

A Fuzzy Analysis on the Causes of Farmers Suicides in India

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Abstract - Indian agriculture is engulfed into a crisis and this is evident from the phenomenon of farmers' suicides. There are many factors which are responsible for this crisis and most of them are economic and political. Many consider this crisis as policy-driven. In this paper we analyse the causes which have contributed to the farmers' suicides using Combined overlap 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 and give suggestions to address the problem.

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

I. INTRODUCTION

Agriculture is considered the backbone of Indian economy. Jawaharlal Nehru who took over as the first prime minister of free India said 'everything else can wait but not agriculture'. Gradually this view which sees agriculture as the most important thing in Indian economy changed over time in the mind of the rulers of this country and now the farmers are left to the mercy of the market forces. Indian agriculture has been pushed into a crisis and it is very much evident from farmers' suicides. According to Crime Bureau Records, between 1995 and 2006 nearly 190,753 farmers have committed suicide. This is first time in India that such a wave of suicides has occurred in any one field of profession. Suri K C says that the 'agrarian distress is not new to India; but farmers' suicides are'. It is also important to note that while farmers are pauperized, on the other hand, agricultural traders and moneylenders have prospered. This suggests that this crisis in which farmers are trapped into is mostly policy-driven.

II. PRELIMINARIES

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

Definition 2.1: An FCM is a directed graph with concepts like 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 fuzzy sets then they are called as fuzzy nodes.

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

Definition 2.4: The edges e_{ij} take values in the fuzzy causal 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 or negative 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 maximal positive or negative degree. Simple FCMs provide a quick first approximation to an expert stand or printed causal knowledge. If increase (or decrease) in one concept leads to increase (or decrease) in another, and then we give the value 1. If there is no relation 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 this way. Consider the nodes or concepts C_1, \dots, C_n of the FCM. Suppose the directed graph is drawn using edge weight $e_{ij} \in \{0, 1, -1\}$. The matrix E be defined by $E = (e_{ij})$, where e_{ij} is the weight of the directed edge $C_i C_j$. 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 always square 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 $i = 1, 2, \dots, n$.

Definition 2.6: Let C_1, C_2, \dots, C_n be the nodes of an FCM. Let $\overrightarrow{C_1 C_2}, \overrightarrow{C_2 C_3}, \dots, \overrightarrow{C_i C_j}$ 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 $\overrightarrow{C_1 C_2}, \overrightarrow{C_2 C_3}, \dots, \overrightarrow{C_i C_j}$ 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 $i = 1, 2, \dots, n$. 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, \dots, 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 $(1, 0, 0, \dots, 0, 1)$. This state vector $(1, 0, 0, \dots, 0, 1)$ is called the fixed point.

Definition 2.11: If the FCM settles down with a state vector repeating in the form $A_1 \rightarrow A_2 \rightarrow \dots \rightarrow A_i \rightarrow A_1$, 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, \dots, E_p be adjacency matrices of the FCMs with nodes C_1, C_2, \dots, C_n , then the combined FCM is got by adding all the adjacency matrices E_1, E_2, \dots, E_p . We denote the combined FCM adjacency matrix by $E = E_1 + E_2 + \dots + E_p$.

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

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

Definition 2.14: Suppose $A = (a_1, \dots, a_n)$ is a vector which is passed into a dynamical system E . Then $AE = (a'_1, a'_2, \dots, a'_n)$. After thresholding and updating the vector suppose we get (b_1, b_2, \dots, b_n) . We denote that by $(a'_1, a'_2, \dots, a'_n) \rightarrow (b_1, b_2, \dots, b_n)$. 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 $C_i C_j$, we have the sum adding to zero thus at all times the connection matrices E_1, \dots, 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 THE HIDDEN PATTERN

Let C_1, C_2, \dots, C_n be the nodes of an FCM, with feedback. Let E be the associated adjacency matrix. Let us find the hidden pattern when C_1 is switched on. When an input is given as the vector $A_1 = (1, 0, 0, \dots, 0)$, the data should pass through the relation matrix E . This is done by multiplying A_1 by the matrix E . Let $A_1 E = (a_1, a_2, \dots, a_n)$ 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 positive integer). We update the resulting concept, the concept C_1 is included in the updated vector by making the first

coordinate as 1 in the resulting vector. Suppose $A_1 E \rightarrow A_2$ then consider $A_2 E$ and repeat the same procedure. This procedure is repeated till we get a limit cycle or a fixed point.

