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CLIMATE ISSUES CAUSED BY GOVERNMENT ACTIONS: FUZZY MATHEMATICS

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Abstract. The purpose of this paper is to make a connection between fuzzy directed graph theory and social choice theory. Our approach is to accomplish this by considering an application to climate change and government decision makers. Let N be a set of individuals. A fuzzy directed graph is associated with each member of N. The set of vertices is a set of options whose directed edges represent the preference of one issue over the other. The fuzzy directed graphs are combined using a particular fuzzy preference relation. It is then determined under what properties a subset C of N will be an oligarchy. How regions compare with respect to energy transition, fossil fuel phase out, and country research w.r.t. climate change is also determined.

Keywords: Oligarchies, dictatorships, fuzzy aggregation rules, fuzzy preference relations, fuzzy directed graphs, country rankings, climate change.

2020 MSC: Primary 03B52, 03E72.

1. Introduction

This paper is motivated by recent events concerning changes in governing methods of countries involving oligarchies and dictatorships. Our approach is in the area of Fuzzy Social Choice Theory. We are interested in making a connection between fuzzy social choice theory and fuzzy directed graph theory. Consequently, our approach is somewhat different than the standard approach to fuzzy social choice theory. Let C be a subset of a finite set of decision makers N. We associate a fuzzy directed graph with each individual i in N.We can then consider the combination of these graphs using a fuzzy aggregation rule and then determine when C is an oligarchy or a dictatorship. A good foundation for the approach provided here can be found in [5].

In Section 2, we define properties such as partially quai-transitive, weakly Paretian, and independence of irrelevant alternatives with respect to fuzzy aggregations. We use these properties to determine when a fuzzy aggregation rule is oligarchic, Theorem 2.14.

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In Section 3, countries are ranked with respect to three categories, energy transition, fossil fuel phase out, and country research. Averages of these rankings are provided and are used to compare how well regions are achieving these climate issues. If a country is not listed in the ranking, it is due to a lack of data. A comparison of all regions is provided. It turns out that the region South America and the Caribbean performs better than most regions.

Social choice theory, which studies how to aggregate individual preferences into collective decisions, is relevant to climate change in several ways. It helps analyze how societies can make decisions about climate policies, especially when those policies involve trade-offs between different groups and future generations. Furthermore, the theory can be applied to understand the challenges of achieving collective action on climate change, such as the difficulty of coordinating voluntary contributions to public goods like a stable climate.

The following provides a look at the connections:

Collective Decision-Making on climate policies

Public Goods and Climate Mitigation

Social Cost of Carbon Climate Change Impacts and Social Justice

See [11].
Other readings can be found in [10, 12].

During his presidency, Donald Trump signed several executive orders related to climate change, primarily aimed a promoting domestic energy production and reversing previous administrations' climate policies. These orders included actions to withdraw from the Paris Agreement, reduce regulations on fossil fuels, and challenge state climate policies.

Key Actions:

Withdrawal from the Paris Agreement

Promoting Energy Independence

Rolling Back Regulations

Changing State Climate Laws

Revoking Previous Climate Initiatives

See [13].

Let X be a set. Then the fuzzy power set of X, denoted $\mathcal{FP}(X)$, is defined to be the set of all fuzzy subsets of X. Define the relations $\wedge$ and $\vee$ on the closed interval $[0,1]$ by for all $a, b \in [0,1], a \wedge b$ is the minimum of a, b and $a \vee b$ is the maximum of a and b. If μ and ν are fuzzy subsets of X , we write $\mu \subseteq \nu$ if and only if $\mu(x) \leq \nu(x)$ for all $x \in X$.

2. **Oligarchies and Dictatorships**

An oligarchy is a governmental system in which the government is controlled by a small group of people, or oligarchs. Some oligarchies can be good and some can be bad. When oligarchy governments become more self-serving, they typically become more authoritative and take on controlling, sometimes even oppressive or exploitative governmental policies. Income inequality tends to increase as wealth is funneled towards rulers instead of those in the working class. The middle class shrinks as the rich get richer and the poor grow poorer. Additionally, a soured oligarchy tends to inhibit economic growth and creative agility due to a ruling class focused on maintaining the status quo, typically at the expense of actions that would benefit the middle and lower classes [14].

