CHAPTER 6  

Application of Mathematical concepts for Analysis of Tribal Environment

6.1 Introduction  

The governments in the states and at the centre in India have launched several special schemes for tribal development since independence. Yet the tribal people still remain backward and ignorant and their interests are being continuously ignored. The development of such people is an important challenge for the nation builders today. It is essential to develop new techniques and tools to understand the various issues involved in tribal development.

Mathematical modelling is widely applied in all areas of socio-economic studies. In this chapter, the concept of fuzzy theory is applied for the analysis of tribal environment. The concept of fuzzy set theory which was introduced by Zadeh (1965) is a strong mathematical expression of sets without precise boundaries. It has been applied widely in modelling various decision making problems involving fuzziness and has been found effective in analysis of unsupervised data. It is possible to obtain the hidden pattern of a dynamical system by applying fuzzy theory. Since the issues related to the tribals involve much uncertainties and unpredictabilities, it would be appropriate to make use of fuzzy theory for such analysis.
6.2 Application of fuzzy theory for the comparison of Tribal welfare in two colonies

Fuzzy poverty index, fuzzy welfare function and fuzzy welfare index are used in this study for comparing the welfare of tribals living in two separate colonies. One of the colonies is located in the interior of the forest with very little interaction with the modern world and the other is located away from the forest with very good interaction with non-tribal communities.

The monthly income of nine individuals in the two different tribal colonies was collected and they are as follows.

Table 6.1. Monthly income of families in the first colony (far away from the forest)

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Name</th>
<th>Monthly income (Rs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Rangaswami Gopalan</td>
<td>400</td>
</tr>
<tr>
<td>2.</td>
<td>Kuttappan</td>
<td>1800</td>
</tr>
<tr>
<td>3.</td>
<td>Gopi</td>
<td>2000</td>
</tr>
<tr>
<td>4.</td>
<td>Babu</td>
<td>1400</td>
</tr>
<tr>
<td>5.</td>
<td>Rangaswami</td>
<td>2200</td>
</tr>
<tr>
<td>6.</td>
<td>Prakash</td>
<td>1200</td>
</tr>
<tr>
<td>7.</td>
<td>Shaji</td>
<td>4000</td>
</tr>
<tr>
<td>8.</td>
<td>Chandran</td>
<td>1500</td>
</tr>
<tr>
<td>9.</td>
<td>Manoj Gopalan</td>
<td>1200</td>
</tr>
</tbody>
</table>

Table 6.2. Monthly income of families in the second colony (inside the forest)

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Name</th>
<th>Monthly income (Rs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Sivaswami</td>
<td>1300</td>
</tr>
<tr>
<td>2.</td>
<td>Ponnuwami</td>
<td>1000</td>
</tr>
<tr>
<td>3.</td>
<td>Thirumoorthy</td>
<td>1000</td>
</tr>
<tr>
<td>4.</td>
<td>Manikandan</td>
<td>800</td>
</tr>
<tr>
<td>5.</td>
<td>S.Thankaraj</td>
<td>1200</td>
</tr>
<tr>
<td>6.</td>
<td>Surendran</td>
<td>750</td>
</tr>
<tr>
<td>7.</td>
<td>Sivamuthu</td>
<td>600</td>
</tr>
<tr>
<td>8.</td>
<td>Palswami</td>
<td>300</td>
</tr>
<tr>
<td>9.</td>
<td>Bhokedran</td>
<td>800</td>
</tr>
</tbody>
</table>

A study on certain tribal communities of Idukki District in Kerala in an environmental perspective
6.2.1 Fuzzy poverty index.

**Definition 6.2.1.** Let \( S = \{x_1, x_2, x_3, \ldots, x_n\} \) be a society with \( n \) individuals. Let \( z \) be the level of income at which poverty begins (with respect to a predetermined poverty line). Let \( y_i, 1 \leq i \leq n \) be the income of the person \( x_i \). Let \( S(z) = \{x_i | y_i < z\} \).

The fuzzy poverty index (FPI) is defined as

\[
p_F = \frac{1}{q} \sum_{i=1}^{q} (p_y(i))^2
\]

where \( q = \) number of elements in the set \( S(z) \) and \( p_y : S(z) \to [0, 1] \) defined by \( p_y(i) = \frac{z - y_i}{z} \). Here \( z = 450 \) is the pre-determined poverty line.

\( p_F \) always lies in the closed interval \([0, 1]\). If everyone have income zero (theoretically assumed, even though it is not possible) then \( p_F = 1 \). If nobody in the society is below the poverty line then \( p_F = 0 \).

Consider the case of the first colony. Here \( S = \{x_1, x_2, \ldots x_9\} \) \( y = \{400, 1800, 2000, 1400, 2200, 1200, 4000, 1500, 1200\} \). Here

\[
S(z) = \{x_1\}, \quad p_y(1) = \frac{z - y_1}{z} = \frac{450 - 400}{450} = \frac{50}{450} = \frac{1}{9}.
\]

\[
\therefore \quad p_F = \frac{1}{1} (p_y(1))^2 = \left(\frac{1}{9}\right)^2 = \frac{1}{81} = 0.012345.
\]

In the case of the second colony \( S = \{x_1, x_2, \ldots x_9\} \). \( y = \{1200, 1000, 1000, 800, 1200, 750, 600, 300, 800\} \). Here

\[
S(z) = \{x_8\}, \quad p_y(8) = \frac{z - y_8}{z} = \frac{450 - 300}{450} = \frac{150}{450} = \frac{3}{9} = \frac{1}{3}.
\]

\[
\therefore \quad p_F = \frac{1}{1} (p_y(8))^2 = \left(\frac{1}{3}\right)^2 = \frac{1}{9} = 0.1111.
\]

Thus fuzzy poverty index of second colony is higher than the first colony, which shows that, based on the income, the people in the second colony which is situated in the forest has high level of poverty. But from direct investigation it is seen that the people
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of second colony have better welfare than the first colony, which is deduced from the following evaluations.