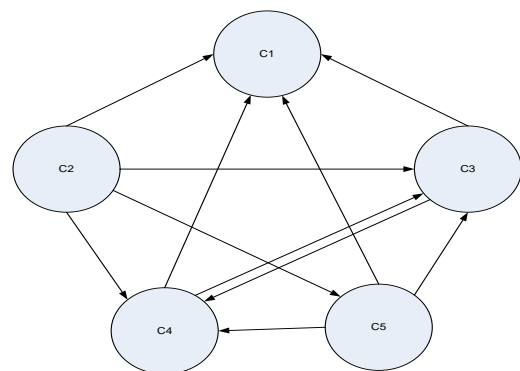
IV. ADAPTATION OF COBFM TO THE PROBLEM

Using the linguistic questionnaire and the experts opinion we have taken the following twelve concepts $\{C_1, C_2, \dots, C_{12}\}$. 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 – Decline in public investment
- C_6 – Break up of joint families
- C_7 – Uncertainty of crop yield
- C_8 – Fluctuation in the prices of agricultural produce
- C_9 – Role of middle men (traders, money lenders, etc.)
- C_{10} – Commercialisation and mechanisation of agriculture
- C_{11} – Frequent droughts or floods
- C_{12} – Depletion of ground water resources; lack of soil conservation.

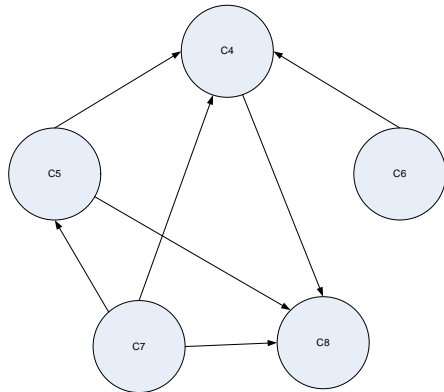
Let us consider the twelve concepts $\{C_1, C_2, \dots, C_{12}\}$. We divide these concepts into cyclic way of classes, each having just four or five concepts in the following way: $S_1 = \{C_1, C_2, C_3, C_4, C_5\}$, $S_2 = \{C_4, C_5, C_6, C_7, C_8\}$, $S_3 = \{C_7, C_8, C_9, C_{10}, C_{11}\}$, $S_4 = \{C_{10}, C_{11}, C_{12}, C_1\}$.

The directed graph and the relation matrix for the class $S_1 = \{C_1, C_2, C_3, C_4, C_5\}$ given by the expert are as follows:



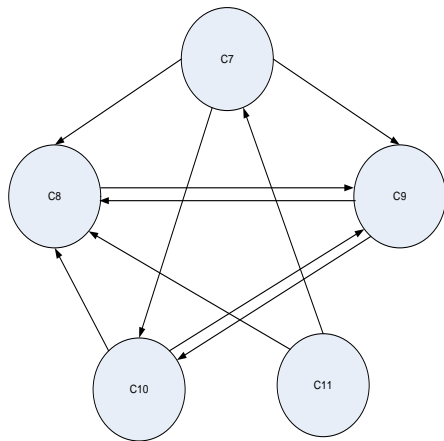
$$E_1 = \begin{matrix} & C_1 & C_2 & C_3 & C_4 & C_5 \\ \begin{matrix} C_1 \\ C_2 \\ C_3 \\ C_4 \\ C_5 \end{matrix} & \begin{pmatrix} 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 1 & 1 & 1 \\ 1 & 0 & 0 & 1 & 0 \\ 1 & 0 & 1 & 0 & 0 \\ 1 & 0 & 1 & 1 & 0 \end{pmatrix} \end{matrix}$$

