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Fuzzy Logic Approach to Analysis of Anemia Reduction Impact on Human Health

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ABSTRACT:
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 the grading in membership function. Present paper attempts to investigate the fuzzy logic methodology a major case study performed by Kotecha. In this paper we have applied the fuzzy logic to the multicriteria decision making by taking the various aspect of the study. The major objectives of this survey were: To measure the anemia prevalence and hemoglobin level of the school girls and see the difference, any, before and after initiation of the intervention programme. To measure the level if of serum ferritin and see the difference, if any, before and after initiation of the intervention programme and fuzzy logic plays a vital role in this analysis.

KEYWORDS: Fuzzy Logic, Membership function Fuzzy Relations, Triangular Fuzzy Numbers, Defuzzification, Multi Criteria

1INTRODUCTION:

The minerals present at levels less than 0.05 percent in the human body are defined as micro-mineral and these are also known as the trace elements. Some micro nutrient minerals are iron, iodine, zinc, copper, fluorine, selenium, manganese, cobalt and molybdenum. Most of the iron in the body is found in the blood, but some is present in every cell bound to iron containing enzymes. Over two-thirds of body iron is usually in the form of functional iron and most of this iron is bound within the structure of haemoglobin and a small amount in myoglobin. Anemia is a serious problem among all vulnerable groups and in all regions of India. Due to iron deficiency anaemia, we feel tired and often look pale. It's a common type of anaemia — a condition in which blood lacks adequate healthy red blood cells, which carry oxygen to tissues. Oxygenated blood gives our body energy and our skin a healthy colour. Iron deficiency anemia is common, especially in women. One in five women and half of all pregnant women are iron deficient. Lack of iron in our diet is one cause of iron deficiency anaemia, but there are other causes as well. We can usually correct iron deficiency anaemia with iron supplementation. Sometimes, additional treatments are necessary, especially if we're bleeding internally.

In general, anaemia causes extreme fatigue, pale skin, weakness, shortness of breath, headache, lightheadedness, and often cold hands and feet. Iron deficiency anaemia symptoms also may include:

- Inflammation or soreness of tongue
- Brittle nails
- Unusual cravings for non-nutritive substances, such as ice, dirt or pure starch
- Poor appetite, especially in infants and children with iron deficiency anaemia

Some people with iron deficiency anaemia experience restless legs syndrome, an uncomfortable tingling or crawling feeling in legs that's generally relieved by moving them. Initially, iron deficiency anaemia can be so mild that it goes unnoticed. But as the body becomes more deficient in iron and anaemia worsens, the signs and symptoms intensify.

CAUSES:

Our blood consists of liquid called plasma and three types of blood cells:

White blood cells: These blood cells fight infection.

Platelets: These blood cells help our blood to clot after a cut.

RED BLOOD CELLS (ERYTHROCYTES):

These blood cells carry oxygen from our lungs, by way of our bloodstream, to our brain and the other organs and tissues. Our body needs a supply of oxygenated blood to function. Oxygenated blood gives our body energy and our skin a healthy glow.

Iron deficiency anaemia causes include:

BLOOD LOSS:

Blood contains iron within red blood cells. If we lose blood, we lose some iron. Women with heavy periods are at risk of iron deficiency anaemia because they lose a lot of blood during menstruation. Slow, chronic blood loss from a source within the body — such as a peptic ulcer, a kidney or bladder tumor, a colon polyp, colorectal cancer, or uterine fibroids — can cause iron deficiency anaemia. Gastrointestinal bleeding can result from regular use of aspirin or other no steroidal anti-inflammatory drugs (NSAIDs). Blood lost from within the body may show up in our urine or stools, producing black or bloody stools.

LACK OF IRON IN OUR DIET:

Our body regularly gets iron from the foods we eat. If we consume too little iron, over time our body can become iron deficient. Examples of iron-rich foods include meat, eggs, dairy products or iron-fortified foods. For proper growth and development, infants and children need iron from their diet, too.

INABILITY TO ABSORB IRON:

Iron from food is absorbed into our bloodstream in our small intestine. An intestinal disorder, such as Crohn's disease or celiac disease, which affects our intestine's ability to absorb nutrients from digested food, can lead to iron deficiency anaemia.

