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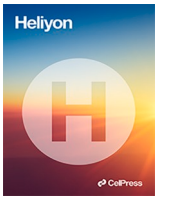

Research article

Global warming communicative actions of publics in Türkiye: Utilizing fuzzy rule based system

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ABSTRACT

The effectiveness of government policies and environmental initiatives to mitigate global warming relies heavily on public support, which is closely tied to public perception and awareness. Despite the scientific evidence communicated, the public remains reluctant to take preventive measures against global warming. The aim of the paper is to investigate the communicative actions of publics proposed as in the situational theory of problem solving to understand publics' communicative actions towards global warming. The paper utilizes a fuzzy rule-based system approach to analyze the communicative actions of publics to reveal non-linear relationships; whereas previous studies mostly used linear statistical analysis. The paper provides a deeper understanding into the interplay between problem recognition, constraint recognition, and involvement in shaping information behavior. The results show that the communicative actions of the publics are at a low-to-moderate level. The paper's interesting finding is the nonlinear effects of constraint recognition on communicative action about global warming. Contrary to the current literature, it was found out that the dominant factor that may convince public to start taking action towards global warming seems to be recognizing being constrained at a moderate level. Based on the results, it is suggested for policy makers and communication strategists to mitigate the negative outcomes of global warming by integrating environmental issues into education at all levels and collaborating with non-governmental organizations for national awareness campaigns which focus on increasing public problem recognition and involvement.

1. Introduction

Global warming has emerged as one of the most challenging issues facing humanity and environmental concerns have become a global phenomenon, prompting nations worldwide to acknowledge the urgency of taking swift actions to mitigate the harmful effects of global warming and advance sustainable development [1]. Anticipated shifts in temperature and precipitation patterns are primarily attributed to the increasing concentrations of greenhouse gases in the atmosphere. Hence, it is crucial to significantly reduce

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Abbreviations

STOPS	Situational theory of problem solving
STP	Situational Theory of Public
FRBS	Fuzzy Rule-Based System
SMPS	Situational motivation in problem-solving
GDP	Gross Domestic Product
Caps	Communicative action in problem-solving
FST	Fuzzy Set Theory
GHG	Greenhouse gas

emissions to prevent undesirable changes. The United Nations and its affiliated organizations have been diligently working to convey the urgency to world leaders regarding the need to limit the increase in global temperature to 1.5 °C. The international community has witnessed various efforts aimed at curbing emissions intensity through emissions-limiting agendas. While participating nations have agreed on prescribed emissions-limiting targets, the main challenge arises from the heterogeneity in country-specific policies that each territory prioritizes [2–4]. Thus, it can be stated that the implementation of regulations related to addressing global warming ultimately relies on country-specific policies and the availability of resources [5].

As European economies have demonstrated a heightened level of environmental consciousness, they have transitioned from reactionary to preventive strategies for addressing environmental issues [5,6]. Developed nations have implemented a range of pro-environmental interventions to achieve environmental sustainability, aiming to reduce emissions intensities across all sectors directly or indirectly linked to the environment [7]. These developed nations have been making significant changes to their legal frameworks, prioritizing the enhancement of pollution control measures such as taxes and emission limits, while also encouraging companies to adopt eco-friendly products to address climate change and global warming [1,8]. Furthermore, The G-7 nations have set ambitious goals to achieve a significant percentage of green growth by the next decade [3].

However, emerging nations is different, they prioritize their economic growth over environmental sustainability, which makes them pay a high price to tackle climate change-induced catastrophes in the long run [4]. To achieve significant reductions in greenhouse gas (GHG) emissions and support global mitigation efforts, there is likely to be involved in all countries, including emerging economies like Türkiye to adopt more ambitious climate strategies [9].

Being aware of the possible pejorative consequences of global warming, Türkiye, a party to international conventions such as Kyoto, Paris, etc., especially the UNFCCC, has prepared policy documents such as the Climate Change Strategy Document (2010–2023) and Climate Change Action Plan (CCAP: 2011–2023), while reflecting its will to combat global warming in its Development Plans [10]. Despite having various policies and institutions in place, Türkiye, a candidate for EU membership and a founding member of the OECD with a growing economy, has made limited progress in addressing climate change. Evidence from the literature suggests that climate policies in Türkiye tend to align with developmental ambitions, resulting in limited success in policy diffusion [11]. Türkiye has seen a rapid rise in GHG emissions, with a 140.1 % increase between 1990 and 2017, making it one of the top 20 largest GHG emitters globally [12]. Furthermore, Türkiye has recently witnessed extreme weather events such as temperatures above seasonal norms, intense stormy weather and lack of precipitation, especially low levels of snowfall even in the regions with a continental climate [10]. This suggests that the consequences of global warming in Türkiye are already evident [13] and Türkiye is one of the countries significantly impacted by climate change, largely attributable to global warming [14]. The increasing temperature in the Earth's atmosphere is largely attributed to human activities and interventions [4]. However, the studies suggest that a significant portion of Turkish society lacks concern about climate change [13–15]. With ample evidence pointing to global warming as a pressing issue in Türkiye, it becomes crucial motivation to research the factors influencing public concern about it in Türkiye. The motivation of the paper is that public behavioral change is required in order to achieve environmental targets which requires research of global warming communication to convince publics. It is known that without widespread public recognition of the seriousness of global warming, implementing measures to curb its progression and achieve sustainable development will be challenging. Therefore, understanding what drives people to be more concerned about global warming is crucial for policymakers to leverage these motivations and foster more environmentally friendly attitudes among publics especially in emerging economies like Türkiye.