6.2.2 Fuzzy Welfare Function.

As the welfare is a fuzzy aspect rather than crisp it is more appropriate to use fuzzy welfare function.

**Definition 6.2.2.** Let $S = \{1, 2, 3, \ldots n\}$ be a finite set representing a society of $n$ individuals and let an $n$-vector $y = (y_1, y_2, \ldots y_n)$ represent the income configuration of the individuals. Let $l$ be the person in the society with largest income and let $y_l$ be his income. Take the ratio $y_i/y_l$ and denote it by $\tilde{y}_i$. Then the function $W_y : S \times S \rightarrow [0, 1]$ defined by $W_y(i, j) = \max\{\tilde{y}_i - \tilde{y}_j, 0\}, i, j \in S$ is called the fuzzy welfare function on $S$ and is denoted by $FWF$.

Here $y_i$ is called the exact income and $\tilde{y}_i$ is called the fuzzy income of the individual $i$. The function $W_y$ assigns to each pair $(i, j) \in S \times S$ a real number between 0 and 1. If $W_y(i, j)$ is strictly greater than 0, one can infer that $i$ is more well off than $j$ and if $W_y(i, j)$ is equal to zero, $i$ is not more well of than $j$. The other extremity 1 is not attained practically. Thus for any two individuals $i, j \in S$, $W_y(i, j)$ is regarded as the degree to which $j$ is not dominated by $i$, in the sense of welfare or equivalently the degree of well being of $i$ over $j$.

In the first colony

$S = \{1, 2, 3, 4, 5, 6, 7, 8, 9\}$,

$y = \{400, 1800, 2000, 1400, 2200, 1200, 4000, 1500, 1200\}$

$l = 7$(the person having the highest income)

$y_i/y_l = \left(\frac{400}{4000}, \frac{1800}{4000}, \frac{2000}{4000}, \frac{1400}{4000}, \frac{2200}{4000}, \frac{1200}{4000}, \frac{4000}{4000}, \frac{1500}{4000}, \frac{1200}{4000}\right)$

$= (0.1, 0.45, 0.5, 0.35, 0.55, 0.3, 1, 0.375, 0.3)$
W_y : S × S → [0, 1] defined by W_y(i, j) = \max\{\tilde{y}_i - \tilde{y}_j, 0\} i, j \in S;

S × S = \{1, 2, 3, 4, 5, 6, 7, 8, 9\} \times \{1, 2, 3, 4, 5, 6, 7, 8, 9\}

= \{(a, b)/a \in S, b \in S\}.

W_y(1, j) = \max\{\tilde{y}_1 - \tilde{y}_j, 0\}

= \max\{-0.35, -0.4, -0.25, -0.45, -0.2, -0.9, -0.275, -0.2, 0\}

= 0.

W_y(2, j) = \max\{\tilde{y}_2 - \tilde{y}_j, 0\}

= \max\{-0.35, -0.05, 0.1, -0.1, 0.15, -0.55, 0.075, 0.15, 0\}

= 0.35.

W_y(3, j) = \max\{\tilde{y}_3 - \tilde{y}_j, 0\}

= \max\{0.4, 0.05, 0.15, -0.05, 0.2, -0.5, 0.125, 0.2, 0\}

= 0.4.

W_y(4, j) = \max\{\tilde{y}_4 - \tilde{y}_j, 0\}

= \max\{0.25, -0.10, -0.15, -0.20, 0.05, -0.65, -0.025, 0\}

= 0.25.

W_y(5, j) = \max\{\tilde{y}_5 - \tilde{y}_j, 0\}

= \max\{0.45, 0.10, 0.20, 0.05, 0.25, -0.45, 0.175, 0.25, 0\}

= 0.45.

W_y(6, j) = \max\{\tilde{y}_6 - \tilde{y}_j, 0\}

= \max\{0.2, -0.15, -0.2, -0.05, -0.25, -0.7, -0.075, 0, 0\}

= 0.2.
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\[ W_y(7,j) = \max\{\tilde{y}_7 - \tilde{y}_j, 0\} \]
\[ = \max\{0.9, 0.55, 0.5, 0.65, 0.45, 0.7, 0.625, 0.7, 0\} \]
\[ = 0.9. \]

\[ W_y(8,j) = \max\{\tilde{y}_8 - \tilde{y}_j, 0\} \]
\[ = \max\{0.275, -0.075, -0.125, -0.025, -0.175, 0.075, -0.625, 0.075, 0\} \]
\[ = 0.275. \]

\[ W_y(9,j) = \max\{\tilde{y}_9 - \tilde{y}_j, 0\} \]
\[ = \max\{0.2, -0.15, -0.2, -0.05, -0.25, 0, -0.7, -0.075, 0\} \]
\[ = 0.2. \]