PREGNANCY:

Without iron supplementation, iron deficiency anaemia occurs in many pregnant women because their iron stores need to serve their own increased blood volume as well as be a source of haemoglobin for the growing fetus. A fetus needs iron to develop red blood cells, blood vessels and muscle.

Iron deficiency anaemia is the most common form of anaemia. Approximately 20% of women, 50% of pregnant women, and 3% of men are iron deficient. Iron is an essential component of haemoglobin, the oxygen-carrying pigment in the blood. Iron is normally obtained through the food in our diet and by recycling iron from old red blood cells. Without it, the blood cannot carry oxygen effectively and oxygen is needed for the normal functioning of every cell in the body. The causes of iron deficiency are too little iron in the diet, poor absorption of iron by the body, and loss of blood. It can also be related to lead poisoning in children.

Present paper attempts to investigate the fuzzy logic methodology a major case study performed by Kotecha. In this paper we have applied the fuzzy logic to the multicriteria decision making by taking the various aspect of the study. The major objectives of this survey were: To measure the anemia prevalence and hemoglobin level of the school girls and see the difference, any, before and after initiation of the intervention programme. To measure the level if of serum ferritin and see the difference, if any, before and after initiation of the intervention programme and fuzzy logic plays a vital role in this analysis.

2 MEMBERSHIP FUNCTION:

Definition:- If the membership function of the fuzzy set $\tilde{b}_1$ on R is

$$\mu_{\tilde{b}_1}(x)=\begin{cases}1, & x=b,\\ 0, & x\neq b,\end{cases}$$

Then $\tilde{b}_1$ is called the level 1 fuzzy point Let $F_p(1)=\{\tilde{b}_1 \mid \text{for all b} \in \text{R}\}$

Definition:-The triangular fuzzy number Ã on R is a fuzzy set with membership function as the following:

$$\mu_{\tilde{A}}(x)=\begin{cases}\dfrac{x-a}{b-a} & a\leq x\leq b,\\ 0 & \text{elsewhere},\\ \dfrac{c-x}{c-b} & b\leq x\leq c,\end{cases}$$

where fuzzy number Ã is denoted by Ã = (a,b,c).

DEFUZZIFICATION:

In certain situations one needs a crisp output when the input number is fuzzy. Defuzzification is the tool that makes it possible. We have several methods of defuzzification in the literature. In this Paper, we have used the centroid method, which is given by the following expression.

$$M_{\tilde{A}}=\frac{\int_{-\infty}^{\infty} x\,\mu_{\tilde{A}}(x)\,dx}{\int_{-\infty}^{\infty}\mu_{\tilde{A}}(x)\,dx}=\frac{1}{3}(a+b+c).$$

Where (a, b, c) is a triangular fuzzy number. Further if c = a = b = $\tilde{b}_1$, then we get ($\tilde{b}_1,\tilde{b}_1,\tilde{b}_1$)= $\tilde{b}_1$.

DISTANCE BETWEEN TWO FUZZY NUMBERS:

Let Ã = (a, b, c) and $\tilde{B}$ = (p, q, r) $\in$ F, then the signed distance of Ã, $\tilde{B}$ is defined as follows:

$$d(\tilde{A},\tilde{B}) = \frac{1}{2}\int_0^1 [\,A_L(\alpha) + A_R(\alpha) - B_L(\alpha) - B_R(\alpha)\,]\,d\alpha = \frac{1}{4}\,(2b+a+c-2q-p-r).$$

Property : Ã = (a, b, c) and $\tilde{B}$ = (p, q, r) $\in$ F and $\tilde{0}_1 \in F_P(1)$:

(1) $d(\tilde{A}, \tilde{0}_1) = \frac{1}{4}(2b+a+c)$,

(2) $d(\tilde{A},\tilde{B}) = d(\tilde{A}, \tilde{0}_1) - d(\tilde{B}, \tilde{0}_1)$,

where $\mu_{\tilde{0}_1}(x) = 1$ if x = 0; $\mu_{\tilde{0}_1}(x) = 0$ if $x \neq 0$.

