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# Farmers' Suicides in India: A Neuro-Fuzzy Analysis

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Abstract - Thousands of farmers in India have committed suicide in the past twenty years. Experts opine that the seeds for this crisis were sown during Green Revolution itself and some also attribute the environmental degradation to this crisis. In this paper we analyse the causes which have contributed to the farmers' suicides using Combined disjoint block Fuzzy Cognitive maps (COBFCM). The first section of the paper gives an introduction to the problem of suicides by farmers and section two and three describe COBFCM model and the way of determining the hidden pattern. In section four we adapt the model to the problem and analyse the data and in section five derive conclusion from our analysis andgive suggestions to address the problem.

Keywords: Fuzzy, Neural networks, Fuzzy cognitive maps, Farmers' suicide, agrarian crisis, Indian agriculture.

## I. INTRODUCTION

Farmers in india have committed suicide in large number in the past twenty years or so. There are differences of opinions among the policy makers, the agricultural experts and environmentalists on what were the causes for this crisis. Some say that the seeds of this crisis were sown duringthe period of Green Revolution itself and therefore it is mainly policy driven. There are others who say that it is because of the vagaries of the market and some others who hold environmental degradation to be the major cause. Iyer and Manick (2000) make a useful distinction between "causative" and "precipitative" factors which push farmers to take this extreme step saying that while the precipitant factors could be social and psychological, the causative factors were economic (primarily indebtedness). Taking all these views into consideration we have identified sixteen attributes which are the causes for farmers' suicides, divided them into four disjoint classes and use Combined disjoint block FCM to analyse the problem.

## II. PRELIMINARIES

Fuzzy Cognitive Maps (FCMs) are more applicable when the datain the first place is an unsupervised one. The FCMs work on the opinion of experts. FCMs model the world as a collection ofclasses and causal relations between classes.

Definition 2.1: An FCM is a directed graph with conceptslike policies, events etc. as nodes and causalities as edges. It represents causal relationship between concepts.

Definition 2.2: When the nodes of the FCM are fuzzysets then they are called as fuzzy nodes.

Definition 2.3: FCMs with edge weights or causalities fromthe set {-1, 0, 1} are called simple FCMs.

Definition 2.4: The edges $e_{ij}$ take values in the fuzzycausal interval [–1, 1]. $e_{ij} = 0$ indicates 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 ornegative causality. $C_j$ decreases as $C_i$ increases (and or $C_j$increases as $C_i$ decreases). Simple FCMs have edge values in {–1, 0, 1}. Then if causality occurs, it occurs to a maximalpositive or negative degree. Simple FCMs provide a quick firstapproximation to an expert stand or printed causal knowledge.If increase (or decrease) in one concept leads to increase (ordecrease) in another, and then we give the value 1. If there is norelation between two concepts, the value 0 is given. If increase(or decrease) in one concept decreases (or increases) another,then we give the value –1. Thus FCMs are described in thisway. Consider the nodes or concepts $C_1, \dots, C_n$ of the FCM. Suppose the directed graph is drawn using edge weight $e_{ij}$ {0, 1, -1}. The matrix E be defined by $E = (e_{ij})$, where $e_{ij}$ is the weight of thedirected edge $C_iC_j$. E is called the adjacency matrix of the FCM,also known as the connection matrix of the FCM. It is important to note that all matrices associated with an FCM are alwayssquare matrices with diagonal entries as zero.

Definition 2.5: Let $C_1, C_2, \dots, C_n$ be the nodes of an FCM. Let $A= (a_1, a_2, \dots, a_n)$, where $a_i \in \{0,1\}$. A is called the instantaneous state vector and it denotes the on-off position of the node at an instant.

$a_i = 0$ if $a_i$ is off and $a_i =1$ if $a_i$ is on, where i = 1, 2, , n.
Definition 2.6: Let $C_1, C_2, , C_n$ be the nodes of an FCM. Let $\overrightarrow{C_1C_2}, \overrightarrow{C_2C_3}, \dots, \overrightarrow{C_iC_j}$be the edges of the FCM ($i \neq j$). Then, the edges form a directed cycle. An FCM is said to be cyclic if it possesses a directed cycle. An FCM is said to be acyclic if it does not possess any directed cycle.

Definition 2.7: An FCM with cycles is said to have a feedback.

