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Analyzing the Health Impacts of Climate Change Using Induced Fam

A.Victor Devadoss, D.Ajay
Department of Mathematics, Loyola College, Chennai
Email: dajaypravin@gmail.com

Abstract - Governments and health organizations across the world have rung alarm bells about the spread of new diseases and about an unusual increase in the frequency of health risks. Though many factors contribute to these concerns, climate change has been identified as playing a lead role. The effects of climate change, health reports suggest, have an adverse impact on the health indices. In this paper we analyze the health impacts of climate change using Induced Fuzzy Associative Memories.

Keywords:climate change, health impact, Induced FAM, human health.

I. CLIMATE CHANGE AND HUMAN HEALTH

Climate change refers to “a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity” [IPCC synthesis report, 2007]. It is one of several global environmental changes that affect human health. Various large-scale environmental changes now simultaneously impinge on human population health, often interactively. An obvious example is the transmission of vector-borne infectious diseases. These are affected by: climatic conditions; population movement; forest clearance and land-use patterns; freshwater surface configurations; human population density; and the population density of insectivorous predators.

Anomalies in temperature and rainfall in a particular season could cause a number of vector-borne and water-borne epidemics, thereafter the weather could return to normal. Storms, tropical cyclones and extreme rainfall can cause immediate death and injuries, as well as increased risk of water-borne diseases in the medium-term and psychological stress on affected communities in the long-term.Extremes of heat can cause heat exhaustion, cardiovascular disease (heart attacks and strokes) while cold spells can lead to hypothermia and increase morbidity and mortality from cardiovascular disease. Higher temperatures, changes in precipitation and climate variability would alter the geographical range and seasonality of transmission of many vector-borne diseases.

Heavy rainfall events can transport terrestrial microbiological agents into drinking-water sources resulting in outbreaks of crytosporidiosis, giardiasis, amoebiasis, typhoid and other infections. Changes in surface water quality and quantity are likely to affect the incidence of diarrhoeal diseases. World Health Organization (WHO) estimates more than one billion people worldwide to be without access to safe drinking water, and that every year approximately 1.7 million die prematurely because they do not have access to safe drinking water and sanitation.

IPCC Synthesis report also suggests that the health status of millions of people is projected to be affected through, for example, increases in malnutrition; increased deaths, diseases and injury due to extreme weather events; increased burden of diarrhoeal diseases; increased frequency of cardio-respiratory diseases due to higher concentrations of ground-level ozone in urban areas related to climate change; and the altered spatial distribution of some infectious diseases.

As World Health Organization Constitution states that “the enjoyment of the highest attainable standard of health is one of the fundamental rights of every human being without distinction of race, religion, political belief, economic or social condition”. Thus analyzing the threats climate change poses to human health and to frame concrete action plan to wage a war against these threats becomes more imperative and it is in the noble sense of assuring this fundamental right to good health.

II. FUZZY ASSOCIATIVE MEMORIES (FAM)

A fuzzy set is a map μ : X → [0, 1] where X is any set called the domain and [0, 1] the range. That is to every element x ∈ X, μ assigns membership value in the interval [0, 1]. Fuzzy theorists often picture membership functions as two-dimensional graphs with the domain X represented as a one-dimensional axis.

The geometry of fuzzy sets involves both domain $X=(x_1, x_2, \ldots x_n)$ and the range [0, 1] of mappings μ: X → [0, 1]. A fuzzy subset equals the unit hyper cube $I^n=[0,1]^n$. The fuzzy set is a point in the cube I^n. Vertices of the cube I^n define a non-fuzzy set. Now within the unit hyper cube $I^n=[0,1]^n$ we are interested in distance between points, which led to measures of size and fuzziness of a fuzzy set and more fundamentally to a measure. Thus within cube theory directly extends to the continuous case when the space X is a subset of R^n. The next step is to consider mappings between fuzzy cubes.

A fuzzy set defines a point in a cube. A fuzzy system defines a mapping between cubes. A fuzzy system S maps fuzzy sets to fuzzy sets. Thus a fuzzy system S is a transformation $S: I^n \to I^p$. The n-dimensional unit hyper cube I^n houses all

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the fuzzy subsets of the domain space or input universe of discourse $X = (x_1, x_2, ...x_n)$. I^p houses all the fuzzy subsets of the range space or output universe of discourse, $Y = (y_1, y_2, ..., y_p)$. X and Y can also denote subsets of R^n and R^p. Then the fuzzy power sets $F(2^X)$ and $F(2^Y)$ replace I^n and I^p.