In statistical theory, we have the following result:

(1-α) 100% confidence interval of population proportion p is

$$\left[\hat{p}-t_\alpha\sqrt{\frac{\hat{p}(1-\hat{p})}{n}},\ \hat{p}+t_\alpha\sqrt{\frac{\hat{p}(1-\hat{p})}{n}}\right]$$

Where, n is sample size and $\hat{p}$ is the point estimate of p.

3 FUZZY LOGIC ANALYSIS TO MEDICAL DIAGNOSIS:

METHOD OF FUZZY ANALYSIS FOR MEDICAL DIAGNOSIS:

The new method for fuzzy analysis for medical diagnosis is as following. We derived the fuzzy matrix with fuzzy numbers as shown below:

$$\tilde{R}^* = \begin{bmatrix} \tilde{r}_{11} & \tilde{r}_{12} & \dots & \tilde{r}_{1m} \\ \tilde{r}_{21} & \tilde{r}_{22} & \dots & \tilde{r}_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{r}_{n1} & \tilde{r}_{n2} & \dots & \tilde{r}_{nm} \end{bmatrix}, \text{ where } \tilde{r}_{ij} = (r_{ij}^{(1)}, r_{ij}, r_{ij}^{(2)}), \text{ i = 1,2,---,n, j = 1,2,---,m, are fuzzy numbers.}$$

$\tilde{R}^*$ is called the fuzzy relation with fuzzy numbers on the set S of symptoms and the set D of diseases. We define operation of $\tilde{Q} o \tilde{R}^*$ as

$$\tilde{Q} o \tilde{R}^* = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{k1} & a_{k2} & \dots & a_{kn} \end{bmatrix} o \begin{bmatrix} \tilde{r}_{11} & \tilde{r}_{12} & \dots & \tilde{r}_{1m} \\ \tilde{r}_{21} & \tilde{r}_{22} & \dots & \tilde{r}_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{r}_{n1} & \tilde{r}_{n2} & \dots & \tilde{r}_{nm} \end{bmatrix} \equiv \begin{bmatrix} \tilde{t}_{11} & \tilde{t}_{12} & \dots & \tilde{t}_{1m} \\ \tilde{t}_{21} & \tilde{t}_{22} & \dots & \tilde{t}_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{t}_{k1} & \tilde{t}_{k2} & \dots & \tilde{t}_{km} \end{bmatrix},$$

$\tilde{t}_{ij} = \left((\tilde{a}_{i1})_1 \square \; \tilde{r}_{1j})\right) \oplus \left((\tilde{a}_{i2})_1 \square \; \tilde{r}_{2j})\right) \oplus --- \oplus \left((\tilde{a}_{in})_1 \square \; \tilde{r}_{nj})\right)$ i = 1,2,--,k, j = 1,2,--,m.--(5.6.3)

Then we have new method of fuzzy analysis for medical diagnosis as following:

The fuzzy relation with fuzzy numbers $\tilde{T}^*$ on the set P of patients and the set D of diseases is $\tilde{T}^* = \tilde{Q} o \tilde{R}^*$. From properties, we have

$$\tilde{t}_{ij} = \left(\sum_{l=1}^{n} a_{il} r_{lj}^{(1)}, \sum_{l=1}^{n} a_{il} r_{lj}, \sum_{l=1}^{n} a_{il} r_{lj}^{(2)}, \right).$$

From this, we can conclude the medical diagnosis for each patient.

Property :- $\tilde{t}_{ij}$, i = 1,2,---,k, j = 1,2,---,m have the following properties:

(1) The centriod of $\tilde{t}_{ij}$ is $M_{\tilde{t}_{ij}} = \sum_{l=1}^{n} a_{il} r_{lj}$.

(2) $d\left(\tilde{t}_{ij}, \tilde{0}_1\right) = \sum_{l=1}^{n} a_{il} r_{lj}$.

(3) $M_{\tilde{t}_{ij}} \geq t_{ij}$ (in (5.6.4)). If $\sum_{l=1}^{n} a_{il} r_{lj} \leq 1$, *then* $M_{\tilde{t}_{ij}} = t_{ij}$.