Let X be a finite set. A *fuzzy relation* on X is a fuzzy subset of $X \times X$. Let $\mathcal{FR}(X)$ denote the set of all fuzzy relations on X. Let N be a finite set (of individuals) with cardinality n. For each $i \in N$, let W_i be a set of fuzzy relations on X. Let $W = W_1 \times ... \times W_n$. If $\rho \in W$, then $\rho = (\rho_1, ..., \rho_n) \in W$, where $\rho_i \in W_i, i = 1, ..., n$. Let $\widetilde{f} : W \to \mathcal{FR}(X)$.Then $\widetilde{f}$ is called a *fuzzy aggregation rule***.** If $\rho \in W$, then $\widetilde{f}(\rho)$ is fuzzy relation on X. In the following, we often use a t-norm to define $\widetilde{f}(\rho)$, e.g., $\forall x, y \in X$, $\widetilde{f}(\rho)(x, y) = \rho_1(x, y) * ... * \rho_n(x, y)$, where $*$ is a t-norm. Let C be a nonempty subset of N. We can associate fuzzy directed graphs with each individual i in N.We can then consider the combination of these graphs using a fuzzy aggregation rule and then determine when C is an oligarchy or a dictatorship.

See [6] for background material.

Definition 2.1. Let X be a set and π a fuzzy preference relation on X. Then π is called a *strict fuzzy preference relation* on X if for all $x, y \in X, \pi(x, y) > 0 \Rightarrow \pi(y, x) = 0$.

Definition 2.2. Let ρ be a fuzzy relation on X. Define the fuzzy relation π on X by for all $x, y \in X, \pi(x, y) = \rho(x, y)$ if $\rho(x, y) > \rho(y, x)$ and 0 otherwise. Then π is called the *strict fuzzy preference relation associated* with ρ.

Definition 2.3. Let $\widetilde{f}$ be a fuzzy aggregation rule.

(1) Let C be a nonempty subset of N. Then C is called an *oligarchy* if for all distinct $x, y \in X$ and for all $\rho = (\rho_1, ..., \rho_n) \in W$,

(i) $\pi_i(x, y) > 0 \forall i \in C$ implies $\pi(x, y) > 0$ and (ii) $\forall j \in C, [\pi_j(x, y) > 0$ implies $\pi(y, x) = 0]$, where π is a strict fuzzy preference relation associated with $\widetilde{f}(\rho)$

(Here π_i is a strict preference relation associated with ρ_i for all $i \in C$.)

(2) An individual $j \in N$ is called a *dictator* if for all distinct $x, y \in X$ and $\rho = (\rho_1, ..., \rho_n) \in W, \pi_j(x, y) > 0 \Rightarrow \pi(x, y) > 0$.

(3) An individual $j \in N$ is called a *vetoer* if for all distinct $x, y \in N$ and all $\rho = (\rho_1, ..., \rho_n) \in W, \pi_j(x, y) > 0 \Rightarrow \pi(y, x) = 0$.

Definition 2.4. Let $\widetilde{f}$ be a fuzzy aggregation rule. Then $\widetilde{f}$ is said to be *weakly Paretian* if $\forall \rho = (\rho_1, ..., \rho_n) \in W, \forall x, y \in X, (\forall i \in N, \pi_i(x, y) > 0$ implies $\pi(x, y) > 0)$.

Definition 2.5. Let $\rho \in \mathcal{FR}^*(X)$. Then

(1) ρ is said to be *quasi-transitive* if $\forall x, y, z \in X, \pi(x, y) * \pi(y, z) \le \pi(x, z)$.

(2) ρ is said to be *partially quasi-transitive* if $\forall x, y, z \in X, \pi(x, y) * \pi(y, z) > 0$ implies $\pi(x, z) > 0$.