In general a fuzzy system S maps families of fuzzy sets to families of fuzzy sets thus $S : I^{n_1} \times ... \times I^{n_r} \to I^{p_1} \times ... \times I^{p_s}$. Here too we can extend the definition of a fuzzy system to allow arbitrary products or arbitrary mathematical spaces to serve as the domain or range spaces of the fuzzy sets. We shall focus on fuzzy systems $S : I^n \to I^p$ that map balls of fuzzy sets in I^n to balls of fuzzy set in I^p. These continuous fuzzy systems behave as associative memories. The map close inputs to close outputs. We shall refer to them as Fuzzy Associative Maps or FAMs.

The simplest FAM encodes the FAM rule or association (A_i, B_i), which associates the p-dimensional fuzzy set B_i with the n-dimensional fuzzy set A_i. These minimal FAMs essentially map one ball in I^n to one ball in I^p. They are comparable to simple neural networks. But we need not adaptively train the minimal FAMs. In general a FAM system $F : I^n \to I^b$ encodes the processes in parallel a FAM bank of m FAM rules $(A_1, B_1)...(A_m, B_m)$. Each input A to the FAM system activates each stored FAM rule to different degree.

The minimal FAM that stores (A_i, B_i) maps input A to $B_i^{'}$ a partly activated version of B_i. The more A resembles A_i, the more $B_i^{'}$ resembles B_i. The corresponding output fuzzy set B combines these partially activated fuzzy sets $B_1^1, B_2^1, ..., B_m^1$. B equals a weighted average of the partially activated sets $B = w_1 B_1^1 + ... + w_n B_m^1$ where w_i reflects the credibility frequency or strength of fuzzy association (A_i, B_i). In practice we usually defuzzify the output waveform B to a single numerical value y_j in Y by computing the fuzzy centroid of B with respect to the output universe of discourse Y.

More generally a FAM system encodes a bank of compound FAM rules that associate multiple output or consequent fuzzy sets $B_i^1, ..., B_i^s$ with multiple input or antecedent fuzzy sets $A_i^1, ..., A_i^r$. We can treat compound FAM rules as compound linguistic conditionals. This allows us to naturally and in many cases easily to obtain structural knowledge. We combine antecedent and consequent sets with logical conjunction, disjunction or negation. For instance, we could interpret the compound association (A^1, A^2, B); linguistically as the compound conditional "IF X^1 is A^1 AND X^2 is A^2, THEN Y is B" if the comma is the fuzzy association (A^1, A^2, B) denotes conjunction instead of say disjunction.

We specify in advance the numerical universe of discourse for fuzzy variables X^1, X^2 and Y. For each universe of discourse or fuzzy variable X, we specify an appropriate library of fuzzy set values $A_1^r, ...A_k^2$ Contiguous fuzzy sets in a library overlap. In principle a neural network can estimate these libraries of fuzzy sets. In practice this is usually unnecessary. The library sets represent a weighted though overlapping quantization of the input space X. They represent the fuzzy set values assumed by a fuzzy variable. A different library of fuzzy sets similarly quantizes the output space Y. Once we define the library of fuzzy sets we construct the FAM by choosing appropriate combinations of input and output fuzzy sets Adaptive techniques can make, assist or modify these choices.

2.1 Induced Fuzzy Associative Memories:

Suppose that there are n attributes, say $x_1, x_2, \ldots, x_n$, where n is finite, associated with the effects of climate change and let $y_1, y_2, \ldots, y_p$ be the attributes associated with the health system. The connection matrix M of order n X p is obtained through the expert. Let C_1 be the initial input vector. A particular component, say c_1, is kept in ON state and all other components in OFF state and we pass the state vector C_1 through the connection matrix M. To convert the resultant vector as a signal function, choose the first two highest values to ON state and other values to OFF state with 1 and 0 respectively. Denote this process by the symbol. The resulting vector is multiplied with M^T and thresholding yields a new vector D_1. This vector is related with the connection matrix and that vector which gives the highest number of attributes to ON state is chosen as C_2. That is, for each positive entry we get a set of resultant vectors; among this vector which contains maximum number of 1s is chosen as C_2. If there are two or more vectors with equal number of 1s in ON state, choose the first occurring one as C_2. Repeat the same procedure till a fixed point or a limit cycle is obtained. This process is done to give due importance to each vector separately as one vector induces another or many more vectors into ON state. Get the hidden pattern by the limit cycle or by getting a fixed point.
Next we choose the vector with its second component in ON state and repeat the same to get another cycle. This process is repeated for all the vectors separately. We observe the hidden pattern of some vectors found in all or many cases. Inference from this hidden pattern highlights the causes.