METHOD OF MULTICRITERA FUZZY ANALYSIS:

For each p $\in$ {1, 2, -----,n}, the fuzzy relation $\tilde{R}_p$ can be estimated from statistics. Usually, we use the past data of N_p patients for each p to estimate the following:

For each S_{pi} , i $\in$ {1, 2,------,n_p}, let the number $N_{pi\,j}$ be the N_p patients who have the symptom S_{pi} in the diagnosis d_j , j = 1, 2,------,m. Then we have for each i, $\sum_{j=1}^{m} N_{pij} = N_{pij}$. Let $r_{pij} = N_{pij} / N_{pi}$, i = 1, 2, -----,$n_p$, j = 1, 2,-------,m. Then we get $\sum_{j=1}^{m} r_{pij} = 1$. For each i $\in$ {1, 2, -----,n_p}, $r_{pi\,j}$ is the entry of $\tilde{R}_p$. Let the patients population proportion in (S_{pi} , d_j) to be $\mu_{pi\,j}$, then we obtain $r_{pi\,j}$ as a point estimate for μ_{pij}. Then from these equations, we get the 99% confidence interval for $\mu_{pi\,j}$ can be derived as following:

$$\left[r_{pij} - 2.575\sqrt{\frac{r_{pij}(1-r_{pij})}{N_{pi}}} \;,\; r_{pij} + 2.575\sqrt{\frac{r_{pij}(1-r_{pij})}{N_{pi}}} \right].$$

Setting

$$r^{(1)}{}_{pij} = r_{pij} - 2.575\sqrt{\frac{r_{pij}(1-r_{pij})}{N_{pi}}} \quad , \quad r^{(2)}{}_{pij} = r_{pij} + 2.575\sqrt{\frac{r_{pij}(1-r_{pij})}{N_{pi}}},$$

we have $\tilde{r}_{pij} = \left(r^{(1)}{}_{pij}, r_{pij}, r^{(2)}{}_{pij} \right) \in F_N, \quad i = 1, 2, ---, n_p, \quad j = 1, 2, ---, m.$

The weight Ã = (a_1, a_2, ----------,a_n) of S_1, S_2,-------,S_n , then $a_p = N_p / N$, p = 1, 2,----,n, where $N = \sum_{p=1}^{n} N_p$.

4 STUDY DETAILS:

We wish to apply our method to a major case study performed by Kotecha . This study was taken up as an impact evaluation survey of ‘Adolescent Girls Anemia Reduction Programme’ in all the secondary and higher secondary sections of 30 schools in Vadodara district with technical and financial support from UNICEF and the Department of Preventive and Social Medicine, Medical College, Vadodara (Gujarat). The major objectives of this survey were:

1. To measure the anaemia prevalence and haemoglobin level of the school girls and see the difference, any, before and after initiation of the intervention programme.
2. To measure the level if of serum ferritin and see the difference, if any, before and after initiation of the intervention programme.

The necessary details of this study are given below:

(1) Micronutrient: Iron
(2) Subject : Adolescent Girls
(3) Title of Report: Adolscent girls anemia reduction programme- impact evaluation (mid term) of Vadodara district, 2002.
(4) Names of Authors: P.V.Kotecha, R.Z.Patel, P.D.Karkar and S. Nirupam, Department of Preventive and Social Medicine, Medical College, Vadodara
(5) Location: Vadodara
(6) Types of study: School and community based
(7) Type of population: Rural, urban and tribal
(8) Age range: 12-19 years
(9) Study design: Stratified random sampling (baseline survey) intervention trial
(10) Sample size: 2860
(11) Year of data collection: 2000
(12) Procedure: Haemologlobin estimation by ABACUS cell counter. Serum ferritin assessed using immulite (automated immuno assay analyzer)

5 OBSERVATIONS OF THE STUDY:

The data obtained after the survey are given in following tables for Prevalence of anaemia before and after intervention and area wise serum ferritin status.