As people's communication about global warming is influenced by whether they notice the problem, feel constrained, or are involved in global warming, it is critical to note that how global warming is recognized has a huge impact on how successfully it is communicated. Thus, the purpose of this paper is to investigate global warming communicative actions using Situational Theory of Problem Solving (STOPS) to understand aspects of the causes that prevent publics from communicating actively about global warming using the Fuzzy Rule-Based System (FRBS). Previous research has focused on inference statistics, such as correlation and regression analysis, in which researchers use breakpoints to investigate linear relationships between variables. The objective of the paper is to highlight the behavior patterns of public segments using a fuzzy theory-based approach, allowing for a better understanding of active communication behavior in terms of global warming. Therefore, the findings of this research are important in providing appropriate strategies for Türkiye to increase public awareness on global warming. Thus, the main research question of the paper is how do the problem recognition, perceived constraints, and involvement affects communicative actions regarding global warming among different segments of the public in Türkiye.

2. STOPS in the context of global warming

STOPS was developed from Situational Theory of Publics (STP), called the "first deep theory in the discipline of public relations," to comprehend how and why stakeholders communicate in specific patterns related to various situations or problems [16], by segmenting the public and predicting various communicative actions. STOPS is an extension of STP because STP's formulation of limited active communication behavior has been transformed into a generalized dependent variable of communicative action such as acquiring, sharing, and selecting information to turn into " a more elaborated theory of communication and problem-solving " [17].

STOPS tries to explain why and how the public becomes active in communicative actions and participates in problem-solving communication [18]. The model suggests 4 explanatory attributes (problem recognition, constraint recognition, involvement recognition, and reference criteria) and one intermediary attribute (SMPS, situational motivation in problem-solving) to find the public's communicative actions (information acquisition, information selection, and information transmission) in a problem-solving setting. According to situational theory research, 3 explanatory attributes, problem recognition, involvement recognition, and constraint recognition, can estimate communicative actions. Recognition of the problem and involvement has a positive relationship with communicative actions, while constraint recognition presents a negative relationship.

The problem is said to be recognized when the public perceives that a(n) issue/situation affects them, the public perceives a problem arising, and begins to talk about solutions [19]. STOPS defines problem recognition as "one's perception that something is missing and there is no immediately applicable solution to it " [17]. People need to understand the seriousness of global warming to be able to communicate in pro-environmental terms. People who view global warming as a real and human-caused problem will express greater urgency to reduce emissions, believe that global warming poses a greater risk, and be more willing to change their behavior to reduce their carbon footprint [20]. Goldberg, van der Linden [21] discovered indirect raises in beliefs that global warming has been occurring and led by humans, and in global warming anxiety, which predicts that the priority of the problem of global warming will increase. Participants in Spain (65 %), Sweden (61 %), and Taiwan (60 %) were highly probable to believe that climate change was primarily a result of human activity, while participants in Indonesia (18 %) and Yemen (21 %) [22].

Involvement recognition refers to the perceived personal commitment or relevance to a situation, problem, or issue [17,19]. It can be said that global warming is not an isolated problem; daily lives are affected by it. However, global warming will indeed have unfair effects, and therefore different levels of involvement should be expected. People tend to believe that global warming is something in the future, that it is not happening right now, that it will not happen to them even if it is happening, or that it will not affect them even if it happens on its own lives. For example, participants in Hungary (96 %), Portugal (95 %), and Costa Rica (94 %) were highly probable to believe that climate change was occurring, while Laos (67 %), Haiti (67 %), and Bangladesh (70 %) were found to be the least likely. Similarly, participants in Mexico (95 %), Portugal (93 %), and Chile (93 %) were most concern or somewhat concerned about climate change, while in Yemen (32 %) and Jordan (48 %), they were the least likely [22]. If people believe that global warming is distant and irrelevant to them, they tend to be passive about it. In the communication of global warming issues, leaving people out of the equation and the subject gives the impression that they are outside the solution. A personal connection to global warming is necessary to motivate the public to start taking action and communicating. People should not be surprised by the magnitude of the problem; instead, they should be aware that steps are being taken to solve this problem and that they can contribute to the solution.

Constraint recognition refers to the degree to which the public recognizes obstacles or barriers that limit progress in a situation/problem. Constraint recognition can be defined as a measure of perceived barriers that prevent people from taking action to resolve an issue. The general public is often reluctant to communicate about "problems or issues about which they believe they can do little or about behaviors they do not believe they have the personal efficacy to execute" [23]. If the public believes that addressing global warming issues requires making difficult decisions, cognitive mental processes reduce the acceptance of preventive measures. For example, if the public believes that combating global warming requires sacrifices in economic growth, such as employment rates, GDP, etc., they are aware of the constraints. Scientists have discovered that feeling hopeless about a situation is cognitively associated with inaction and predicts a decrease in targeted behavior [24], which means that people are less likely to communicate about global warming because it is inevitable.

The theory also suggests that people's communicative actions in problem-solving may be influenced by experiential or knowledge-based information derived from previous problematic situations [18]. This is because people are more likely to recall relevant past experiences to resolve a particular problem [25]. In theory, the reference criterion is an experience or knowledge of the past [17]. Referent criterion did not operationalize in the model in this paper because it has nothing to do with an earlier problematic situation.

In addition, STOPS introduced SMPS, a moderating variable that links situational perceptions to communicative action. It is defined as a person's situational cognitive and epistemic readiness to solve problems [17]. SMPS refers to how willing a public is to find out and consider a particular problem, as a result of detecting a problematic status, discovering a close link with one's interest, and/or envisioning fewer constraints in solving the problem. Thus, it can be said that it increases both the recognition of the issue and the degree of involvement but reduces the perceived constraints [17].