In the second colony

\[ S = \{1, 2, 3, 4, 5, 6, 7, 8, 9\}, \]
\[ y = \{1300, 1000, 1000, 800, 1200, 750, 600, 300, 800\} \]
\[ l = 1 \text{(the person having the highest income)} \]
\[ y_i/y_l = \left(\frac{1300}{1300}, \frac{1000}{1300}, \frac{1000}{1300}, \frac{800}{1300}, \frac{1200}{1300}, \frac{750}{1300}, \frac{600}{1300}, \frac{300}{1300}, \frac{800}{1300}\right) \]
\[ = \{(1, 0.769, 0.769, 0.615, 0.923, 0.5769, 0.462, 0.231, 0.615)\} \]

\[ W_y : S \times S \to [0, 1] \text{ defined by } W_y(i,j) = \max\{\tilde{y}_i - \tilde{y}_j, 0\} \text{ for } i, j \in S; \]

\[ W_y(1,j) = \max\{\tilde{y}_1 - \tilde{y}_j, 0\} \]
\[ = \max\{0.23, 0.23, 0.38, 0.08, 0.42, 0.54, 0.77, 0.38, 0\} \]
\[ = 0.77. \]

\[ W_y(2,j) = \max\{\tilde{y}_2 - \tilde{y}_j, 0\} \]

A study on certain tribal communities of Idukki District in Kerala in an environmental perspective
\[ = \max\{-0.23, 0, 0.15, -0.15, 0.192, 0.31, 0.54, 0.15, 0\} \]
\[ = 0.54. \]

\[ \hat{W}_{y}(3, j) = \max\{\tilde{y}_3 - \tilde{y}_j, 0\} \]
\[ = \max\{-0.23, 0, 0.15, -0.15, 0.192, 0.31, 0.54, 0.15, 0\} \]
\[ = 0.54. \]

\[ \hat{W}_{y}(4, j) = \max\{\tilde{y}_4 - \tilde{y}_j, 0\} \]
\[ = \max\{-0.39, -0.15, -0.15, -0.31, 0.038, 0.153, 0.38, 0, 0\} \]
\[ = 0.38. \]

\[ \hat{W}_{y}(5, j) = \max\{\tilde{y}_5 - \tilde{y}_j, 0\} \]
\[ = \max\{-0.08, 0.15, 0.15, 0.31, 0.346, 0.46, 0.69, 0.31, 0\} \]
\[ = 0.69. \]

\[ \hat{W}_{y}(6, j) = \max\{\tilde{y}_6 - \tilde{y}_j, 0\} \]
\[ = \max\{-0.42, -0.192, -0.192, -0.038, -0.346, 0.115, 0.346, -0.038, 0\} \]
\[ = 0.346. \]

\[ \hat{W}_{y}(7, j) = \max\{\tilde{y}_7 - \tilde{y}_j, 0\} \]
\[ = \max\{-0.54, -0.307, -0.307, -0.153, -0.115, 0.231, -0.153, 0\} \]
\[ = 0.231. \]

\[ \hat{W}_{y}(8, j) = \max\{\tilde{y}_8 - \tilde{y}_j, 0\} \]
\[ = \max\{-0.769, -0.538, -0.538, -0.384, -0.692, -0.346, -0.231, -0.384, 0\} \]
\[ = 0. \]

\[ \hat{W}_{y}(9, j) = \max\{\tilde{y}_9 - \tilde{y}_j, 0\} \]
$\max\{-0.385, -0.154, -0.154, 0, -0.31, 0.038, 0.153, 0.384, 0\} = 0.384$.

**Table 6.3.** Fuzzy welfare function of the member of the first colony

<table>
<thead>
<tr>
<th>Person</th>
<th>Monthly Income (Rs.)</th>
<th>Fuzzy welfare function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>400</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>1800</td>
<td>0.35</td>
</tr>
<tr>
<td>3</td>
<td>2000</td>
<td>0.4</td>
</tr>
<tr>
<td>4</td>
<td>1400</td>
<td>0.25</td>
</tr>
<tr>
<td>5</td>
<td>2200</td>
<td>0.45</td>
</tr>
<tr>
<td>6</td>
<td>1200</td>
<td>0.2</td>
</tr>
<tr>
<td>7</td>
<td>4000</td>
<td>0.9</td>
</tr>
<tr>
<td>8</td>
<td>1500</td>
<td>0.275</td>
</tr>
<tr>
<td>9</td>
<td>1200</td>
<td>0.2</td>
</tr>
</tbody>
</table>

**Table 6.4.** Fuzzy welfare function of the member of the second colony

<table>
<thead>
<tr>
<th>Person</th>
<th>Monthly Income (Rs.)</th>
<th>Fuzzy welfare function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1300</td>
<td>0.77</td>
</tr>
<tr>
<td>2</td>
<td>1000</td>
<td>0.54</td>
</tr>
<tr>
<td>3</td>
<td>1000</td>
<td>0.54</td>
</tr>
<tr>
<td>4</td>
<td>800</td>
<td>0.38</td>
</tr>
<tr>
<td>5</td>
<td>1200</td>
<td>0.69</td>
</tr>
<tr>
<td>6</td>
<td>750</td>
<td>0.346</td>
</tr>
<tr>
<td>7</td>
<td>600</td>
<td>0.231</td>
</tr>
<tr>
<td>8</td>
<td>300</td>
<td>0</td>
</tr>
<tr>
<td>9</td>
<td>800</td>
<td>0.384</td>
</tr>
</tbody>
</table>

### 6.2.3 Fuzzy welfare index.

Sen (1982) says there are many reasons to think that sometimes a richer person may have lower welfare than a poorer person e.g. if he is cripple. This points out the need of taking more parameters along with the income to determine one’s welfare. So it is necessary to determine a welfare index of the society by taking one or more indicators, which contribute to the welfare of an individual along with income. Appropriate weights
should be given to each indicator. Any factor which can contribute to the welfare of a person such as income, education, employment, leisure, social status, physical fitness, access to power etc., can be taken as an indicator for calculating the index by attributing appropriate weight for each indicator.