Definition 2.8: When there is a feedback in an FCM, i.e., when the causal relations flow through a cycle in a revolutionary way, the FCM is called a dynamical system.

Definition 2.9: Let $\overrightarrow{C_1C_2}, \overrightarrow{C_2C_3}, \dots, \overrightarrow{C_iC_j}$be a cycle. When $C_i$ is switched on and if the causality flows through the edges of a cycle and if it again causes $C_i$, we say that the dynamical system goes round and round. This is true for any node $C_i$, for i = 1, 2, …, n. The equilibrium state for this dynamical system is called the hidden pattern.

Definition 2.10: If the equilibrium state of a dynamical system is a unique state vector, then it is called a fixed point. Consider a FCM with $C_1, C_2, \ldots, C_n$ as nodes. For example let us start the dynamical system by switching on $C_1$. Let us assume that the FCM settles down with $C_1$ and $C_n$on, i.e. the state vector remains as (1, 0, 0, …, 0, 1). This state vector(1, 0, 0, …, 0, 1) is called the fixed point.

Definition 2.11: If the FCM settles down with a state vector repeating in the form $A_1 \rightarrow A_2 \rightarrow \ldots\ldots \rightarrow A_i \rightarrow A_1$, then this equilibrium is called limit cycle.

Definition 2.12: Finite number of FCMs can be combined together to produce the joint effect of all the FCMs. Let $E_1$, $E_2, \ldots, E_p$ be adjacency matrices of the FCMs with nodes $C_1$, $C_2$, , $C_n$, then the combined FCM is got by adding all the adjacency matrices $E_1$, $E_2, \ldots$, $E_p$. We denote the combined FCM adjacency matrix by $E = E_1 + E_2 + \ldots + E_p$.

Definition 2.13: Let P be the problem under investigation. Let $\{C_1, C_2, ..., C_n\}$ be n concepts associated with P (n very large). Now divide the number of concepts $\{C_1, C_2, \ldots, C_n\}$ into classes $S_1, ..., S_t$ where the classes are such that

(i) $S_i \cap S_{i+1} = \emptyset$ where (i = 1, 2, ..., t-1)
(ii)$\cup S_i = \{C_1, C_2, ..., C_n\}$
(iii) $|S_i| = |S_j|$ if $i \neq j$ in general.

Definition 2.14: Suppose $A = (a_1, \ldots, a_n)$ is a vector which is passed into a dynamical system E. Then $AE = (a_1', a_2', \ldots, a_n')$. After thresholding and updating the vector suppose we get$(b_1, b_2, \ldots, b_n)$.We denote that by$(a_1', a_2', \ldots, a_n') \rightarrow (b_1, b_2, \ldots, b_n)$. Thus the symbol means that the resultant vector has been thresholded and updated. FCMs have several advantages as well as some disadvantages. The main advantage of this method it is simple. It functions on expert's opinion. When the data happens to be an unsupervised one the FCM comes handy. This is the only known fuzzy technique that gives the hidden pattern of the situation. As we have a very well known theory, which states that the strength of the data depends on the number of experts' opinion we can use combined FCMs with several experts' opinions. At the same time the disadvantage of the combined FCM is when the weightages are 1 and –1 for the same $C_iC_j$, we have the sum adding to zero thus at all times the connection matrices $E_1, \ldots$, $E_k$ may not be comfortable for addition. This problem will be easily overcome if the FCM entries are only 0 and 1.

## III. METHOD OF DETERMINING THEHIDDEN PATTERN

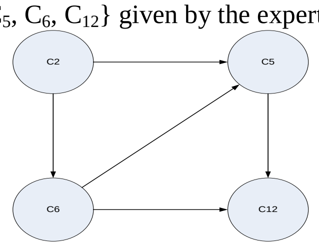
Let $C_1$, $C_2$,., $C_n$ be the nodes of an FCM, with feedback. Let E bethe associated adjacency matrix. Let us find the hidden patternwhen $C_1$is switched on. When an input is given as the vector $A_1 = (1, 0, 0, \ldots, 0)$, the data should pass through the relation matrixE. This is done by multiplying $A_1$ by the matrix E. Let $A_1E = (a_1, a_2, \ldots, a_n)$ with the threshold operation that is by replacing $a_i$by 1 if $a_i > k$ and $a_i$ by 0 if $a_i < k$ (k is a suitable positiveinteger).We update the resulting concept, the concept $C_1$ isincluded in the updated vector by making the first coordinate as1 in the resulting vector. Suppose $A_1E \rightarrow A_2$ then consider $A_2E$ and repeat the same procedure. This procedure is repeated tillwe get a limit cycle or a fixed point.