Definition 2.6. Let $\widetilde{f}$ be a fuzzy aggregation rule. Then

(1) $\widetilde{f}$ is said to be *nondictatorial* if it is not the case that there exists $i \in N$ such that for all $\rho \in W, \forall x, y \in X, \pi_i(x, y) > 0$ implies $\pi(x, y) > 0$.

(2) $\widetilde{f}$ is said to be *partially transitive* if $\forall \rho \in W, \forall x, y, z \in X, \widetilde{f}(\rho)(x, y) > 0$ and $\widetilde{f}(\rho)(y, z) > 0$ implies $\widetilde{f}(\rho)(x, z) > 0$.

(3) $\widetilde{f}$ is said to be *partially quasi-transitive* if $\forall \rho \in W, \forall x, y, z \in X, \widetilde{f}(\rho)$ is partially quasi-transitive.

(4) $\widetilde{f}$ is said to be *independent of irrelevant alternatives* if $\forall \rho, \rho' \in W, \forall x, y \in X, \mathrm{Supp}(\rho_i\rceil_{\{x,y\}}) = \mathrm{Supp}(\rho'_i\rceil_{\{x,y\}}) \forall i \in N \Rightarrow \mathrm{Supp}(\widetilde{f}(\rho)\rceil_{\{x,y\}}) = \mathrm{Supp}(\widetilde{f}(\rho')\rceil_{\{x,y\}})$.

Let $T = \{\rho \in \mathcal{FR}(X) | \forall x, y \in X, \rho(x, y) \neq \rho(y, x)\}$. Let $\rho_0 \in T$. Let $T_{\rho_0} = \{\rho' \in T | \forall x, y \in X, \rho'(x, y) > \rho'(y, x) \Leftrightarrow \rho_0(x, y) > \rho_0(y, x)\}$.

Proposition 2.7. *Let $\widetilde{f}$ be a fuzzy aggregation rule. $\forall i \in N$, let $W_i = T_{\rho_0}$. Then $\forall x, y \in X, \forall \rho \in W_1 \times ... \times W_n, \pi(x, y) = \pi_1(x, y) * ... * \pi_n(x, y)$, where π corresponds to $\widetilde{f}(\rho)$.*

Proof. Let $\rho = (\rho_1, ..., \rho_n)$, where $\rho_i \in W_i, i = 1, ..., n$. Let $x, y \in X$. Then $\forall i \in N, \rho_i(x, y) > \rho_i(y, x)$ or $\forall i \in N, \rho_i(x, y) < \rho_i(y, x)$. Say the former holds. Then $\pi_i(x, y) = \rho_i(x, y) > 0$ for all $i \in N$. Let π correspond to $\widetilde{f}(\rho)$. Then

$$\begin{aligned} \pi(x, y) &= \widetilde{f}(\rho)(x, y) = \rho_1(x, y) * ... * \rho_n(x, y) \\ &= \pi_1(x, y) * ... * \pi_n(x, y). \end{aligned}$$

Let $Z = \{\rho \in \mathcal{FR}(X) | \rho$ is partially quasi-transitive$\}$. □

Proposition 2.8. *Let $\widetilde{f}$ be a fuzzy aggregation rule. Let $W_i = Z \cap T_{\rho_0}, i = 1, ...n$. Then for all $\rho \in W = W_1 \times ... \times W_n, \widetilde{f}(\rho)$ is partially quasi-transitive.*

Proof. Let $x, y, z \in X$ and $\rho \in W$. Suppose $\pi(x,y) * \pi(y,z) > 0$, where π corresponds to $\widetilde{f}(\rho)$. Then $\pi(x,y) > 0$ and $\pi(y,z) > 0$.Now

$$\begin{aligned}\pi(x,y) &= \widetilde{f}(\rho)(x,y) = \rho_1(x,y) * ... * \rho_n(x,y) > 0 \text{ and}\\ \pi(y,z) &= \widetilde{f}(\rho)(y,z) = \rho_1(y,z) * ... * \rho_n(y,z) > 0.\end{aligned}$$