In addition, SMPS improves communicative action in problem-solving (CAPS) which is the public's act of picking, transmitting, and acquiring information. These three communicative efforts are divided into active and passive sub-variables. The selection of information is divided into two categories: information forefending (active) and information permitting (passive). When the public actively manages the information received for problem-solving purposes, they systematically assess the usefulness of the information and pick pertinent and practical information while ignoring information that is irrelevant or has little diagnostic virtue for problem-solving [26].

The specific and systematic selection of information regarding an individual's subjective view of an appropriate solution is known as information forefending. It is unlikely that the public active in problem-solving will accept all information as true; instead, they

consistently choose the information that is most useful and appropriate. On the other hand, information permitting, defined as the passive acceptance of messages from various sources, means the extent to which the general public recognizes any information without using a filtering process [17]. To take a stand on global warming, people need to think and understand, which necessitates the use of reliable communication channels.

Information transmission manifests itself in two ways: information forwarding (active) and information sharing (passive). Forwarding information is the deliberate dissemination of information to others, whereas information sharing is the reactive dissemination of information only when requested. The forwarding of information is critical to ensuring a continuous flow of information and message dissemination. The multipliers of global warming communication are social interactions, and conversations with friends, family, and colleagues in a society. Telling and sharing stories voiced by close social actors is one of the most powerful tools to demonstrate that global warming is occurring and those individuals can take action. Stories help individuals share facts, information, and experiences about the causes and effects of global warming by representing how individuals make sense of the world they live in.

Information Acquisition is linked to information seeking (active), "purposive acquisition of information from selected information carriers" [27], and information attending (passive). While seeking means that the public scan their surroundings in a planned way for messages about a specific problem, attending means that the public has an unplanned encounter with information about the problem. An active problem solver researches and deals with information about a particular problem or topic, while a passive problem solver can only crunch information when it is presented to him.

Also, because the general public is not uniform, STOPS offers methods to segment the general public according to their level of problem recognition, involvement recognition, and constraint recognition. Publics are divided into four main segments; non-public, latent, aware, and active/activist publics. The non-public public is not aware of the problematic situation and is therefore not aware of the need for involvement or constraints. The latent public is aware of the consequences of a problem but has not yet recognized it. The aware public recognizes the problem but does not take any action to solve it due to the high level of recognized constraints. Finally, the active/activist public has already begun to coordinate their actions to solve the problem [26].

3. Linguistic variables, fuzzy set representation, and modeling employing fuzzy rule-based systems

To investigate verbal evaluations, crunch them to extract insights, and finally generate models to establish a relationship between inputs and output, there are exactly two different ways available in the literature. While the first way contains transforming those verbal statements into numerical representations and plugging them into data analysis tools to generate results, the second one deals with representing those verbal statements by Fuzzy Set Theory (FST) and its tools, so those verbal statements represented by FST can be utilized in all types numerical computations without almost no loss of information in data analysis. By doing so, the loss of the data will be quite limited when compared with applying any type of transformation to verbal data. Therefore, to better represent what has been researched and applied to the research problem in this paper, some notions and definitions needed to be presented regarding FST and its tools.

Since social science fields heavily depend upon collecting data in the form of verbal statements generated by questionnaires, they must be transformed into numerical representations with a certain cost of losing some key insights of datasets, and these transformed data are also expected to follow and verify the assumptions of the implemented methods since applying a transformation to verbal statements has been assessed as the generic approach to deal with. However, verbal, or linguistic data can be alternatively transformed into forms that can be better mathematically manipulated by employing FST and its tools [28]. The core motivation of FST was to model the uncertainty that naturally exists in natural languages, so systems could be built to mimic the decision process of human beings. For instance, citizens are asked to assess their economic views related to lately increased inflation rate. The potential answers from citizens are assumed to be one of the following: Very badly, Badly, Slightly Badly, Almost None, or None. Assumed that while the first person chose the expression "Very Badly", the second one picked "Badly". If the conventional way of assigning numerical values such as 5 and 4 to those expressions is adopted, the uncertainty that exists in between would be omitted since a transition exists between those expressions. No one knows where "Badly" starts with. Namely, perception merely depends on personal assessment.

FST was introduced in the mid-60s and can cope directly with verbal expressions [29]. It means that FST is a tool that copes with the uncertainty that has existed in natural languages, which is strictly different from the uncertainty presented by the probability theory so, data analysis tools using FST do not need to verify the assumption of conventional data analysis tools when verbal data is presented numerically. Thus, even though the main motivation of the FST was to generate a tool mimicking the process of human decision-making in the field of artificial intelligence implementations, its mathematical structure and adaptability to several research fields make it a broadly implemented tool in areas other than artificial intelligence.

For example, if the economic views of citizens example are revisited, one says that "the inflation is high", the meaning of high differs from citizen to citizen since the perception of highness for each citizen is distinct. Thus, distinct levels of highness could be possibly attained. The level of uncertainty changing in the views of citizens is generically called an impression. So, the method of modeling employs the FST that transforms verbal statements into mathematical representations called membership functions, which could be established either by utilizing expert knowledge or employing available data at hand.

The terminology and definition that will be adopted in the manuscript are presented as follows.

Definition 1. A fuzzy set is a function from the universe of disclosure (Real Numbers (R) in general) to an [0,1] interval. Each membership function is represented by an ordered pair, which is the value of the linguistic variable or verbal statement and its membership degree expressed in Eq. (1).

$$K_M(x) : R \rightarrow [0,1] \leftrightarrow \{x \in M | K_M(x) \in [0,1]\} \quad (1)$$

Where M denotes the verbal statement and $K_M(x)$ is called a membership degree.