**Definition 6.2.3.** Let $u$ be any parameter of the welfare of an individual in a society. Let $\alpha$ any real number such that $0 \leq \alpha < 1$, and let $u_i$ be another real number such that $0 \leq u_i \leq 1$. Define a function $u : S \rightarrow [0, 1]$ by $u(i) = u_i$. The fuzzy welfare index of the person $i$ in the society $S$ is defined as the real number

$$w_i = (1 - \alpha)\tilde{y}_i + \alpha u_i.$$

Using this index, the FWF, $w_y$ can be modified.

**Definition 6.2.4.** The modified FWF is defined as $W'_y : S \times S \rightarrow [0, 1]$ by

$$W'_y(i, j) = \max\{w_i - w_j, 0\}, \ i, j \in S.$$

The modified FWF, $W'_y$ takes in to account one or more parameter $u$ along with the income. In general if there are $m$ parameters say $u_1, u_2, \ldots u_m$ of an individual’s welfare other than his income parameter $y_i$, then

$$u_k : S \rightarrow [0, 1], \text{ by } u_k(i) = u_{ki}, \ k = 1, 2, \ldots m, \ i = 1, 2\ldots n.$$

Then $w_i$ is calculated using the formula

$$W_i = \left(1 - \sum_{k=1}^{m} \alpha_k\right) \tilde{y}_i + \sum_{k=1}^{m} \alpha_k u_k, \ k = 1, 2, \ldots m, \ i = 1, 2\ldots n.$$

Once the indicators and their respective weights are identified, this modified fuzzy welfare function can measure welfare of individual or country in a better way and comparison of welfare between individuals or countries makes easy. Attributes considered here are income, education (traditional/general), employment (traditional/general),

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leisure, social status, physical fitness, access to power, access to forest and their respective weights are 0.5, 0.6, 0.4, 0.4, 0.5, 0.3, 0.6 respectively. Here all attributes other than income are fuzzy and values between 0 and 1 for each such attributes and after closely observing and seeking information from experts who knows them, the conclusion is arrived at.

The modified fuzzy welfare function of the first colony: (Table 6.5)

\[ W_i = \left( 1 - \sum_{k=1}^{7} \alpha_k \right) \tilde{y}_i + \sum_{k=1}^{7} \alpha_k u_i. \]

\[ W_1 = 1 - (0.5 + 0.6 + 0.4 + 0.4 + 0.5 + 0.3 + 0.6) \times 0.1 + 0.5 \times 0.1 + 0.6 \times 0.1 \]
\[ + 0.4 \times 0.4 + 0.4 \times 0.2 + 0.5 \times 0.1 + 0.3 \times 0.1 + 0.6 \times 0.1 \]
\[ = (1 - 3.3) \times 0.1 + 0.05 + 0.06 + 0.16 + 0.08 + 0.05 + 0.03 + 0.12 \]
\[ = -2.3 \times 0.1 + 0.55 \]
\[ = -0.23 + 0.55 \]
\[ = 0.32. \]

\[ W_2 = -2.3 \times 0.45 + 0.10 + 0.18 + 0.16 + 0.08 + 0.15 + 0.06 + 0.12 \]
\[ = -1.035 + 0.85 \]
\[ = -0.185. \]

\[ W_3 = -2.3 \times 0.5 + 0.20 + 0.18 + 0.20 + 0.12 + 0.20 + 0.09 + 0.12 \]
\[ = -1.15 + 1.11 \]
\[ = -0.04. \]
Table 6.5. General information - Colony I

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Name</th>
<th>Income (Rs.)</th>
<th>$y_i$</th>
<th>Education (Tribal/General)</th>
<th>Emploment (Tribal General)</th>
<th>Leisure</th>
<th>Social status</th>
<th>Physical fitness</th>
<th>Access to Power</th>
<th>Access to Forest</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rangaswami Gopalan</td>
<td>400</td>
<td>0.1</td>
<td>0.1</td>
<td>0.4</td>
<td>0.2</td>
<td>0.1</td>
<td>0.1</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Kuttappan</td>
<td>1800</td>
<td>0.45</td>
<td>0.2</td>
<td>0.3</td>
<td>0.4</td>
<td>0.2</td>
<td>0.3</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Gopi</td>
<td>2000</td>
<td>0.5</td>
<td>0.4</td>
<td>0.3</td>
<td>0.5</td>
<td>0.3</td>
<td>0.4</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Babu</td>
<td>1400</td>
<td>0.35</td>
<td>0.3</td>
<td>0.5</td>
<td>0.5</td>
<td>0.2</td>
<td>0.5</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Rangaswami</td>
<td>2200</td>
<td>0.55</td>
<td>0.3</td>
<td>0.4</td>
<td>0.4</td>
<td>0.2</td>
<td>0.5</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Prakash</td>
<td>1200</td>
<td>0.3</td>
<td>0.4</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.4</td>
<td>0.3</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Shaji</td>
<td>4000</td>
<td>1</td>
<td>0.7</td>
<td>0.5</td>
<td>0.4</td>
<td>0.6</td>
<td>0.5</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Chandran</td>
<td>1500</td>
<td>0.375</td>
<td>0.3</td>
<td>0.4</td>
<td>0.3</td>
<td>0.3</td>
<td>0.4</td>
<td>0.3</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Manoj Gopalan</td>
<td>1200</td>
<td>0.3</td>
<td>0.3</td>
<td>0.2</td>
<td>0.3</td>
<td>0.2</td>
<td>0.4</td>
<td>0.2</td>
<td></td>
</tr>
</tbody>
</table>