The directed graph and the relation matrix for the class $S_2 = \{C_4, C_5, C_6, C_7, C_8\}$ given by the expert are as follows:



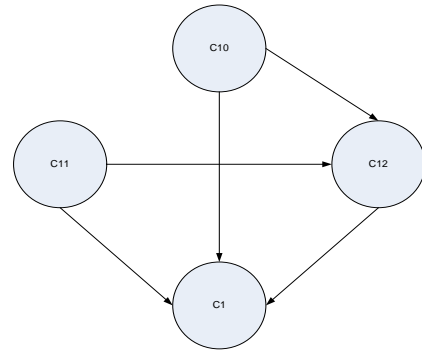
$$E_2 = \begin{matrix} & C_4 & C_5 & C_6 & C_7 & C_8 \\ \begin{matrix} C_4 \\ C_5 \\ C_6 \\ C_7 \\ C_8 \end{matrix} & \begin{pmatrix} 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 \end{pmatrix} \end{matrix}$$

The directed graph and the relation matrix for the class $S_3 = \{C_7, C_8, C_9, C_{10}, C_{11}\}$ given by the expert are as follows:



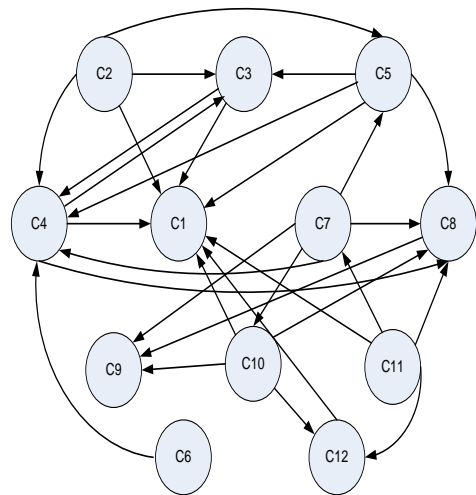
$$E_3 = \begin{matrix} & C_7 & C_8 & C_9 & C_{10} & C_{11} \\ \begin{matrix} C_7 \\ C_8 \\ C_9 \\ C_{10} \\ C_{11} \end{matrix} & \begin{pmatrix} 0 & 1 & 1 & 1 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 0 & 0 \\ 1 & 1 & 0 & 0 & 0 \end{pmatrix} \end{matrix}$$

The directed graph and the relation matrix for the class $S_4 = \{C_{10}, C_{11}, C_{12}, C_1\}$ given by the expert are as follows:



$$E_4 = \begin{matrix} & C_{10} & C_{11} & C_{12} & C_1 \\ \begin{matrix} C_{10} \\ C_{11} \\ C_{12} \\ C_1 \end{matrix} & \begin{pmatrix} 0 & 0 & 1 & 1 \\ 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{pmatrix} \end{matrix}$$

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



$$E = \begin{matrix} & C_1 & C_2 & C_3 & C_4 & C_5 & C_6 & C_7 & C_8 & C_9 & C_{10} & C_{11} & C_{12} \\ \begin{matrix} C_1 \\ C_2 \\ C_3 \\ C_4 \\ C_5 \\ C_6 \\ C_7 \\ C_8 \\ C_9 \\ C_{10} \\ C_{11} \\ C_{12} \end{matrix} & \begin{pmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 1 & 2 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 1 & 0 & 0 & 2 & 1 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix} \end{matrix}$$