For example, assumed that a data set consisting of n numbers of citizens provide opinions about how inflation affects citizens based on verbal statements such as Very badly, Badly, Slightly Badly, Almost None, or None. In conventional transformation, those statements are numerically transformed to 1, 2, 3, 4, and 5, respectively to represent them. However, instead of representing them as just a single value, FST provides a new form of representation called membership functions, which are also called fuzzy numbers. Depending on the datasets, several types of fuzzy numbers could be employed to represent verbal statements such as symmetric triangular, Gaussian, trapezoidal, or asymmetric triangular fuzzy numbers. To make the introduction easier, instead of presenting them mathematically, they are presented in a parametric form since when they are applied, parametric forms of these numbers are used. So, for example, any symmetric triangular fuzzy number is expressed by M= (m, n, p), where m denotes a left endpoint, n characterizes a center point and p represents a right endpoint, respectively. Let M represent a linguistic term or verbal statement of "the impact of inflation". When inflation is characterized by a symmetric triangular membership function, the parameters of m, n, and p are assigned by experts or by utilizing the sampled data [30,31].

Fig. 1 depicts the most implemented membership functions such as symmetric triangular, asymmetric triangular, and trapezoidal ones.

The association between a set of independent attributes and a dependent attribute could be generically expressed by y = f(x) which is generally not known. The usual presupposition is to be a linear form. Nevertheless, the non-linear form is generically encountered in implementations. Many models regarding non-linearity exist. Nevertheless, when attributes are delineated linguistically, the construction of a linear model or even a non-linear model is difficult. So, FRBS emerge as a non-linear model that directly implements verbal statements by corresponding to membership function representations.

FRBS is a model establishing a relation between a set of explanatory attributes and an output attribute when IF-THEN structured rules are presented, which is written as follows:

When a set of explanatory attributes, $X_j = (xj_1, xj_2, \ldots, xj_n)$ j = 1,2, …,n, is assumed to relate with an output attribute Y, IF-THEN rule is a construction delineated by.

IF X_1 is denoted by A_1 and X_2 is denoted by A_2 and … and X_n is denoted by A_n, THEN Y is represented by B, where A_i's (i = 1,2, …,n) and B are linguistic terms characterized by membership functions [32].

FRBS is one of the data-driven approaches that is also employed in Big Data implementations. While the IF part is called the antecedent, the THEN part is called the consequent. Alternatively, while the IF part presents independent attributes, the THEN part includes an output attribute variable. One illustration from the engineering disciplines is presented as follows:

IF the velocity of an automobile is High and the road status is Slippery THEN brake Slowly which is a rule to control an automobile. High, Slippery, and Slow are such linguistic terms related to attributes Speed, Road Status, and Brake respectively.

In the basic illustrative rule, the IF-THEN structure contains two independent attributes and one output attribute. The speed of the automobile is represented by X_1 and the road status is characterized by X_2, the brake is represented by Y. When membership functions are set to High, Slippery, and Slow by a specialist or utilizing an existing dataset, a rule is fired.

The common form of an IF-THEN rule is delineated as follows:

R_i:*IF* x_1 *is* A_{1i},x_2 is A_{2i}, …,x_n *is* A_{ni} *THEN* y is B_i i = 1,2, …,k

The steps of implementation of FRBS can be summarized as follows.

1. Fuzzification stage: Converting numerical values into linguistic values (If necessary).
2. Construction stage of IF-THEN rules utilizing existing datasets or employing an expert's knowledge.
3. Conducting the FRBS model to infer.

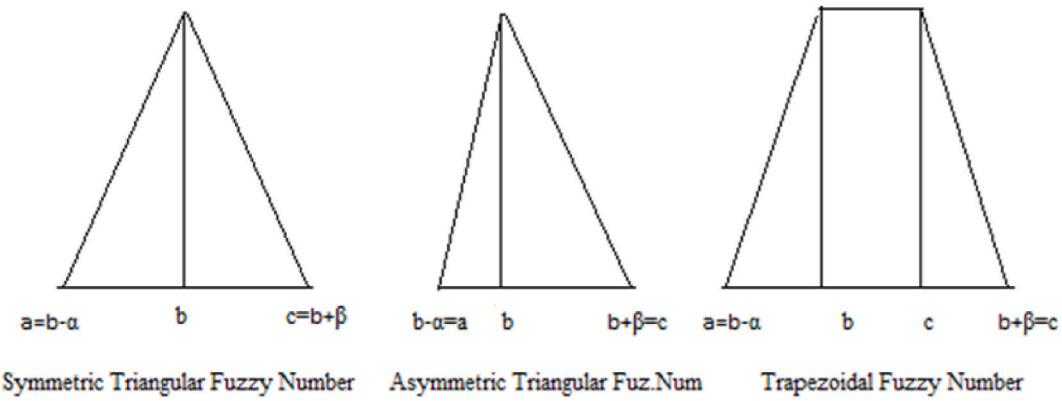


Fig. 1. Special fuzzy numbers.

4. Defuzzification: Converting linguistic terms into numerical ones (If necessary)

4. Method

Data is collected anonymously using an online questionnaire where an online consent form has to be confirmed and respondents have the option to end answering anytime, a total of 304 respondents participated in the study, approved by the Alanya Alaaddin Keykubat University Social Sciences Ethical Committee number 2024/03. The research operationalizes the STOPS scale, validated in Turkish [33]. The online questionnaire consists of 58 items capturing STOPS dimensions information forefending (4 items), information permitting (6 items), information forwarding (6 items), information sharing (4 items), information seeking (5 items), information attending (4 items), problem recognition (7 items), constraint recognition (5 items), involvement (5 items), referent criteria (6 items), situational motivation (5 items), which are measured with 7 point Likert type scale (1 = Strongly disagree, 7 = Strongly agree), and demographics (gender, family size, household income, car ownership, house ownership, and education). In line with the aim of the study, the study did not operationalize referent criteria and situational motivation as they are not used in the segmentation of the publics in STOPS. The paper used Matlab 2022b version to run fuzzy logic algorithms. it.