Hence $\rho_i(x,y) > 0$ and $\rho_i(y,z) > 0$ for all $i \in N$. By Proposition 2.8,

$$\begin{aligned}\pi(x,y) &= \widetilde{f}(\rho)(x,y) = \pi_1(x,y) * ... * \pi_n(x,y) > 0 \text{ and}\\ \pi(y,z) &= \widetilde{f}(\rho)(y,z) = \pi_1(y,z) * ... * \pi_n(y,z) > 0.\end{aligned}$$

Thus $\pi_i(x,y) > 0$ and $\pi_i(y,z) > 0$ for all $i \in N$. Since $*$ has no zero divisors, $\pi_i(x,y) * \pi_i(y,z) > 0$ for all $i \in N$. Thus $\pi_i(x,z) > 0$ for all $i \in N$. Therefore, $\pi(x,z) = \widetilde{f}(\rho)(x,z) = \rho_1(x,z) * ... * \rho_n(x,z) = \pi_1(x,z) * ... * \pi_n(x,z) > 0$. □

Example 2.9. *Let $N = \{1,2,3\}$ and $X = \{x,y,z\}$. Let $T = \{\rho \in \mathcal{FR}(X) | \rho(x,y) > \rho(y,x), \rho(y,z) > \rho(z,y), \rho(z,x) > \rho(x,z)\}$. Then no ρ is partially quasi-transitive.*

Let $N = \{1,2,3\}$ and $X = \{x,y,z\}$. Let $T = \{\rho \in \mathcal{FR}(X) | \rho(x,y) > \rho(y,x), \rho(y,z) > \rho(z,y), \rho(x,z) > \rho(z,x)\}$. Then every ρ is partially quasi-transitive.

Proposition 2.10. *Let $\widetilde{f}$ be a fuzzy aggregation rule. Let $W_i = Z \cap T_{\rho_0}, i = 1, ...n$, and $W = W_1 \times ... \times W_n$. Suppose $*$ has no zero divisors. Then $\widetilde{f}$ is weakly Paretian.*

Proof. Let $\rho = (\rho_1, ..., \rho_n) \in W$. Let $x, y \in X$. Suppose $\pi_i(x,y) > 0 \forall i \in N$, where π_i is the strict fuzzy preference relation associated with $\rho_i, i = 1, ..., n$. By the Proposition 2.9, $\pi(x,y) = \pi_1(x,y) * ... * \pi_n(x,y)$. Since $*$ has no zero divisors, $\pi(x,y) > 0$. □

Proposition 2.11. *Let $\widetilde{f}$ be a fuzzy aggregation rule. Suppose $*$ has no zero divisors. Then $\widetilde{f}$ is independent of irrelevant alternatives.*

Proof. Let $\rho, \rho' \in W$ and $x, y \in X$. Suppose that $\text{Supp}(\rho_i \rceil_{\{x,y\}}) = \text{Supp}(\rho'_i \rceil_{\{x,y\}}) \forall i \in N$. Now $\widetilde{f}(\rho)(x,y) = \rho_1(x,y) * ... * \rho_n(x,y)$ and $\widetilde{f}(\rho')(x,y) = \rho'_1(x,y) * ... * \rho_n(x,y)$. Since $\text{Supp}(\rho_i \rceil_{\{x,y\}}) = \text{Supp}(\rho'_i \rceil_{\{x,y\}}) \forall i \in N$ and $*$ has no zero divisors, $\widetilde{f}(\rho)(x,y) > 0$ if and only if $\widetilde{f}(\rho')(x,y) > 0$. □

Definition 2.12. Let $\widetilde{f}$ be a fuzzy aggregation rule. Let $(x,y) \in X \times X$. Let λ be a fuzzy subset of N. Then λ is called *decisive* for x against y, written $xD_\lambda y$, if $\forall \rho \in \mathcal{FR}(X), [\pi_i(x,y) > 0 \forall i \in \text{Supp}(\lambda)] \Rightarrow \pi(x,y) > 0$. λ is called *decisive* if $\forall (x, y \in X \times X$, λ is decisive for x against y.