$\alpha_1 = 0.5 \quad \alpha_2 = 0.6 \quad \alpha_3 = 0.4 \quad \alpha_4 = 0.4 \quad \alpha_5 = 0.5 \quad \alpha_6 = 0.3 \quad \alpha_7 = 0.6$
\[ W_4 = -2.3 \times 0.35 + 0.15 + 0.30 + 0.20 + 0.08 + 0.25 + 0.12 + 0.12 \]
\[ = -0.805 + 1.22 \]
\[ = 0.415. \]

\[ W_5 = -2.3 \times 0.55 + 0.15 + 0.24 + 0.16 + 0.08 + 0.25 + 0.06 + 0.12 \]
\[ = -1.265 + 1.06 \]
\[ = -0.205. \]

\[ W_6 = -2.3 \times 0.3 + 0.20 + 0.18 + 0.12 + 0.12 + 0.20 + 0.09 + 0.12 \]
\[ = -0.67 + 1.03 \]
\[ = 0.34. \]

\[ W_7 = -2.3 \times 1 + 0.35 + 0.30 + 0.16 + 0.24 + 0.25 + 0.12 + 0.12 \]
\[ = -2.3 + 1.54 \]
\[ = -0.76. \]

\[ W_8 = -2.3 \times 0.375 + 0.15 + 0.24 + 0.12 + 0.12 + 0.20 + 0.09 + 0.12 \]
\[ = -0.8625 + 1.04 \]
\[ = 0.1775. \]

\[ W_9 = -2.3 \times 0.3 + 0.15 + 0.12 + 0.12 + 0.08 + 0.20 + 0.06 + 0.12 \]
\[ = -0.69 + 0.85 \]
\[ = 0.16 \]

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Table 6.6. Fuzzy welfare index of first colony

<table>
<thead>
<tr>
<th>Person</th>
<th>Income (Rs.)</th>
<th>Welfare index</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>400</td>
<td>0.32</td>
</tr>
<tr>
<td>2</td>
<td>1800</td>
<td>-0.185</td>
</tr>
<tr>
<td>3</td>
<td>2000</td>
<td>-0.04</td>
</tr>
<tr>
<td>4</td>
<td>1400</td>
<td>0.415</td>
</tr>
<tr>
<td>5</td>
<td>2200</td>
<td>-0.205</td>
</tr>
<tr>
<td>6</td>
<td>1200</td>
<td>0.34</td>
</tr>
<tr>
<td>7</td>
<td>4000</td>
<td>-0.76</td>
</tr>
<tr>
<td>8</td>
<td>1500</td>
<td>0.1775</td>
</tr>
<tr>
<td>9</td>
<td>1200</td>
<td>0.16</td>
</tr>
</tbody>
</table>

The modified fuzzy welfare function of the second colony: (Table 6.7)

\[ W_i = \left( 1 - \sum_{K=1}^{7} \alpha_K \right) \tilde{y}_i + \sum_{K=1}^{7} \alpha_K u_i. \]

\[ W_1 = (1 - 0.5 + 0.6 + 0.4 + 0.4 + 0.5 + 0.3 + 0.6) \times 0.1 \]
\[ + 0.40 + 0.42 + 0.28 + 0.24 + 0.35 + 0.06 + 0.48 \]
\[ = -2.3 + 2.23 \]
\[ = -0.07. \]

\[ W_2 = -2.3 \times 0.8 + 0.25 + 0.30 + 0.32 + 0.20 + 0.35 + 0.03 + 0.48 \]
\[ = -1.84 + 1.93 \]
\[ = 0.09. \]

\[ W_3 = -2.3 \times 0.8 + 0.35 + 0.36 + 0.28 + 0.24 + 0.30 + 0.03 + 0.54 \]
\[ = -1.84 + 2.10 \]
\[ = 0.26. \]

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Table 6.7. General information - Colony II

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Name</th>
<th>Income (Rs.)</th>
<th>$y_i$</th>
<th>Education (Tribal/General)</th>
<th>Employment (Tribal/General)</th>
<th>Leisure</th>
<th>Social status</th>
<th>Physical fitness</th>
<th>Access to Power</th>
<th>Access to Forest</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sivaswami</td>
<td>1300</td>
<td>1</td>
<td>0.8</td>
<td>0.7</td>
<td>0.7</td>
<td>0.6</td>
<td>0.7</td>
<td>0.2</td>
<td>0.8</td>
</tr>
<tr>
<td>2</td>
<td>Ponnuswami</td>
<td>1000</td>
<td>0.8</td>
<td>0.5</td>
<td>0.8</td>
<td>0.5</td>
<td>0.7</td>
<td>0.7</td>
<td>0.1</td>
<td>0.8</td>
</tr>
<tr>
<td>3</td>
<td>Thirumoorthy</td>
<td>1000</td>
<td>0.8</td>
<td>0.7</td>
<td>0.6</td>
<td>0.6</td>
<td>0.6</td>
<td>0.6</td>
<td>0.1</td>
<td>0.9</td>
</tr>
<tr>
<td>4</td>
<td>Manikandan</td>
<td>800</td>
<td>0.6</td>
<td>0.4</td>
<td>0.6</td>
<td>0.4</td>
<td>0.6</td>
<td>0.6</td>
<td>0.1</td>
<td>0.7</td>
</tr>
<tr>
<td>5</td>
<td>S.Thankaraj</td>
<td>1200</td>
<td>0.9</td>
<td>0.8</td>
<td>0.7</td>
<td>0.7</td>
<td>0.8</td>
<td>0.7</td>
<td>0.2</td>
<td>0.8</td>
</tr>
<tr>
<td>6</td>
<td>Suresh</td>
<td>750</td>
<td>0.6</td>
<td>0.3</td>
<td>0.4</td>
<td>0.4</td>
<td>0.7</td>
<td>0.7</td>
<td>0.2</td>
<td>0.7</td>
</tr>
<tr>
<td>7</td>
<td>Sivamuthu</td>
<td>600</td>
<td>0.5</td>
<td>0.4</td>
<td>0.5</td>
<td>0.5</td>
<td>0.6</td>
<td>0.6</td>
<td>0.1</td>
<td>0.6</td>
</tr>
<tr>
<td>8</td>
<td>Palswami</td>
<td>300</td>
<td>0.2</td>
<td>0.4</td>
<td>0.4</td>
<td>0.5</td>
<td>0.5</td>
<td>0.7</td>
<td>0.2</td>
<td>0.6</td>
</tr>
<tr>
<td>9</td>
<td>Bhokedran</td>
<td>800</td>
<td>0.6</td>
<td>0.5</td>
<td>0.6</td>
<td>0.6</td>
<td>0.6</td>
<td>0.6</td>
<td>0.2</td>
<td>0.8</td>
</tr>
</tbody>
</table>