Methodology details are given in Fig. 2.

4.1. Respondents

Data is collected from 304 participants in Türkiye, %49 of whom are male and %51 of whom are female. %19 of respondents are living alone, %21 are sharing a house with a partner, %24,7 live with three people, %32,2 four, and %13,5 are five and more. %19,4 of the respondents has a household income below minimum wage, %51,3 up to 3 times the minimum wage, and %28,3 above 3 times the minimum wage. %44,1 own a car, %36,2 own a house, %31,3 reside in one of relative's house and %31,9 are tenants. %2,6 are primary school graduates, %6,9 are secondary school, %28 high school, %14,8 collage, %36,8 are graduates and %10,9 are post graduates.

4.2. Statistical analysis

First, arithmetic means for the three input attributes (problem recognition, constraint recognition, involvement) and 6 output variables (forefending, permitting, forwarding, sharing, seeking, attending) are calculated, ranging minimum of 1 to a maximum of 7. The arithmetic means are scaled min.0-max.100 to help easy interpretation, and calculated standard deviations, for each variable. The variables are graded based on indices values as LOW, MEDIUM, and HIGH. One standard deviation above the arithmetic mean is accepted as HIGH, and one standard deviation below is accepted as LOW (Table 1).

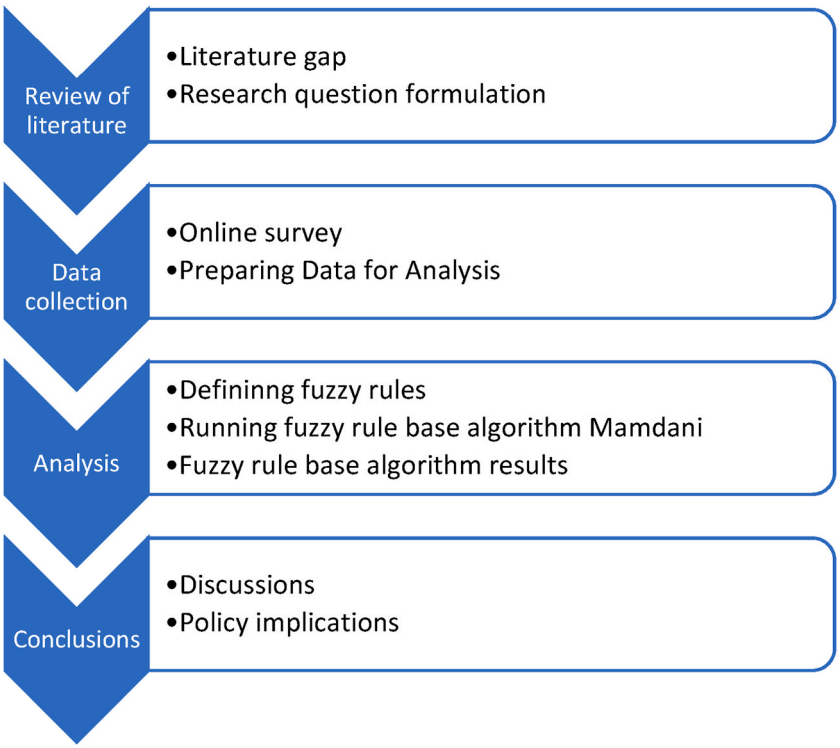


Fig. 2. Methodological steps accomplished.

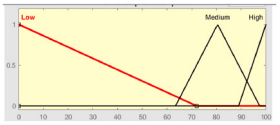
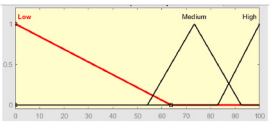
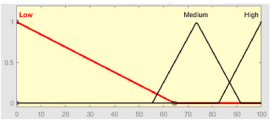
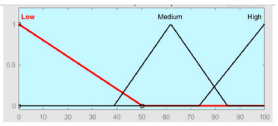
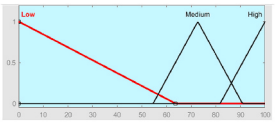
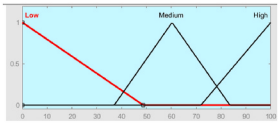
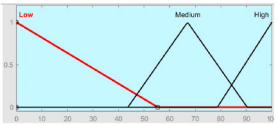
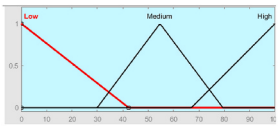
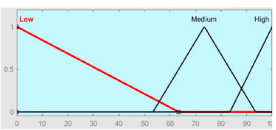
Such language values are converted into a datum stated in Fuzzy logic.

The following is an IF-THEN statement that will eventually become a rule in FRBS:

Table 1 shows the membership functions that will be utilized in FRBS, which are expressed in the form of asymmetric triangular fuzzy numbers. It should be highlighted that each linguistic attribute value should correspond to a membership function stated in parametric form so that FRBS can employ them. Instead of defining a mathematical function, the parametric form containing numerical values, such as "LOW" = (0 0 71.94), is used since MatLab allows fuzzy numbers expressed in parametric form.

