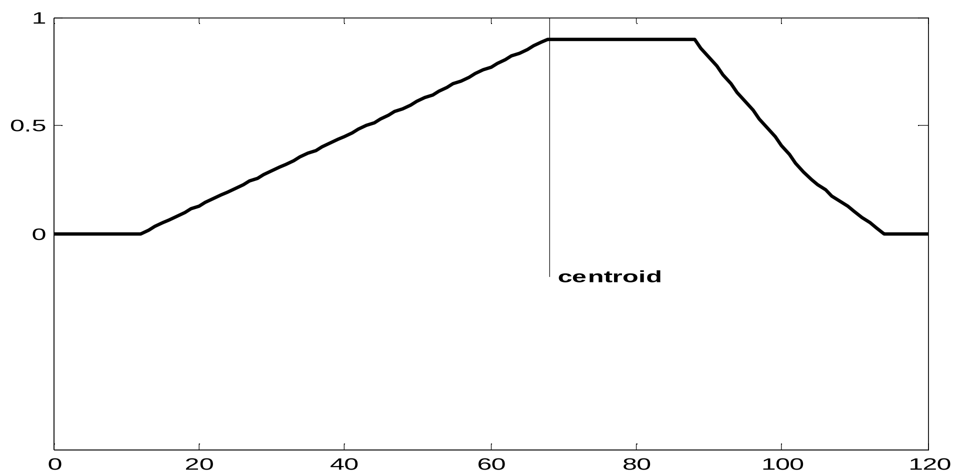

Figure 11:

This value yields the combined effect of prevalence of Goiter +ve on the age groups of 10-14, irrespective of the sex.

(d) Defuzzification of Goiter +ive grades among males and females of age group (15-19 years) of area II:-

x=0:1:120;
y=trapmf(x,[0 40 80 120]);
Plot(x, y)
xlabel('trapmf, P=[0 40 80 120]')
mf1 = trapmf(x,[8 50 70 90]);
mf2 = trapmf(x,[14 74 94 114]);
*mf1 = max(0.5*mf2,max(0.9*mf1,0.1*mf2));*
Plot(x, mf1,'LineWidth', 2);
Set (gca,'YLim', [-1 1],'YTick', [0 .5 1])
X1 = defuzz(x, mf1,'centroid')
h1 = line ([x1 x1], [-0.2 1.2],'Color','k');
t1 = text (x1,-0.2,' centroid','FontWeight','bold');
X1 = 60.6613

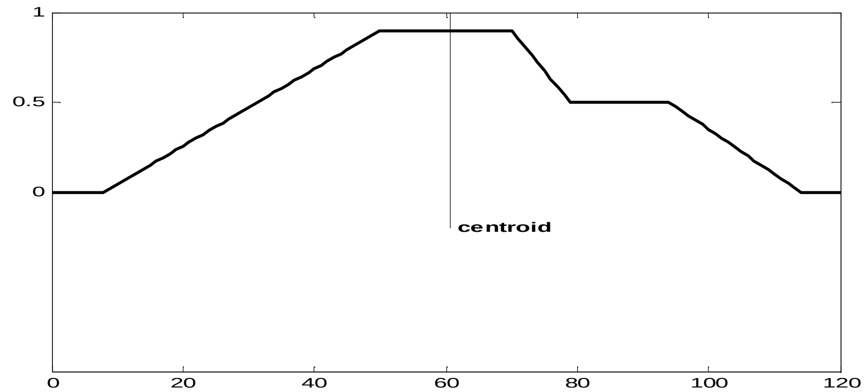

Figure 12:
This value yields the combined effect of prevalence of Goiter +ve on the age groups of 15-19, irrespective of the sex.

10. DEFUZZIFICATION OF IODINE DEFICIENCY (ALL AGES) FOR AREA-I

For defuzzification, we take the fuzzy union of the trapezoidal numbers for all age groups of area I. The resulting trapezoidal number is then defuzzified. Using Matlab:

```
x=0:1:4.0;
y=trapmf(x, [0 1.3 2.6 4.0]);
Plot(x, y)
Xlabel ('trapmf, P= [0 1.3 2.6 4.0]')
mf1 = trapmf(x,[1 1.5 2.1 2.4]);
mf2 = trapmf(x,[1 1.8 2.8 3.2]);
mf3 = trapmf(x,[1 1.8 2.8 3.2]);
mf4 = trapmf(x,[1 1.8 2.8 3.2]);
mf1 = max (max (0.5*mf2, 0.1*mf4), max (0.9*mf1, 0.1*mf3));
Plot(x, mf1,'LineWidth', 2);
Set (gca,'YLim', [-1 1],'YTick', [0 .5 1])
X1 = defuzz(x,mf1,'centroid')
h1 = line ([x1 x1], [-0.2 1.2],'Color','k');
t1 = text (x1,-0.2,' centroid','FontWeight','bold');
X1 =2.2174
```