## IV. ADAPTATION OF COBFCM TO THE PROBLEM

Using the linguistic questionnaire and the experts opinion we have taken the following twelve concepts $\{C_1, C_2, ..., C_{16}\}$. These concepts are taken as the main nodes for our problem.

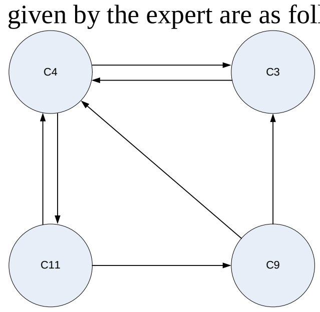
$C_1$ – Indebtedness
$C_2$ – Liberalisation policies
$C_3$ – Changed cropping pattern
$C_4$ – Growing costs of cultivation
$C_5$ – Lack of remunerative prices
$C_6$ – Decline in public investment
$C_7$ – Break up of joint families
$C_8$ – Uncertainty of crop yield
$C_9$ – Fluctuation in the prices of agricultural produce
$C_{10}$ – Lack of helplines to counsel the farmers in despair
$C_{11}$ – Role of middle men (traders, money lenders, etc.)
$C_{12}$ – Commercialisation and mechanisation of agriculture
$C_{13}$ – Frequent droughts or floods
$C_{14}$ – Greater dependence of on monetized inputs such as seeds, fertilizer and pesticide
$C_{15}$ – Withdrawal of institutional support
$C_{16}$ – Depletion of ground water resources; lack of soil conservation.

Let us consider the twelve concepts $\{C_1, C_2, ..., C_{16}\}$. We divide these concepts into cyclic way of classes, each having just four or five concepts in the following way: $S_1$, = $\{C_2, C_5, C_6, C_{12}\}$, $S_2 = \{C_3, C_4, C_9, C_{11}\}$,$S_3 = \{C_8, C_{13}, C_{14}, C_{16}\}$, $S_4 = \{C_1, C_7, C_{10}, C_{15}\}$. The directed graph and the relation matrix for the class $S_1 = \{C_2, C_5, C_6, C_{12}\}$ given by the expert are as follows:




$$E_1 = \begin{pmatrix} 0 & 1 & 1 & 1 \\ 0 & 0 & 0 & 1 \\ 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 0 \end{pmatrix}$$

The directed graph and the relation matrix for the class $S_2 = \{C_3, C_4, C_9, C_{11}\}$ given by the expert are as follows:



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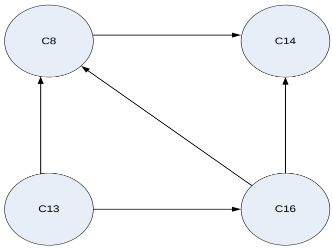
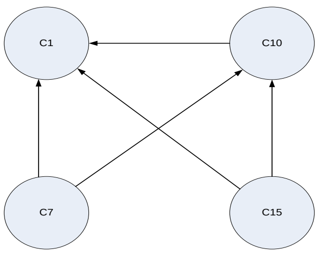
$$E_2 = \begin{pmatrix} 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 1 \\ 1 & 1 & 0 & 0 \\ 0 & 1 & 1 & 0 \end{pmatrix}$$

The directed graph and the relation matrix for the class $S_3 = \{C_8, C_{13}, C_{14}, C_{16}\}$ given by the expert are as follows:




$$E_3 = \begin{pmatrix} 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 \end{pmatrix}$$

The directed graph and the relation matrix for the class $S_4 = \{C_1, C_7, C_{10}, C_{15}\}$ given by the expert are as follows:




$$E_4 = \begin{pmatrix} 0 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 \end{pmatrix}$$