IF PROBLEM RECOGNITION IS LOW AND CONSTRAINT RECOGNITION IS HIGH AND INVOLVEMENT IS LOW THEN

Table 1
Membership function plots: $F_{uzzy\ linguistic\ attributes\ and\ numerical\ scores\ of\ their\ membership\ functions.}$

	LOW	MEDIUM	HIGH	
INPUTS				
Problem R	[0 0 71.94]	[63.44 80.44 97.44]	[88.94 100 100]	
Constraint R	[0 0 30.06]	[22.35 37.78 53.21]	[45.5 100 100]	
Involvement	[0 0 62.7]	[53.17 72.23 91.28]	[81.75 100 100]	
OUTPUTS				
Forefending	[0 0 50.33]	[38.8 61.86 84.91]	[73.39 100 100]	
Permitting	[0 0 63.63]	[54.57 72.69 90.8]	[81.75 100 100]	
Forwarding	[0 0 48.62]	[36.99 60.25 83.5]	[71.88 100 100]	
Sharing	[0 0 55.33]	[43.67 67 90.32]	[78.66 100 100]	
Seeking	[0 0 42.28]	[29.91 54.66 79.41]	[67.04 100 100]	
Attending	[0 0 63.38]	[53.34 73.41 93.47]	[83.44 100 100]	

INFORMATION FOREFENDING IS LOW.

Indeed, MatLab does not accept the rule as written. It should be written in the form of membership functions, as seen below:

IF PROBLEM RECOGNITION IS [0 0 71.94] AND CONSTRAINT RECOGNITION IS [45.5 100 100] AND INVOLVEMENT IS [0 0 62.7] THEN INFORMATION FOREFENDING IS [0 0 50.33].

The above rule is then a genuine rule that will be crunched by FRBS. FRBS is run after all rules have been written in MatLab. The result can then be observed for specific values of input linguistic variables set by the researcher. The final phase of FRBS is defuzzification, which converts the membership function into a crisp (real number) if necessary. Because of the requirement to understand the system in terms of numerical values, the use of crisp values in science fields such as engineering and mathematics can be more helpful. It is also feasible to use linguistic values as output.

STOPS-based public segmentation suggests that the public can be segmented according to problem recognition, constraint recognition, and involvement levels (Table 2). For example, if the public recognizes high problem recognition and low constraint recognition, and high involvement then the public is active.

After all rules are entered into Matlab, the Fuzzy Rule Base System Mamdani algorithm is run and possible scenarios are tested.

4.2.1. Active public

Those who do something about the problem are active public. The active public is characterized by high problem recognition, low constraint recognition, and high involvement. FRBS parametric form is;

IF problem recognition is high (98) and constraint recognition is low (28) and involvement is high (95), THEN information forefending is low (50,1), information permitting is low (49,5), information forwarding is medium (50,1), information sharing is low (50), information seeking is medium (50,1), information attending is low (78,6) (Table 3).

IF problem recognition is high (90) and constraint recognition is low (10) and involvement is high (85), THEN information forefending is low (23,7), information permitting is medium (72,7), information forwarding is medium (41), information sharing is low (50), information seeking is low (38,9), information attending is low (50) (Table 3).

FRBS results suggest that active publics employ low level of information selection, they do not deliberately choose messages, or they do not passively accept the messages about global warming issues. They show medium levels of information forwarding, active public shares their information even if no one requested, however they will not share information at low levels when asked. Active public tends to acquire information at low and medium levels. They search for information about global warming issues planned and unplanned.

4.2.2. Active/aware public

Those who recognize the problem are aware public. The aware public is characterized by High problem recognition, High constraint recognition, and a Low level of involvement.

IF problem recognition is high (98) and constraint recognition is high (80) and involvement is low (10), THEN information forefending is low (50), information permitting is low (50), information forwarding is medium (50), information sharing is low (50), information seeking is medium (50), information attending is low (50) (Table 3).

According to FRBS results, the active/aware public will not actively or passively select information, they won't deliberately select information about global warming or they do not accept global warming messages passively. However, they will forward global warming messages to others and share them when requested at a medium level. The aware public will scan their surroundings about global warming at a medium level and unplanned encounters with information about global warming.

IF problem recognition is high (90) and constraint recognition is high (48) and involvement is low (10), THEN information forefending is medium (41,6), information permitting is Medium (78), information forwarding is medium (41), information sharing is Medium (44,4), information seeking is Low (19,9), and information attending is Medium (77,4) (Table 3).

4.2.3. Aware/active public

The active public is characterized by high problem recognition, high constraint recognition, and high involvement. FRBS parametric form is;

Table 2
Public segmentations.

	High Involvement	Low Involvement
Problem-Facing Behavior High Problem Recognition Low Constraint Recognition	*1-Active Public*	*2-Active/Aware Public*
Constrained Behavior High Problem Recognition High Constraint Recognition	*3-Aware/Active Public*	*4-Latent/Aware Public*
Routine Behavior Low Problem Recognition Low Constraint Recognition	*5-Active (Reinforcing) Public*	*6-None/Latent Public*
Fatalistic Behavior Low Problem Recognition High Constraint Recognition	*7-Latent Public*	*8-Non-Public*

Table 3
Tested possible scenarios.