$\alpha_1 = 0.5$  $\alpha_2 = 0.6$  $\alpha_3 = 0.4$  $\alpha_4 = 0.4$  $\alpha_5 = 0.5$  $\alpha_6 = 0.3$  $\alpha_7 = 0.6$
\[ W_4 = -2.3 \times 0.6 + 0.20 + 0.24 + 0.24 + 0.16 + 0.30 + 0.03 + 0.42 \]
\[ = -1.38 + 1.59 \]
\[ = 0.21. \]

\[ W_5 = -2.3 \times 0.9 + 0.35 + 0.48 + 0.28 + 0.24 + 0.40 + 0.06 + 0.48 \]
\[ = -2.07 + 2.29 \]
\[ = -0.22. \]

\[ W_6 = -2.3 \times 0.6 + 0.15 + 0.24 + 0.20 + 0.16 + 0.35 + 0.06 + 0.42 \]
\[ = -1.38 + 1.58 \]
\[ = 0.2. \]

\[ W_7 = -2.3 \times 0.5 + 0.20 + 0.30 + 0.24 + 0.20 + 0.30 + 0.03 + 0.36 \]
\[ = -1.15 + 1.63 \]
\[ = 0.48. \]

\[ W_8 = -2.3 \times 0.2 + 0.20 + 0.24 + 0.20 + 0.20 + 0.35 + 0.06 + 0.36 \]
\[ = -0.46 + 1.61 \]
\[ = 1.15. \]

\[ W_9 = -2.3 \times 0.6 + 0.25 + 0.30 + 0.24 + 0.24 + 0.30 + 0.06 + 0.48 \]
\[ = -1.38 + 1.81 \]
\[ = 0.43. \]

Fuzzy theory can be effectively applied for the study of tribal welfare. The tribal situation in Kerala is highly complex and tribal welfare programs of the government are
Table 6.8. Fuzzy welfare index of the second colony

<table>
<thead>
<tr>
<th>Person</th>
<th>Income (Rs.)</th>
<th>Welfare index</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1300</td>
<td>−0.07</td>
</tr>
<tr>
<td>2</td>
<td>1000</td>
<td>0.09</td>
</tr>
<tr>
<td>3</td>
<td>1000</td>
<td>0.26</td>
</tr>
<tr>
<td>4</td>
<td>800</td>
<td>0.21</td>
</tr>
<tr>
<td>5</td>
<td>1200</td>
<td>−0.22</td>
</tr>
<tr>
<td>6</td>
<td>750</td>
<td>0.2</td>
</tr>
<tr>
<td>7</td>
<td>600</td>
<td>0.48</td>
</tr>
<tr>
<td>8</td>
<td>400</td>
<td>1.15</td>
</tr>
<tr>
<td>9</td>
<td>800</td>
<td>0.43</td>
</tr>
</tbody>
</table>

not always effective in bringing about the desired outcome. The preferences and the inclinations of the tribals are not always understood well before implementing welfare programs for them.

From the previous analysis the conclusion is that tribal groups which live in the interior forest with very little interaction with the outside world, (as in the second colony of this study) lead a happy and contented life. On the other hand, the tribal communities having better access to modern facilities and development (as in the first colony) are not necessarily happier than their counterparts in interior forests.

6.3 Application of simple Fuzzy Cognitive maps for the study of Tribal Empowerment and Conservation of Biodiversity

Fuzzy Cognitive Maps (FCMs) have a wide range of applications as they are the best suited tool in the study and analysis of unsupervised data. The hidden pattern of a dynamical system can be obtained using FCMs. In this section the relationship between the conservation of environment and the empowerment of Tribals is analysed in the case of tribals living in the newly established tribal gramapanchayath of Edamalakudy in Idukki district of Kerala state.
6.3.1 Fuzzy cognitive maps (FCMs) as a mathematical tool for evaluating the suitability and effectiveness of various tribal development programs. FCMs are the best suited tool in the study and analysis of the unsupervised data. For they are the only structures which can give the hidden pattern of the dynamical system. Let $C_1, C_2, \ldots, C_n$ be $n$ attributes or nodes. Suppose there is some causal flow of relation between the concepts $C_i$ and $C_j$ where $1 \leq i, j \leq n$, this relation of how much the occurrence of $C_i$ influences variations or changes in $C_j$ can be described by signed directed graphs with feedback. Fuzzy cognitive maps are fuzzy signed directed graphs with feedback. The directed edge $e_{ij}$ from causal concept $C_i$ to concept $C_j$ measures how much $C_i$ causes $C_j$. The edges $e_{ij}$ take values in the real interval $[-1, 1]$. $e_{ij} = 0$ indicate no causality. $e_{ij} > 0$ indicates causal increase; $C_j$ increases as $C_i$ increases, or $C_j$ decreases as $C_i$ decreases. $e_{ij} < 0$ indicates causal decrease or negative causality that is $C_j$ increases as $C_i$ decreases or $C_j$ decreases as $C_i$ increases.