III. ADAPTATION OF IFAM TO THE PROBLEM

We select the following attributes related with the effects of climate change as nodes of the domain space from the opinion of the experts:
C_1 – Heat waves and cold spells
C_2 - Air, water and land pollution
C_3 – Threatened food supply

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C_4- Weather disasters such as floods, droughts
C_5- Species extinction
C_6 –Higher concentrations of ground level ozone in urban areas
C_7 – Decrease in fresh water availability
C_8- Sea level rise

The following attributes related with human health are taken as nodes of the range space:

P_1 - Increased frequency of cardio vascular and respiratory illness
P_2 – Asthma
P_3 – Malaria, Typhoid, Dengue, Yellow fever, Encephalitis
P_4– Toxic algae, cholera
P_5 - Increase in malnutrition
P_6- Infectious diarrohea/Infectious disease vector
P_7 – Over-crowding, poor sanitation
The expert's opinion is given in the form of the relational matrix M

$$\begin{array}{cc} & \begin{array}{ccccccc} P_1 & P_2 & P_3 & P_4 & P_5 & P_6 & P_7 \end{array} \\ M = \begin{array}{c} C_1 \\ C_2 \\ C_3 \\ C_4 \\ C_5 \\ C_6 \\ C_7 \\ C_8 \end{array} & \begin{pmatrix} 0.7 & 0.6 & 0.7 & 0.5 & 0.7 & 0.8 & 0 \\ 0.4 & 0.7 & 0.9 & 0.6 & 0.3 & 0.4 & 0.2 \\ 0 & 0.1 & 0.3 & 0.5 & 1 & 0.3 & 0.2 \\ 0.1 & 0 & 0.8 & 0.8 & 0.8 & 0.6 & 0.7 \\ 0.2 & 0.1 & 0.1 & 0.1 & 0.6 & 0.1 & 0.2 \\ 0.9 & 0.5 & 0.2 & 0.1 & 0.1 & 0.4 & 0.6 \\ 0.3 & 0 & 0.7 & 0.7 & 0.8 & 0.8 & 0.7 \\ 0.1 & 0.1 & 0.2 & 0.2 & 0.3 & 0.1 & 0.6 \end{pmatrix} \end{array}$$

Let us choose the input vector C_1 =(1 0 0 0 0 0 0 0). That is the attribute Heat wave and Cold spells in kept in ON and the rest of the nodes in OFF state.

C_1=(1 0 0 0 0 0 0 0)
C_1 M=(.7 .6 .7 .5 .7 .8 0)
↪ (1 0 1 0 1 1 0)
(1 0 1 0 1 1 0) MT =(.8 .9 1 .8 .6 .9 .8 .3)
↪(0 1 1 0 0 1 0 0)= C_2
$C_2^{(1)}$=(0 1 0 0 0 0 0 0)
$C_2^{(2)}$=(0 0 1 0 0 0 0 0)
$C_2^{(3)}$=(0 0 0 0 0 1 0 0)
$C_2^{(1)}$M = (.4 .7 .9 .6 .3 .4 .2)
↪(0 1 1 0 0 0 0)
(0 1 1 0 0 0 0) MT = (.7 .9 .3 .8 .1 .5 .7 .2)
↪(0 1 0 1 0 0 0 0)
The sum is 2.

$C_2^{(2)}$M = (0 .1 .3 .5 1 .3 .2)
↪(0 0 0 1 1 0 0)
(0 0 0 1 1 0 0) MT = (.7 .6 1 .8 .6 .1 .8 .3)
↪(0 0 1 1 0 0 1 0)

The sum is 3.
$C_2^{(3)}$M=(.9 .5 .2 .1 .1 .4 .6)
↪(1 0 0 0 0 0 1)
(1 0 0 0 0 0 1) M^T =(.7 .4 .2 .7 .2 .9 .7 .6)
↪(1 0 0 1 0 1 1 0)
The sum is 4.

Therefore C_3 =(1 0 0 1 0 1 1 0)
C_3M=(.9 .6 .8 .8 .8 .8 .7)
↪(1 0 1 1 1 1 0)
(1 0 1 1 1 1 0) M^T =(.8 .9 1 .8 .6 .9 .8 .3)
↪(0 1 1 0 0 1 0 0)=C_2

Thus the binary pair {(1 0 0 0 0 0 0 0), (0 1 1 0 0 1 0 0)} represents the fixed point.

IV. CONCLUSION AND SUGGESTIONS

1. When we take the first node i.e., Heat waves and cold spells in ON state we see that the nodes Air, water and Land pollution, Threatened food supply and Decrease in Fresh water availability also result in ON state. Thus according to the experts' opinion Heat waves and cold spells leads to the many other causes implying more effects on human health.

2. From our study we also conclude that methods and policies should be enforced to control pollution which is a prominent cause of concern for human health.

3. Lack of Food supply and fresh water availability also cause severe health risks. Hence actions should be taken to provide hygienic food and water.

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