PREVALENCE OF ANAEMIA BEFORE AND AFTER INTERVENTION:

Area	N	Anaemia Before Intervation	n	Anaemia After Intervation	Difference (%)	Membership Value
Tribal	895	73.7	775	57.5	16.2	P<0.05
Rural	977	74.5	986	50.4	24.1	P<0.05
Urban	988	75.8	1005	52.5	23.3	P<0.05
Total	2860	74.7	2766	53.2	20.5	P<0.05

Table-1

PREVALENCE OF ANAEMIA ACCORDING TO SEVERITY BEFORE AND AFTER INTERVENTION:

Area	Anaemia level in girls							
	Severe (Hb < 70 gm/ l)		Moderate (Hb 70-99.9 gm/l)		Mild (Hb 100-119.9 gm/l)		Normal (Hb > 120 gm/l)	
	Before	After	Before	After	Before	After	Before	After
Tribal	1.5	0.5	14.5	7.7	57.8	49.3	26.3	42.5
Rural	1.8	0.4	13.8	5.0	58.9	45.0	25.5	49.6
Urban	1.5	0.6	16.9	9.5	57.4	42.5	24.2	47.5
Total	1.6	0.5	15.1	7.4	58.0	45.3	25.3	46.8
Reduction in % from Baseline	68.75%		50.99%		21.9%		84.98% rise in normal girls after programme	

Table 2

AREA WISE SERUM FERRITIN STATUS:

Area	Serum Ferritin < 12 ng / ml		Serum Ferritin (ng/ml) Mean ± SD	
	Before Intervation	After Intervation	Before Intervation	After Intervation
Tribal	46.3	37.1	18.6±19.37	21.32±20.76
Rural	50.5	40.1	16.8±17.19	22.19±24.79
Urban	52.6	40.5	16.75±20.35	23.05±24.00
Total	49.7	39.4	17.40±18.80	22.18±23.58
N	1983	804	1983	804

Table 3

6 FUZZY LOGIC ANALYSIS OF THE STUDY:

Let the sets A, S respectively denote the classification of areas and the severity of the ailment as given below:

$A = \{A_1$ (Rural), A_2 (Tribal), A_3 (Urban)$\}$

S = {Normal, Mild, Moderate, Severe}

Further let Anaemia Prevalence = $\{P_1, P_2\}$ and Serum Ferritin = $\{S_1, S_2\}$

(i) Prevalence of Anaemia level in girls before intervention is given by the row vector

$= S_{A_1} = [.737 \quad .745 \quad .758]$

(ii) Prevalence of Anaemia level in girls after intervention is given by the row vector

$= S_{A_2} = [.575 \quad .504 \quad .525]$

(iii) Anaemia levels in girls for severe (Hb < 70 mg/l) before intervention is given by the column vector

$$= S_{S_1} = \begin{bmatrix} .15 \\ .18 \\ .15 \end{bmatrix}$$

(iv) Anaemia levels in girls for severe (Hb < 70 mg/l) after intervention is given by the column vector

$$= S_{S_2} = \begin{bmatrix} .05 \\ .04 \\ .06 \end{bmatrix}$$

(v) Anaemia levels in girls for moderate (Hb 70 - 99.9 mg/l) before intervention is given by the column vector

$$= S_{Mo_1} = \begin{bmatrix} .145 \\ .138 \\ .169 \end{bmatrix}$$

(vi) Anaemia levels in girls for moderate (Hb 70 - 99.9 mg/l) after intervention is given by the column vector

$$= S_{Mo_2} = \begin{bmatrix} .077 \\ .050 \\ .095 \end{bmatrix}$$

(vii) Anaemia levels in girls for mild (Hb 100 - 119.9 mg/l) before intervention is given by the column vector

$$= S_{M_1} = \begin{bmatrix} .578 \\ .589 \\ .574 \end{bmatrix}$$

(viii) Anaemia levels in girls for mild (Hb 100 - 119.9 mg/l) after intervention is given by the column vector

$$= S_{M_2} = \begin{bmatrix} .493 \\ .450 \\ .425 \end{bmatrix}$$

(ix) Anaemia levels in girls for normal (Hb > 120 mg/l) before intervention is given by the column vector

$$= S_{N_1} = \begin{bmatrix} .263 \\ .255 \\ .242 \end{bmatrix}$$

(x) Anaemia levels in girls for normal (Hb > 120 mg/l) after intervention is given by the column vector

$$= S_{N_2} = \begin{bmatrix} .425 \\ .496 \\ .475 \end{bmatrix}$$

(xi) Serum ferritin status before intervention is given by the column vector

$$= S_{S_{e1}} = \begin{bmatrix} .463 \\ .505 \\ .526 \end{bmatrix}$$

(xii) Serum ferritin status after intervention is given by the column vector

$$= S_{S_{e2}} = \begin{bmatrix} .371 \\ .401 \\ .405 \end{bmatrix}$$

After normalizing these vectors, we obtain

(i) Prevalence of Anaemia level in girls before intervention is given by row vector