				Information Selection		Information Transmission		Information Acquisition	
	Problem Recognition	Constraint Recognition	Involvement	Forefending	Permitting	Forwarding	Sharing	Seeking	Attending
Active Public	High (98)	Low (28)	High (95)	Low (50,1)	Low (49,5)	Medium (50,1)	Low (50)	Medium (50,1)	Medium (78,6)
	High (90)	Low (10)	High (85)	Low (23,7)	Medium (72,7)	Medium (41)	Low (50)	Low (38,9)	Low (50)
Active/Aware Public	High (98)	High (80)	Low (10)	Low (50)	Low (50)	Medium (50)	Low (50)	Medium (50)	Low (50)
	High (90)	High (48)	Low (10)	Medium (41,6)	Medium (78)	Medium (41)	Medium (44,4)	Low (19,9)	Medium (77,4)
Aware/Active Public	High (98)	High (80)	Low (95)	Low (49,6)	Low (48,4)	Medium (71,4)	Medium (74,7)	Medium (49,9)	Low (48,6)
	High (90)	High (48)	Low (85)	Medium (50)	Medium (50)	Medium (50)	Medium (50)	Low (50)	Medium (50)
Latent/Aware Public	High (90)	High (48)	Low (10)	Medium (41,6)	Medium (78)	Medium (41)	Medium (44,4)	Low (19,9)	Medium (77,4)
	High (98)	High (85)	Low (60)	Low (50,1)	Medium (79)	Medium (50,1)	Low (50,1)	Medium (50,1)	Low (49,7)
Active (Reinforcing) Public	Low (10)	Low (10)	High (95)	Low (50)	Low (50)	Medium (50)	Low (50)	Medium (50)	Low (50)
	Low (70)	Low (27)	High (85)	Low (50)	Low (50)	Medium (50)	Low (50)	Medium (50)	Low (50)
None/Latent Public	High (10)	High (10)	Low (10)	Low (17,9)	Low (22,7)	Low (17,3)	Low (19,7)	Low (15)	Low (22,6)
	High (70)	High (28)	Low (60)	Low (46,4)	Low (50)	Medium (41,4)	Medium (44,8)	Low (39,3)	Medium (46,4)
Latent Public	High (10)	High (48)	Low (85)	Medium (61,8)	Medium (77,7)	Medium (69)	Medium (44,7)	Medium (54,7)	Medium (73,4)
	High (70)	High (85)	Low (95)	Medium (61,8)	Medium (77,6)	Medium (69)	Medium (44,8)	Medium (54,7)	Medium (73,4)
Non-Public	High (10)	High (48)	Low (10)	High (89)	Medium (79)	Medium (60,3)	Medium (67)	Medium (54,7)	Medium (73,4)
	High (70)	High (48)	Low (60)	High (87,1)	Medium (77,6)	Medium (60,4)	Medium (67)	Medium (54,7)	Medium (73,4)
	High (70)	High (85)	Low (60)	Low (50)	Low (50)	Medium (50)	Low (50)	Low (50)	Low (50)

IF problem recognition is high (98) and constraint recognition is high (80) and involvement is high (95), THEN information forefending is low (49,6), information permitting is low (48,4), information forwarding is medium (71,4), information sharing is medium (74,7), information seeking is medium (49,9), and information attending is low (48,6) (Table 3).

IF problem recognition is high (90) and constraint recognition is high (48) and involvement is high (85), THEN information forefending is medium (41,6), information permitting is low (50), information forwarding is medium (50), information sharing is low (50), information seeking is medium (50), and information attending is low (50) (Table 3).

4.2.4. Latent/aware public

The active public is characterized by high problem recognition, low constraint recognition, and high involvement. FRBS parametric form is;

IF problem recognition is high (90) and constraint recognition is high (48) and involvement is low (10), THEN information forefending is medium (41,6), information permitting is medium (78), information forwarding is medium (41), information sharing is medium (44,4), information seeking is Low (19,9), information attending is medium (77,4) (Table 3).

IF problem recognition is high (98) and constraint recognition is high (85) and involvement is low (60), THEN information forefending is Low (50,1), information permitting is medium (79), information forwarding is medium (50,1), information sharing is Low (50,1), information seeking is Medium (50,1), information attending is low (49,7) (Table 3).

4.2.5. Active (reinforcing) public

The active public is characterized by low problem recognition, low constraint recognition, and high involvement. FRBS parametric form is;

IF problem recognition is low (10) and constraint recognition is low (10) and involvement is high (95), THEN information forefending is low (50), information permitting is low (50), information forwarding is medium (50), information sharing is low (50), information seeking is medium (50), and information attending is low (50) (Table 3).

IF problem recognition is high (98) and constraint recognition is low (10) and involvement is high (95), THEN information forefending is low (50), information permitting is low (50), information forwarding is medium (50), information sharing is low (50),

information seeking is medium (50), information attending is low (50) (Table 3).

4.2.6. None/latent public

The None/Latent public is characterized by low problem recognition, low constraint recognition, and low involvement. FRBS parametric form is;

IF problem recognition is low (10) and constraint recognition is low (10) and involvement is low (10), THEN information forefending is low (17,9), information permitting is low (22,7), information forwarding is low (17,3), information sharing is low (19,7), information seeking is low (15), information attending is low (22,6) (Table 3).

IF problem recognition is high (70) and constraint recognition is low (28) and involvement is low (60), THEN information forefending is low (46,4), information permitting is low (50), information forwarding is medium (41,4), information sharing is medium (44,8), information seeking is low (39,3), and information attending is low (46,4) (Table 3).

4.2.7. Latent public

Those publics who do not face a problem are nonpublic.

IF problem recognition is low (10) and constraint recognition is high (48) and involvement is high (85), THEN information forefending is medium (61,8), information permitting is medium (77,7), information forwarding is medium (69), information sharing is medium (44,7), information seeking is medium (54,7), and information attending is medium (73,4) (Table 3).

IF problem recognition is low (70) and constraint recognition is high (85) and involvement is high (95), THEN information forefending is medium (61,8), information permitting is medium (77,6), information forwarding is medium (69), information sharing is medium (44,8), information seeking is medium (54,7), information attending is medium (73,4) (Table 3).

4.2.8. Non-public

IF problem recognition is low (10) and constraint recognition is high (48) and involvement is low (10), THEN information forefending is high (89), information permitting is medium (79), information forwarding is medium (60,3), information sharing is medium (67), information seeking is medium (54,7), and information attending is medium (73,4) (Table 3).

IF problem recognition is low (70) and constraint recognition is high (48) and involvement is low (60), THEN information forefending is high (87,1), information permitting is medium (77,6), information forwarding is medium (60,4), information sharing is medium (67), information seeking is medium (54,7), information attending is medium (73,4) (Table 3).