Definition 2.13. A fuzzy aggregation rule is called *oligarchic* if there exists a fuzzy subset λ of X such that (1) every member of $\text{Supp}(\lambda)$ has a veto and (2) λ is decisive.

Theorem 2.14. *Let $\widetilde{f}$ be a fuzzy aggregation rule such that $Im(\widetilde{f}) \subseteq \mathcal{FB}$, where $\mathcal{FB}$ is the set of all fuzzy relations of X which are reflexive and complete. Let $W_i = Z \cap T_{\rho_0}, i = 1, ...n$. Suppose $*$ has no zero divisors. Then $\widetilde{f}$ is oligarchic.*

Proof. The result follows from Propositions 2.9, 2.11, 2.12 and [[7], Theorem 3.9]. □

3. Climate Change

It is stated in [2] that as the global energy transition is plateauing due to equity challenges, major economies are showing significant progress. The Energy Transition Index (ETI) benchmarks countries on their current energy system performance and provides a forward-looking measure of transition readiness. Despite making progress on decarbonation and improving on infrastructure, the world still falls short of achieving balanced progress on all aspects of the energy triangle.

The following is from [8]. Renewable energy is making rapid progress an almost every high-emitting country. However, too many countries are still clinging to prolonging the fossil fuels business model, especially for gas. This is shown in the Climate Change Performance Index (CCPI). The CCPI assesses the progress made by the largest emitters worldwide in terms of emissions, renewables and climate policy.

Nature Index (NI) is one indicator of institutional research performance. Metrics are used to order NI listings and are bases on an institution's or a country's publication output in 145 natural-science and health science journals.

In [9], countries ranked with respect to their leadership concerning climate change.

In the following tables, ET stands for Energy Transition, FF stands for Fossil Fuel Phase Out, NI stands for Nature Index. We find averages of these rankings for regions and then make comparisons of the regional averages. In the following tables, the scores are presented together with the ranking they determine are presented. A high ranking (low number) is good.

OECD

Country	ET	FF	NI
Australia	63.6 / 20	52 / 29	10 / 9
Austria	68.3 / 9	23 / 14	22 / 17
Belgium	59.2 / 32	35 / 19	21 / 16
Canada	64.2 / 17.5	62 / 33	7 / 6
Chile	62.5 / 25	12 / 6	34 / 25
Czech Rep.	58.6 / 34	49 / 28	27 / 21
Denmark	76.1 / 2	4 / 1	17 / 15
Estonia	68.2 / 10	14 / 8	42 / 31
Finland	72.8 / 4	37 / 21	25 / 19
France	70.6 / 6.5	25 / 15	6 / 5
Germany	67.5 / 11	16 / 10	3 / 2
Greece	60.9 / 28	22 / 13	37 / 28
Hungary	64.3 / 16	45 / 25	35 / 26
Iceland	70.6 / 6.5		47 / 33
Ireland	59.3 / 31	29 /16	33 / 24
Israel	62.7 / 23		16 / 14
Italy	60.6 / 29	43 / 24	12 / 10
Japan	63.3 / 22	58 / 32	5 / 4
Korea Rep.	62.3 / 26	63 / 34	8 / 7
Latvia	63.4 / 21	36 / 20	
Lithuania	61.2 / 27	18 / 11	
Luxembourg	64.2 / 17.5	13 / 7	44 / 32
Mexico	54.1 / 36	39 /22	39 / 29
Netherlands	68.8 / 8	5 / 2	14 / 12
New Zealand	63.7 / 19	41 / 23	29 / 23
Norway	73.7 / 3	9 / 4	26 / 20
Poland	59.7 / 30	47 / 27	24 / 18
Portugal	65.8 / 14	15 / 9	28 / 22
Slovak Rep.	58.8 / 33	46 / 26	
Slovenia	62.6 / 24	30 / 17	41 / 30
Spain	65.0 / 15	19 / 12	13 / 11
Sweden	78.5 / 1	11 / 5	15 / 13
Switzerland	72.4 / 5	33 / 18	9 / 8
Turkey	54.3 / 35	53 / 30	36 / 27
United Kingdom	66.2 / 13	6 / 3	4 / 3
United States	66.3 / 12	57 / 31	1 / 1