$$= S^1{}_{A_1} = \begin{bmatrix} .329 & .333 & .338 \end{bmatrix}$$

(ii) Prevalence of Anaemia level in girls after intervention is given by row vector

$$= S^1{}_{A_2} = \begin{bmatrix} .359 & .314 & .327 \end{bmatrix}$$

(iii) Anaemia levels in girls for severe (Hb < 70 mg/l) before intervention is given by column vector

$$= S^1{}_{S_1} = \begin{bmatrix} .3125 \\ ..3750 \\ .3125 \end{bmatrix}$$

(iv) Anaemia levels in girls for severe (Hb < 70 mg/l) after intervention is given by column vector

$$= S^1{}_{S_2} = \begin{bmatrix} .333 \\ .267 \\ .400 \end{bmatrix}$$

(v) Anaemia levels in girls for moderate (Hb 70 - 99.9 mg/l) before intervention is given by the column vector

$$= S^1{}_{Mo_1} = \begin{bmatrix} .321 \\ .305 \\ .374 \end{bmatrix}$$

(vi) Anaemia levels in girls for moderate (Hb 70 - 99.9 mg/l) after intervention is given by the column vector

$$= S^1{}_{Mo_2} = \begin{bmatrix} .347 \\ .225 \\ .428 \end{bmatrix}$$

(vii) Anaemia levels in girls for mild (Hb 100 - 119.9 mg/l) before intervention is given by the column vector

$$= S^{1}{}_{M_1} = \begin{bmatrix} .332 \\ .338 \\ .330 \end{bmatrix}$$

(viii) Anaemia levels in girls for mild (Hb 100 - 119.9 mg/l) after intervention is given by the column vector

$$= S^{1}{}_{M_2} = \begin{bmatrix} .360 \\ .329 \\ .311 \end{bmatrix}$$

(ix) Anaemia levels in girls for normal (Hb > 120 mg/l) before intervention is given by the column vector

$$= S^{1}{}_{N_1} = \begin{bmatrix} .346 \\ .336 \\ .318 \end{bmatrix}$$

(x) Anaemia levels in girls for normal (Hb > 120 mg/l) after intervention is given by the column vector

$$= S^{1}{}_{N_2} = \begin{bmatrix} .305 \\ .355 \\ .340 \end{bmatrix}$$

(xi) Serum ferritin status before intervention is given by column vector

$$= S^{1}{}_{S_{e1}} = \begin{bmatrix} .310 \\ .338 \\ .352 \end{bmatrix}$$

(xii) Serum ferritin status after intervention is given by column vector

$$= S^{1}{}_{S_{e2}} = \begin{bmatrix} .315 \\ .341 \\ .344 \end{bmatrix}$$

(a) Anaemia level in girls before intervention in severe case

$$T_1 = S^{1}{}_{A_1} 0 S^{1}{}_{S_1} = \max\begin{bmatrix} .329 & .333 & .338 \end{bmatrix} 0 \begin{bmatrix} .3125 \\ .3750 \\ .3125 \end{bmatrix}$$

$$= \max\begin{bmatrix} \min(.329, .3125) & \min(.333, .3750) & \min(.338, .3125) \end{bmatrix}$$

$$= \max\begin{bmatrix} .3125 & .333 & .3125 \end{bmatrix} = .333$$

(b) Anaemia level in girls before intervention in moderate case

$$T_2 = S^{1}{}_{A_1} 0 S^{1}{}_{Mo_1} = \max\begin{bmatrix} .329 & .333 & .338 \end{bmatrix} 0 \begin{bmatrix} .321 \\ .305 \\ .374 \end{bmatrix}$$

$$= \max\left[\min(.329,.321) \quad \min(.333,.305) \quad \min(.338,.374)\right]$$

$$= \max\left[.321 \quad .305 \quad .338\right] = .338$$

(c) Anaemia level in girls before intervention in mild case

$$T_3 = S^1{}_{A_1} 0 S^1{}_{M_1} = \max\left[.329 \quad .333 \quad .338\right] 0 \begin{bmatrix} .332 \\ .338 \\ .330 \end{bmatrix}$$