The combined directed graph and the combined overlapping block FCM matrix M are given below:

$$M = \begin{pmatrix} 0&0&0&0&0&0&0&0&0&0&0&0&0&0&0&0 \\ 0&0&0&0&1&1&0&0&0&0&0&1&0&0&0&0 \\ 0&0&0&1&0&0&0&0&0&0&0&0&0&0&0&0 \\ 0&0&1&0&0&0&0&0&0&0&1&0&0&0&0&0 \\ 0&0&0&0&0&0&0&0&0&0&0&1&0&0&0&0 \\ 0&0&0&0&1&0&0&0&0&0&0&1&0&0&0&0 \\ 1&0&0&0&0&0&0&0&0&1&0&0&0&0&0&0 \\ 0&0&0&0&0&0&0&0&0&0&0&0&0&1&0&0 \\ 0&0&1&1&0&0&0&0&0&0&0&0&0&0&0&0 \\ 1&0&0&0&0&0&0&0&0&0&0&0&0&0&0&0 \\ 0&0&0&1&0&0&0&0&1&0&0&0&0&0&0&0 \\ 0&0&0&0&0&1&0&0&0&0&0&0&0&0&0&0 \\ 0&0&0&0&0&0&0&1&0&0&0&0&0&0&0&1 \\ 0&0&0&0&0&0&0&0&0&0&0&0&0&0&0&0 \\ 1&0&0&0&0&0&0&0&0&1&0&0&0&0&0&0 \\ 0&0&0&0&0&0&0&1&0&0&0&0&0&0&0&0 \end{pmatrix}$$

Now using the matrix M of the combined overlap block FCM, we determine the hidden pattern. Suppose that the concept $C_3$ is in ON state and all other nodes are in OFF state. Let the initial input vector be $C_3$ = (0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0), where Changed cropping pattern is taken as ON state and all other nodes are in OFF state.

The effect of $C_3$ on the dynamical system M is given by:

$C_3M$ = (0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0)
↪(0 0 1 1 0 0 0 0 0 0 0 0 0 0 0 0) = $X_1$

$X_1M$ = (0 0 1 1 0 0 0 0 0 0 1 0 0 0 0 0)
↪ (0 0 1 1 0 0 0 0 0 0 1 0 0 0 0 0) = $X_2$

$X_2M$ = (0 0 1 2 0 0 0 0 1 0 1 0 0 0 0 0)
↪(0 0 1 1 0 0 0 0 1 0 1 0 0 0 0 0) = $X_3$

$X_3M$ = (0 0 2 3 0 0 0 0 1 0 1 00 0 0 0)
↪(0 0 1 1 0 0 0 0 1 0 1 0 0 0 0 0) =$X_3$

Therefore $X_3$ is the hidden pattern, which is also the fixed point.The following table gives different fixed points that we get for different input vectors.

| Input vector | Hidden pattern |
|---|---|
| (1000000000000000) | (1000000000000000) |
| (0100000000000000) | (0100110000010000) |
| (0010000000000000) | (0011000010100000) |
| (0001000000000000) | (0011000010100000) |
| (0000100000000000) | (0000110000010000) |
| (0000010000000000) | (0000110000010000) |
| (0000001000000000) | (1000001001000000) |
| (0000000100000000) | (0000000100000100) |
| (0000000010000000) | (0011000010100000) |
| (0000000001000000) | (1000000001000000) |
| (0000000000100000) | (0011000010100000) |
| (0000000000010000) | (0000110000010000) |
| (0000000000001000) | (0000000100001101) |
| (0000000000000100) | (0000000000000100) |
| (0000000000000010) | (1000000001000010) |
| (0000000000000001) | (0000000100000101) |

## V. CONCLUSION AND SUGGESTIONS

From the table above it can be observed that when one of the attributes $C_2$, $C_3$, $C_4$, $C_9$, $C_{11}$ and $C_{13}$ is kept in ON state it induces more number of other attributes to be ON state. Therefore it can be said that these six attributes play a lead role in worsening the condition of the farmers and push them to commit suicide. In order to address this phenomenon of farmers' suicides the policy makers should reverse their policies as liberalization has worsened the situation by pushing farmers prematurely into global market without creating level field. Growing costs of cultivation should be controlled and the seed and pesticides should be provided to the farmers at subsidized rates. The role of traders and seed companies in manipulating the market condition to their favour should be

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addressed. As the agricultural production is affected by frequent droughts and floods, crop insurance policy should be introduced to create confidence among the farmers.

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