Simple FCMs have edge values in $\{-1, 0, 1\}$. If causality occurs, it occurs to maximal positive or negative degree. Simple FCMs provide a quick first-hand information to an expert’s stated causal knowledge. In this study, only the simple FCMs are used. Using the directed graphs obtain the causal connection matrix $m$ which is a $n \times n$ matrix with entries from the set $\{-1, 0, 1\}$. $A = (a_1, a_2, \ldots, a_n)$ is called a state vector where either $a_i = 0$ or $1$. $a_i = 0$ implies the concept $C_i$ is in the off state. $a_i = 1$ implies the concept $C_i$ is in the on state.

We pass state vectors $C_i$ repeatedly through the FCM connection matrix $M$. An equilibrium in this system is attained when there is a set of repeating patterns, which can be fixed points or limit cycles. A fixed point is a single recurring pattern such as,
say, $C_3 \Rightarrow C_3$ in the pattern $C_1 \Rightarrow C_2 \Rightarrow C_3 \Rightarrow C_3$. A limit cycle is a set of multiple repeating patterns such as $C_3 \Rightarrow C_4 \Rightarrow C_5, C_1 \Rightarrow C_2 \Rightarrow C_3 \Rightarrow C_4 \Rightarrow C_5 \Rightarrow C_3 \Rightarrow C_4 \Rightarrow C_5, \ldots$. Thus the fixed point or limit cycle is known as the hidden pattern of the system. The state vector is updated and thresholded at each stage. Inference from the hidden pattern summarizes the joint effects of all interacting fuzzy knowledge. Since the data is an unsupervised one and the study is done using experts opinion, an unbiased analysis of the problem is made.

6.3.2 Adaptation of FCM to tribal problems.

Using the linguistic questionnaire and the experts opinion the following eight attributes $P_1, P_2, P_3, P_4, P_5, P_6, P_7, P_8$ are taken. These eight attributes are taken as the main nodes for study.

$P_1$ - A role for tribals in Conservation of biodiversity - to be given
$P_2$ - Forest dependence of tribals for their basic needs - to be permitted
$P_3$ - Troubles from outsiders and forest officials - to be avoided
$P_4$ - Education and health care with tribal orientation - to be given
$P_5$ - Remunerative prices for tribal agriculture and forest produces - given
$P_6$ - Tribal agriculture and modern agriculture - to be promoted together
$P_7$ - Acceptance of traditional laws, folklore and culture to be promoted
$P_8$ - Tribal handicrafts and ecotourism for livelihood - Promoted.

The causal connection matrix $M_1$ is given by the expert who is a teacher in a single teacher school for tribals in Edamalakudy.

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Using the dynamical system given by the expert we determine the hidden pattern. Suppose that $P_1$ is in the ON state and all the nodes are in the OFF state.

Let the initial input vector be $X = (10000000)$, where conservation of biodiversity by giving a specific role to the Tribals is in the ON state and all other nodes are in the OFF state. The effect of $X$ on the dynamical system $M_1$ is given by

$$X \ M_1 = (00100001)$$

$$\rightarrow (10100001) = X_1$$

$$X_1 \ M_1 = (11101001) = X_2$$

$$X_2 \ M_1 = (11101101)$$

$$\rightarrow (11101101) = X_3$$

$$X_3 \ M_1 = (11101101)$$

$$\rightarrow (11101101) = X_3.$$
Where $\rightarrow$ denote the resultant vector after thresholding and updating. $X_3$ is the hidden pattern. Suppose that $P_4$ is in the ON state and all the nodes are in the OFF state. Let the initial input vector be $X = (00010000)$, where giving education and health care is in ON state and all other nodes are in the OFF state. The effect of $X$ on the dynamical system $M_1$ is given by

$$X M_1 = (00100101)$$

$$\rightarrow (00110101) = X_1$$

$$X_1 M_1 = (11101101)$$

$$\rightarrow (11111101) = X_2$$

$$X_2 M_1 = (11101101)$$

$$\rightarrow (11111101) = X_2.$$

$X_2$ is hidden pattern. The conclusion is that all attributes except $P_7$ will be satisfied if a role is given to tribals in conservation of biodiversity (represented by $P_1$). The hidden pattern for various other initial inputs such as $P_2, P_3, \ldots$ can also be obtained.

This analysis also shows that Edamalakudy is a place where the welfare of tribals and the conservation of biodiversity should meet together in harmony. It shows how biodiversity and empowerment of tribals is related. By conserving the environment of the area and finding alternate solutions to various problems it is possible to empower them and make them better off than the tribals who do not have access to such a natural environment. So for the empowerment of tribals the attributes are to be followed.
6.4 Application of Fuzzy Relational Maps (FRMs) for analysis of the role of forest dwelling tribes in biodiversity management

The fuzzy relational maps can be used as effective tools for analysing unsupervised data. The hidden pattern of a dynamical system can be obtained using fuzzy relational maps (FRMs). In this section, FRMs are used to analyse the role of forest dwelling tribes in biodiversity management.