Averages: ET $\frac{2334.3}{36} = 64.84$; FF $\frac{1067}{34} = 31.36$; NI $\frac{730}{33} = 22.12$

East and South Asia

Country	ET	FF	NI
Bangladesh	113 / 1		
Bhutan			
Brunei Darussalam	105 / 4		
Cambodia	84 / 7		
China	17 / 16	55 / 8	
India	67 / 10	10 / 2	11 / 1
Indonesia	55 /12	42 / 6	
Korea, Dem. Rep.		63 / 9	
Lao PDR	83 / 8		
Malaysia	35 / 15	48 / 7	
Maldives			
Mongolia	111 / 2		
Myanmar			
Nepal	97 / 5		
Pakistan	107 / 3	31 / 5	43 / 4
Philippines	94 / 6	7	
Singapore	70 / 9		18 / 2
Sri Lanka	66 / 11		
Thailand	54 / 13	24 / 4	40 / 3
Timor Leste			
Vietnam	43 / 14	21 / 3	46 / 5

Averages: ET $\frac{1201}{16} = 75.06$; FF $\frac{301}{9} = 33.44$; NI $\frac{158}{5} = 31.6$

Eastern Europe and Central Asia

Country	ET	FF	NI
Afghanistan			
Albania	21 / 15		
Andorra			
Armenia			
Azerbaijan	32 / 14		
Belarus		56 / 6	
Bosnia and Herzegovina	50 / 10		
Bulgaria	48 / 12	50 / 4	
Croatia	33 / 13	40 / 2	
Cyprus	52 / 9	44 / 3	
Georgia	62 / 7		
Kazakhstan	76 / 4	61 / 7	
Kygz Rep.	91 / 2		
Liechterstein			
Malta	61 / 8	34 / 1	
Moldova	101 / 1		
Monaco			
Montenegro	69 / 6		
North Macedonia	80 / 3		
Romania	49 / 11		49 / 3
Russian Federation		64 / 8	20 / 1
San Marino			
Serbia			
Tajikistan	73 / 5		
Turkmenistan			
Ukraine			48 / 2
Uzbekistan		54 / 5	

Averages: ET $\frac{898}{15} = 59.87$; FF $\frac{403}{8} = 50.38$; NI $\frac{117}{3} = 39$

Latin America and the Caribbean

Country	ET	FF	NI
Antigua and Barbuda			
Argentina	85 / 7		38 / 2
Bahamas, The			
Barbados			
Belize			
Bolivia	74 / 9		
Brazil	14 / 18	28 / 2	23 / 1
Columbia	39 / 14	27 / 1	50 / 3
Costa Rica	25 / 16		
Cuba			
Dominica			
Dominican Rep.	63 / 10		
Ecuador	78 / 8		
El Salvador	47 / 13		
Grenada			
Guatemala	87 /6		
Guyana			
Haiti			
Honduras	100 / 4		
Jamaica	115 / 1		
Nicaragua	114 / 2		
Panama	51 / 12		
Paraguay	34 / 15		
Peru	53 / 11		
St. Kitts and Nevis			
St. Lucia			
St. Vincent and the Grenadines			
Suriname			
Trinidad and Tobago	98 / 5		
Uruguay	23 / 17		
Venezuela	103 / 3		

Averages: ET $\frac{702}{18} = 39$; FF $\frac{55}{2} = 27.5$; NI $\frac{111}{3} = 37$

Middle East and North Africa

Country	ET	FF	NI
Algeria		51 / 3	
Bahrain	110 / 3		
Egypt	79 / 7	20 / 2	
Iran			32 / 2
Iraq			
Jordan	71 / 8		
Kuwait	102 / 4		
Lebanon	112 / 2		
Libya			
Morocco	56 / 12	8 / 1	
Oman	90 / 5		
Qatar	59 / 10		
Saudi Arabia	57 / 11	66 / 5	30 / 1
Syria			
Tunisia	89 / 6		
United Arab Emirates	63 / 9	65 / 4	45 / 3
Yemen, Rep.	120 / 1		

Averages: ET $\frac{1008}{12} = 84$; FF $\frac{210}{5} = 42$; NI $\frac{107}{3} = 35.67$.