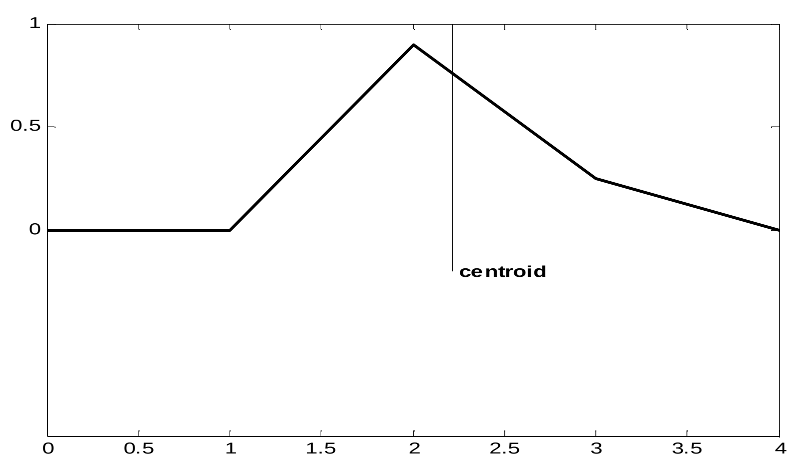

Figure 13:
This value yields percentage of the retarded physical growth taking into consideration all age groups.

11. DEFUZZIFICATION OF IODINE DEFICIENCY FOR (ALL AGES) AREA-II

For defuzzification, we take the fuzzy union of the trapezoidal numbers for all age groups of area II. The resulting trapezoidal number is then defuzzified. Using Matlab:

```
x=0:1:9.0;
y=trapmf(x, [0 3 6 9]);
Plot(x, y)
xlabel('trapmf, P=[0 3 6 9]')
mf1 = trapmf(x,[1 1.5 2.1 2.4]);
mf2 = trapmf(x,[2 3.4 5.0 5.6]);
mf3 = trapmf(x,[2 4.8 6.8 7.8]);
mf4 = trapmf(x,[2 3.8 6.0 7.2]);
mf1 = max(max(0.5*mf2,0.1*mf4),max(0.9*mf1,0.1*mf3));
Plot(x, mf1,'LineWidth', 2);
Set (gca,'YLim', [-1 1],'YTick', [0 .5 1])
X1 = defuzz(x, mf1,'centroid')
h1 = line ([x1 x1], [-0.2 1.2],'Color','k');
t1 = text (x1,-0.2,' centroid','FontWeight','bold');
X1 =3.5006
```

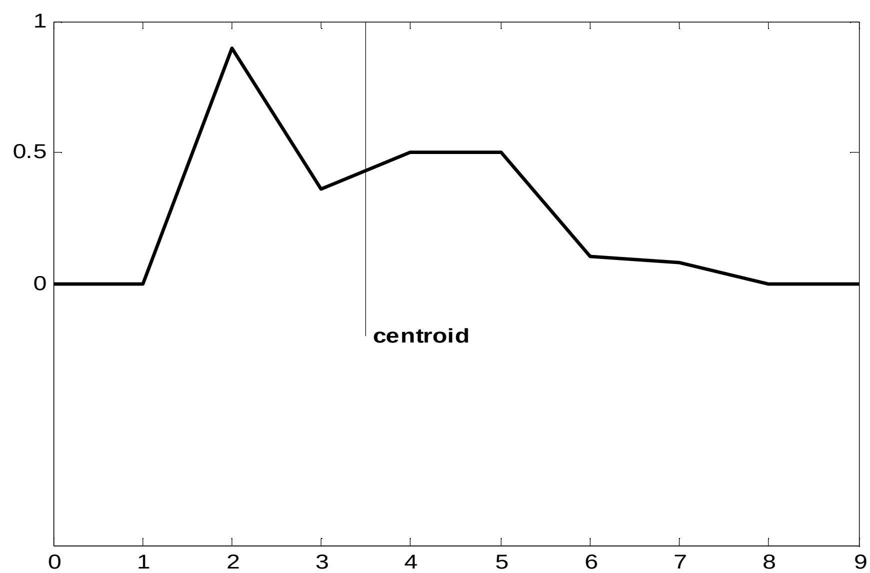

Figure 14:
This value yields percentage of the retarded physical growth taking into consideration all age groups.

12. RESULTS AND DISCUSSION

On the basis of the fuzzy analysis following interpretations can be obtained:

1. In Area-I and II both, the Goiter +ve values are maximum for the age group10-14 years and minimum for 0-4 years.
2. The Goiter +ve effect is much stronger in Area-II in comparison to Area-I.
3. In either of the two areas, Goiter +ve effect is found more in females than males.
4. Taking into consideration all the age groups together, the percentage of retarded physical growth in Area-I is 2.2174 and 3.5006 in Area-II.

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