$$= \max\left[\min(.329,.332) \quad \min(.333,.338) \quad \min(.338,.330)\right]$$

$$= \max\left[.329 \quad .333 \quad .330\right] = .333$$

(d) Anaemia level in girls before intervention in normal case

$$T_4 = S^1{}_{A_1} 0 S^1{}_{N_1} = \max\left[.329 \quad .333 \quad .338\right] 0 \begin{bmatrix} .346 \\ .336 \\ .318 \end{bmatrix}$$

$$= \max\left[\min(.329,.346) \quad \min(.333,.336) \quad \min(.338,.318)\right]$$

$$= \max\left[.329 \quad .333 \quad .318\right] = .333$$

(e) Anaemia level in girls before intervention with serum ferritin less than 12 ng/ml

$$T_5 = S^1{}_{A_1} 0 S^1{}_{Se_1} = \max\left[.329 \quad .333 \quad .338\right] 0 \begin{bmatrix} .310 \\ .338 \\ .352 \end{bmatrix}$$

$$= \max\left[\min(.329,.310) \quad \min(.333,.338) \quad \min(.338,.352)\right]$$

$$= \max\left[.310 \quad .333 \quad .338\right] = .338$$

(f) Anaemia level in girls after intervention and severe case

$$T_6 = S^1{}_{A_2} 0 S^1{}_{S_2} = \max\left[.359 \quad .314 \quad .327\right] 0 \begin{bmatrix} .333 \\ .267 \\ .400 \end{bmatrix}$$

$$= \max\left[\min(.359,.333) \quad \min(.314,.267) \quad \min(.327,.400)\right]$$

$$= \max\left[.333 \quad .267 \quad .327\right] = .333$$

(g) Anaemia level in girls after intervention and moderate case

$$T_7 = S^1{}_{A_2} 0 S^1{}_{Mo_2} = \max\left[.359 \quad .314 \quad .327\right] 0 \begin{bmatrix} .347 \\ .225 \\ .428 \end{bmatrix}$$

$$= \max[\min(.359,.347) \quad \min(.314,.225) \quad \min(.327,.428)]$$

$$= \max[.347 \quad .225 \quad .327] = .347$$

(h) Anemia level in girls after intervention and mild case

$$T_8 = S^1{}_{A_2} 0 S^1{}_{M_2} = \max[.359 \quad .314 \quad .327] 0 \begin{bmatrix} .360 \\ .329 \\ .311 \end{bmatrix}$$

$$= \max[\min(.359,.360) \quad \min(.314,.329) \quad \min(.327,.311)]$$

$$= \max[.359 \quad .314 \quad .311] = .359$$

(i) Anaemia level in girls after intervention and normal case

$$T_9 = S^1{}_{A_2} 0 S^1{}_{N_2} = \max[.359 \quad .314 \quad .327] 0 \begin{bmatrix} .305 \\ .355 \\ .340 \end{bmatrix}$$

$$= \max[\min(.359,.305) \quad \min(.314,.355) \quad \min(.327,.340)]$$

$$= \max[.305 \quad .314 \quad .327] = .327$$

(j) Anaemia level in girls after I ntervention with serum ferritin less than 12 ng/ml

$$T_{10} = S^1{}_{A_2} 0 S^1{}_{Se_2} = \max[.359 \quad .314 \quad .327] 0 \begin{bmatrix} .315 \\ .341 \\ .344 \end{bmatrix}$$

$$= \max[\min(.359,.315) \quad \min(.314,.341) \quad \min(.327,.344)]$$

$$= \max[.315 \quad .314 \quad .327] = .327$$

7 INTERPRETATIONS OF RESULTS:

Following observations can be observed from the fuzzy operations on different row and column vectors:

1. The anaemia levels of girls, combining the rural, tribal and urban population together, before intervention, are 33.3% in severe, mild and normal cases whereas 33.8% in moderate case.
2. The anaemia levels of girls, combining the rural, tribal and urban population together, after intervention, are 33.3%, 34.7%, 35.9% and 32.7% respectively in severe, moderate, mild and normal cases.
3. The serum ferritin level is found to be less than 12ng/ml in 32.7% after the intervention as against 33.8% before intervention.

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