Conservation of biodiversity is a matter of great concern for modern man. Large scale destruction of floral and faunal diversity on account of human activities is making the planet earth increasingly inhospitable to all living organisms including man. The tribals living in deep forests depend almost entirely on their environment for their nourishment and livelihood. In spite of numerous legislative steps for establishing the rights of tribals over their ancestral lands in the forests, they are being prevented by the forest and revenue departments from gaining unrestricted access to forest resources out of the concern for conservation of forest ecosystems. In this section, the role of acknowledging the rights of tribals over their ancestral forest land in biodiversity conservation is analysed using fuzzy relational maps.

Fuzzy relational maps (FRMs) were introduced by Dr. Vasantha and Sultana (2000). In FRMs association is divided into two disjoint units, a domain space and a range space which are disjoint in the sense of concept, and no intermediate relations exist within the domain and the range space.

The elements of the domain space are taken from the real vector space of dimensions \( n \), and that of the ranges space are real vectors from the vector space of dimension \( m \).

Let \( R_1, R_2, \ldots, R_m \) be the nodes of the range space where \( R_1 = \{(x_1, x_2, \ldots x_m)/x_i = 0 \text{ or } 1\} \) for \( i = 1, 2, \ldots m \).

If \( x_i = 1 \), it means that the node \( R_i \) is in the ON state and if \( x_i = 0 \) it means that the node \( R_i \) is in the OFF state.
Similarly $D$ denotes the nodes $D_1, D_2, \ldots, D_m$ of the domain space where $D_i = \{(x_1, x_2, \ldots, x_n)/x_i = 0 \text{ or } 1\}$ for $i = 1, 2, \ldots, n$. If $x_i = 1$, the node $D_i$ is in the ON state and $x_i = 0$ means that the node $D_i$ is in the OFF state.

FRM is a directed graph or a map from $D$ to $R$ with concepts like policies or events etc. as nodes and causalities as edges. Every edge in the FRM is weighted with a number in the set $\{0, 1\}$. Let $D_i$ and $R_j$ denote the two nodes of an FRM and let $e_{ij}$ be the weight of the edge $D_i R_j$. The FRMs can be a rectangular matrix with rows corresponding to the domain space and columns corresponding to the range space. When the causal relations flow through a cycle in a revolutionary manner, then the FRM is called a dynamical system. The equilibrium state of this dynamical system is called the hidden pattern.

Let $R_1, R_2, \ldots, R_m$ and $D_1, D_2, \ldots, D_n$ be the nodes of a FRM. Let $E$ be the $n \times m$ relational matrix. Let us find the hidden pattern when $D_1$ is switched ON, that is when an input is given as vector $A_1 = (100 \ldots 0)$ in $D$ the data should pass through the relational matrix $E$. This is done by multiplying $A_1$ with the relational matrix $E$.

Let $A_1 E = (r_1, r_2 \ldots r_m)$ after thresholding and updating the resultant vector say $B$ belongs to $R$. Now let $B$ pass on into $E^T$ and obtain $BE^T$. After thresholding and updating $BE^T$ it is seen that the resultant vector say $A_2$ belongs to $D$. This procedure is repeated till a limit cycle or a fixed point is obtained.

6.4.1 Adaptation of FRM to the problem. Using the linguistic questionnaire and the experts’ opinion the following attributes are taken, and using these attributes and the opinion of the experts FRM is used to analyse the problem.

Attributes related to the domain space $D$ given by $D = \{D_1, D_2, \ldots, D_5\}$.

- $D_1$ - Deforestation
- $D_2$ - Pollution due to factories, vehicles
- $D_3$ - Construction of roads, dams, buildings
- $D_4$ - Climate change/global warming
- $D_5$ - Disappearance of some species of plants and animals.

Attributes related to the range space $R$ given by $R = \{R_1, R_2, \ldots, R_7\}$
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$R_1$ - Corrupted forest officials/selfishness of man
$R_2$ - Insensitiveness of modern man to nature
$R_3$ - Desire for profit ignoring nature.
$R_4$ - Formation of new, strong harmful viruses and bacteria
$R_5$ - Desire of more comfort ignoring impact on environment
$R_6$ - Not recognising ancestral land holdings of tribes or given power to protect forest and biodiversity
$R_7$ - Use of chemicals, fertilizers and pesticides.

Now using the expert’s opinion who is a teacher of tribe school, the following relational matrix is obtained

$$E = \begin{bmatrix}
1 & 0 & 1 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 \\
0 & 0 & 1 & 0 & 1 & 0 & 0 \\
1 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 1
\end{bmatrix}.$$  

Consider the effect of the ON state of the node (not recognising tribal) and all other nodes are in the OFF state. The hidden pattern of the state vector

$$X = \begin{bmatrix}
0 \\
0 \\
0 \\
0 \\
0 \\
1 \\
0
\end{bmatrix}$$

is obtained by the following method

$$EX = \begin{bmatrix}
1 \\
0 \\
0 \\
0 \\
0 \\
1 \\
0
\end{bmatrix} = Y$$

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The above analysis shows that when $R_6$ is in ON state $D_1, D_3, D_4, R_1, R_2, R_3, R_5, R_6$ are in ON state. This drives to the conclusion that, by recognising the rights of tribes over their ancestral forest lands, it will be possible to prevent deforestation, destruction of forests for development activities and depletion of biodiversity and there by contribute to the prevention of climate change and global warming. It also shows that this step can reduce the impact of corrupt forest officials and the insensitivity of modern man to destruction of nature and natural endowments and at the same time enable the indigenous communities to lead a happy and contented life in tune with nature.