IF problem recognition is low (70) and constraint recognition is high (85) and involvement is low (60), THEN information forefending is low (50), information permitting is low (50), information forwarding is medium (50), information sharing is low (50), information seeking is medium (50), information attending is low (50) (Table 3).

5. Conclusion and implications

The paper underscores the importance of understanding public segmentation in addressing global warming. The paper conducts the application of the STOPS in the context of global warming, to segment the publics based on problem recognition, constraint recognition, and involvement. Thus, the paper researches global warming communicative actions of publics by using STOPS to understand the aspects of the causes that prevent publics from communicating actively about global warming. By employing fuzzy logic within the framework of STOPS, the diverse ways in which different public segments engage with information about global warming were investigated. The communicative actions of the publics at different levels of problem recognition, constraint recognition and involvement recognition were tested and the contribution of the paper to the current literature lies in this testing method. Current literature on STOPS is based on linear relationships whereas fuzzy rule-based systems allow non-linear relationships which enables to understand hidden relationships which cannot be studied by inferential statistics. Thus, this study contributes to the refinement of STOPS by integrating fuzzy logic, offering a more detailed understanding of how problem recognition, constraint recognition, and involvement interact to influence information behavior.

The majority of the findings of the paper were found to be congruent with the literature such that, as the problem recognition and involvement level are increased and constraint recognition is decreased, communicative action increases. However, FRBS suggest a fluctuation in global warming communicative actions in general, but, they do not exceed a medium level. Furthermore, an interesting finding which contradicts with the current literature detected in this paper is the general view of the theory proposing when problem recognition is low, the constraint is high and involvement is low, communicative action is expected to be low. FRBS results suggest that if problem recognition and involvement levels are low, and constraint recognition is high, communicative action is found to be medium at all levels. However, if constraint recognition is increased further, a drop in communicative actions is witnessed. To sum up, constraint recognition prevents communicative action at extremely high levels, but at low-level constraint recognition, communicative action is also medium. This contradicting finding with the literature can be interpreted as; if the public recognizes that s/he is constrained at a medium level, constraint recognition acts as a signal that something is wrong, something is missing, and thus, stimulates the search for information, that's why communicative action increases. If the public does not recognize constrained, they show low to medium-level communicative action. If only the public recognizes extremely high levels of constraints, their communicative action drops. Contrary to current literature stating that involvement is the most influential variable for communicative action [34–36], the results of the paper suggested that the dominant factor that may convince public to start taking action towards global warming seems to be recognizing being constrained.

Recognizing being constrained increases communicative actions in terms of global warming. When people recognize the problem of

global warming and realize it affects them, they are expected to seek information. Recognition of being constrained may play an interesting role here, as recognizing constraints may create a sense of uncertainty. Although it is frequently used negatively, a sense of uncertainty motivates people to learn more, discover, be curious, and seek about global warming.

The findings of the paper provide insights into public behavior and offer practical and theoretical implications for policy makers and communication strategists to mitigate the negative outcomes of global warming. Firstly, increasing problem recognition and involvement through education can transform latent publics into more active participants. As its interdisciplinary nature requires its inclusion across all educational levels, it is important to integrate the issue of global warming into the curriculum of primary and secondary level education to increase the awareness among students. Gamification methods or visual material as teaching tools can be developed effectively to enhance the understanding. The government should incorporate environmental education into both formal and informal academic institutions.

Secondly, increasing problem recognition and involvement through awareness campaigns can also transform latent publics into more active participants. Governments should collaborate with non-profit organizations to organize awareness campaigns at national levels. These awareness campaigns should aim at educating and motivating people to modify their lifestyles and energy consumption habits. These steps can cultivate a culture of sustainable energy use and decrease overall energy consumption. Awareness campaigns or educational programs should address specific constraints identified within each segment. Developing customized messages that resonate with each segment's unique characteristics can enhance the effectiveness of the communication campaign. It is also particularly significant to organize these programs backed by media to enhance levels of knowledge about global warming. Furthermore, offering incentives for behaviors such as sharing and seeking information can motivate less engaged groups. Policies can include subsidies, or tax deductions for sustainable practices and participation in environmental programs, and promote the adoption of low-carbon technology.

These insights are invaluable for developing targeted policies and practical strategies to enhance public engagement and drive collective action towards mitigating global warming. Future research should continue to explore the dynamic interactions between problem recognition, constraints, and involvement to further refine public segmentation models and their applications in various domains. This research is not beyond limitations. The study's sample size can be adequate for initial insights, however, may not be fully representative of the broader population globally which requires comparative studies in different countries as cultural and contextual factors unique to Türkiye may influence the results, and these factors might differ significantly in other countries, affecting the applicability of the findings on a global scale. Also, focusing on younger demographics and their engagement with global warming could provide insights into how future generations perceive and address environmental issues. This could also highlight educational and outreach strategies to foster proactive environmental citizenship. Furthermore, complementing quantitative data with qualitative methods such as interviews and focus groups could provide deeper insights into the motivations, beliefs, and barriers faced by different segments of the public. Addressing these limitations in future research could provide a more comprehensive understanding of public engagement with global warming and improve the robustness of the findings.

CRediT authorship contribution statement

Mehmet Özer Demir: Writing – original draft, Supervision, Methodology, Formal analysis, Conceptualization. **Zuhal Gök Demir:** Writing – review & editing, Writing – original draft, Conceptualization. **Çiğdem Karakaya:** Writing – review & editing, Writing – original draft, Project administration. **Fulya Erendağ Sümer:** Writing – review & editing, Writing – original draft, Resources.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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