Now using the matrix M of the combined overlap block FCM, we determine the hidden pattern. Suppose that the concept C₃ is in ON state and all other nodes are in OFF state. Let the initial input vector be C₃ = (0 0 1 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 C₃ on the dynamical system M is given by:

$$\begin{aligned}
 C_3M &= (1\ 0\ 0\ 1\ 0\ 0\ 0\ 0\ 0\ 0\ 0) \\
 \hookrightarrow (1\ 0\ 1\ 1\ 0\ 0\ 0\ 0\ 0\ 0\ 0) &= X_1 \\
 X_1M &= (2\ 0\ 1\ 1\ 0\ 0\ 0\ 1\ 0\ 0\ 0) \\
 \hookrightarrow (1\ 0\ 1\ 1\ 0\ 0\ 0\ 1\ 0\ 0\ 0) &= X_2 \\
 X_2M &= (2\ 0\ 1\ 1\ 0\ 0\ 0\ 1\ 1\ 0\ 0) \\
 \hookrightarrow (1\ 0\ 1\ 1\ 0\ 0\ 0\ 1\ 1\ 0\ 0) &= X_3 \\
 X_3M &= (2\ 0\ 1\ 1\ 0\ 0\ 0\ 2\ 1\ 1\ 0) \\
 \hookrightarrow (1\ 0\ 1\ 1\ 0\ 0\ 0\ 1\ 1\ 1\ 0) &= X_4 \\
 X_4M &= (3\ 0\ 1\ 1\ 0\ 0\ 0\ 3\ 2\ 1\ 0) \\
 \hookrightarrow (1\ 0\ 1\ 1\ 0\ 0\ 0\ 1\ 1\ 1\ 0) &= X_5 \\
 X_5M &= (4\ 0\ 1\ 1\ 0\ 0\ 0\ 3\ 2\ 1\ 0) \\
 \hookrightarrow (1\ 0\ 1\ 1\ 0\ 0\ 0\ 1\ 1\ 1\ 0) &= X_6 = X_5
 \end{aligned}$$

Therefore X₅ 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
(1 0 0 0 0 0 0 0 0 0 0)	(1000 0 0 0 0 0 0 0 0 0)
(0 1 0 0 0 0 0 0 0 0 0)	(1111 1 0 0 1 1 1 0 1)
(0 0 1 0 0 0 0 0 0 0 0)	(1011 0 0 0 1 1 1 0 1)
(0 0 0 1 0 0 0 0 0 0 0)	(1011 0 0 0 1 1 1 0 1)
(0 0 0 0 1 0 0 0 0 0 0)	(1011 1 0 0 1 1 1 0 1)
(0 0 0 0 0 1 0 0 0 0 0)	(1011 1 0 1 1 1 1 0 1)
(0 0 0 0 0 0 1 0 0 0 0)	(1000 0 0 0 1 1 1 0 1)
(0 0 0 0 0 0 0 1 0 0 0)	(1000 0 0 0 1 1 1 0 1)
(0 0 0 0 0 0 0 0 1 0 0)	(1000 0 0 0 1 1 1 0 1)
(0 0 0 0 0 0 0 0 0 1 0)	(1011 1 0 1 1 1 1 1 1)
(0 0 0 0 0 0 0 0 0 0 1)	(1000 0 0 0 0 0 0 0 1)

V. CONCLUSION

When every attribute from C₂ to C₁₂ is kept in ON state we see in the fixed point that the attribute C₁ is turned ON. This implies that the attribute C₁ie. Indebtedness per se does not push farmers to commit suicide but is the other attributes which leaves farmer neck deep in debt. Therefore to relieve the farmers from crisis it is important to address indebtedness through addressing all the other attributes. It is also important to note that the attributes C₃ and C₇ turn most other attributes to ON state. Therefore Changed cropping pattern and Uncertainty of crop yield become central to this farm crisis. Traditional patterns of farming, which proved to be sustainable, should be encouraged and to the risks associated with uncertainty over crop yield the government should provide a reasonable amount as minimum procurement price and introduce insurance for agricultural crops. Policy makers should give priority to agriculture by increasing public investment in agriculture. As frequent droughts and floods play a major role to lead into regional level agricultural crises, the National disaster management authority should be advised to create a separate wing to protect agricultural lands from disasters and to see that all agricultural lands are insured.

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