Averages: ET $\frac{831}{8} = 103.88$; FF NI insufficient data.

A high average indicates poor achievement.
We have for ET that Sub-Saharan Africa > Middle East and North Africa > East and South Asia > OECD > Eastern Europe and Central Asia > South America and the Caribbean.

For ET, we see that Sub-Saharan Africa's achievement is the lowest while South America and the Caribbean's is the highest.

For FF we have that Eastern Europe and Central Asia > Middle East and North Africa > East and South Asia > OECD > South America and the Caribbean.

For NI we have that Eastern Europe and Central Asia > South America and the Caribbean > Middle East and North Africa > East and South Asia > OECD.

4. **Commentary**

Information concerning Trump's executive order on climate change can be found in [15].

The following is taken from [17]. Earth's warming could trigger sweeping changes in the natural world that would be hard, if not impossible, to reverse.

We humans are reconfiguring Earth's climate bit by bit. Hotter summers and wetter storms. Higher seas and fiercer wild fires.

We might also be changing the climate in an even bigger way. For the past two decades, scientists have been raising alarms about great systems in the natural world that warming, caused by carbon emissions, might be pushing toward collapse. These systems are so vast that they stay somewhat in balance even as temperatures rise. But only to a point.

Once we warm the planet beyond certain levels, this balance might be lost, scientists say. The effect would be sweeping and hard to reverse.

Mass death of coral reefs

Abrupt thawing of permafrost

Collapse of Greenland ice

Breakup of West Antarctic ice

Sudden shift in the West African Monsoon

Loss of Amazon Rainforest

Shutdown of Atlantic currents

5. Conclusion

This paper is motivated by recent events concerning changes in governing methods of countries involving foreign aid, oligarchies and dictatorships. Our approach is in the area of Fuzzy Social Choice Theory. We are interested in making a connection between fuzzy social choice theory and fuzzy directed graph theory. Consequently, our approach is slightly different than the standard approach to fuzzy social choice theory. We associated with each member of a set of decision makers, a fuzzy directed graph. Their joint decision is determined by combining their fuzzy directed graphs into one fuzzy directed graph using t-norms. The fuzzy directed graphs and their combination use techniques from Fuzzy Social Choice Theory. This approach thus allows concepts from each discipline to be carried over from one to the other.

We also provided rankings of countries in specific regions with respect to properties concerning climate change. We then determined how regions compared with respect to these properties.

The world faces many serious issues such as global poverty, global hunger, human trafficking, modern slavery, homelessness, terrorism, and biodiversity. The most serious issue is climate change. Climate change creates poverty and poverty makes all the above mentioned issues worse. Also, climate change has the potential to make the earth uninhabitable. These problems could cause governments to create policies to aid other countries and to intervene within themselves to not cut foreign aid and not to make decisions that help economically for the short term, but have serious negative effects for the future.

Climate change mitigation policies include a wide range of actions, including efforts to reduce greenhouse grass emissions from fossil fuel combustion, energy efficiency and end–use innovations, and reducing carbon emissions through avoided deforestation. Such policies can affect poverty in developing countries. It can also have negative short term economic affects on developed countries. Detailed research on these concepts can be found in [1, 3, 4, 16].

A future research project would be to determine the fuzzy similarity measures of rankings of countries with respect to properties concerning climate change. Another project could be to use techniques used here to consider government decisions involving hunger and disease.

6. Author Contributions

Coceptualization, methodology J N Mordeson; resources, J N Mordeson ; writing—original draft preparation, validation, J N Mordeson, S Mathew; writing—review and editing,S. Mathew; Conceptualization, J N Mordeson, S Mathew.

7. Data Availability Statement

Data used in the work is from references [5], [6] and [8].

8. Funding

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9. Conflict of interest

The authors declare no conflict of interest.

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