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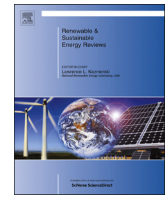

Assessing the effectiveness of community-promoted environmental protection policy by using a Delphi-fuzzy method: A case study on solar power and plain afforestation in Taiwan

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ABSTRACT

Taiwan is a nation densely concentrated with industrial properties, causing a high level of greenhouse gas emissions. Therefore, poor air quality and environmental pollution in Taiwan are severe societal problems. Although Taiwan has formulated severe environmental protection-related penalties, the excessive use of energy and high level of pollution remain a persisting environmental problem in Taiwan. Because communities are collective groups beneficial for the promotion of local policies, several subsidy policies for environmental quality improvement are currently promoted through community development in Taiwan. These policies consider factors such as Taiwan's long-day geographical environment and the increase in idle agricultural land after the process of economic transition. To explore the effectiveness of promoting these policies, this study applied the Delphi method and fuzzy logic theory to establish a quantified effectiveness assessment model. In addition, we determined that communities that encourage the participation of its residents and factors such as proenvironment, solar power, and plain afforestation enhanced the overall environmental protection of the community and reduced the emission of CO_2. Furthermore, the core problems that hinder the improvement of current policies were identified.

Contents

1. Introduction

The high greenhouse gas emissions worldwide have not been effectively controlled despite the consensus reached when the Kyoto

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Protocol that defines the CO_2 emission limitations was established in 1997. The development requirements and interests of various nations' economy led to the failure of countries worldwide to achieve the expected decrease in global CO_2 emissions. Numerous researchers are concerned about the climate crises that occur because of the high CO_2 emission volume. Although the Kyoto Protocol is to be extended to 2020, such extension cannot solve the root problems that cause high CO_2 emissions. If various nations cannot mitigate economical and industrial competition and reduce their dependence on petroleum, coal, and other energy sources, completely solving the problem of high CO_2 emissions is extremely challenging. Furthermore, carbon taxes are unlikely to alter the energy use habit of high-consumption groups and high-profit-gaining businesses. In addition to national policies upholding the concept of global responsibility, businesses must possess social responsibility [1] and families and individuals must maintain an attitude based on social responsibility [2]. Thus, the critical problem of CO_2 emission and global warming can be resolved.

Currently, the Taiwan government has combined environmental protection policies with community development policies through incentives or subsidies. Citizen participation [3], citizen social responsibility, and citizen empowerment can be enhanced to increase the effectiveness of environmental protection policies. In addition, citizen participation strengthens community empowerment [4], which yields concrete outcomes regarding residents' rights and the cultivation and teaching of knowledge and professional skills, thereby enhancing cohesion among residents' community consensus and identity. In addition to promoting community development, the government in Taiwan has formulated diverse subsidy policies. Among these policies, community environmental protection policies encompass multiple dimensions, including ecological communities, green communities, solar energy, low-carbon communities, air quality improvement, and plain afforestation. By encouraging public participation and fostering people's ability to participate, these policies can help residents cultivate social responsibility behaviors and alter their proenvironmental attitudes and behaviors [5–8]. Subsequently, the residents can develop individual- and community-based proenvironmental behaviors [9] and environmentally responsible behaviors [10–12].

Excessive global energy consumption has led to problems such as environmental damage, high greenhouse gas emissions, and global warming, which is, as indicated by Bamberg [13], "a new answer to an old question." Numerous policies relevant to reducing energy consumption are available [14,15]; however, these problems still persist. In addition, Zhang explained that reducing aggregated energy consumption and promoting energy conservation may increase China's economic growth [16]. Although energy sources such as petroleum and coal can induce environmental damages, changing the energy use habits of various industries and individuals is not a simple task. This is one of the reasons that the Kyoto Protocol was extended. If the factors that influence the acceptability of energy policies can be understood [17], effective energy policies can be formulated, which can facilitate a change in the attitude of people toward the use of energy resources.

After Taiwan became industrialized, its energy consumption substantially increased each year. Zhang reported that in 2002, the average per capita CO_2 emission in Taiwan was 10.4 metric tons [18], which is over twice that of the world (4.38 metric tons). The amount of CO_2 emission in Taiwan has increased from 114.7 million metric tons in 1990 to 276.2 million metric tons in 2007, yielding a percentage increase of 140.9% at a rate 3.7 times the global average value, which is second only to that of China, Iran, and Indonesia [18,19]. Presently, the Taiwan government is actively developing various alternative energy sources to implement the CO_2 mitigation strategy [20]. Because Taiwan is located in a subtropical region where adequate long-day sunlight is obtained throughout the year, the development of solar energy policies can reduce the problem of high CO_2 emission. As Hrastnik [21] suggested, a national energy program for the use of solar energy should be implemented. After the agricultural society in Taiwan has transformed into an industrial production society, the income obtained from agricultural production is inadequate for covering farmers' living expenses, causing a large young population from farming regions to migrate and work in cities. Consequently, large areas of fallow agricultural land are generated because of social changes. If new relevant policies can be formulated to mitigate this problem, the confrontations encountered during social development can be prevented.

Solar power system subsidy policies and plain afforestation policies currently promoted in Taiwan are highly practical environmental policies. In the subsidy policies for solar power system, people are encouraged to install solar power systems [22,23] on the roofs of residential buildings and tall buildings, in unused spaces, factory plants, and in schools. These institutions can subsequently sell electricity to the public sector of the power company. In addition, subsidies are provided for installing solar water heaters, and energy- and water-saving appliances and equipment. Plain afforestation policies involve the planting of trees to achieve carbon sequestration [24]. Plain afforestation is beneficial in that it can facilitate the sequestration of CO_2 gases emitted in communities and provide other benefits such as community beautification, ecological restoration, environmental protection, and improvement in air quality. Taiwan's plain afforestation subsidy policies are integrated with fallow agricultural land subsidy policies, which aim to benefit the reuse of fallow lands.

Plain afforestation policies enable environmental beautification and protection, carbon sequestration, the reuse of fallow agricultural lands, and help farmers who possess carbon sequestering rights to earn income from carbon emissions trading. Based on the 2011 Environmental White Paper issued by Taiwan's Environmental Protection Administration, Executive Yuan, Taiwan's total land area was approximately 36,000 km^2, of which 58.5% of land is forest area with limited agricultural land resources and arable land area comprised approximately 810,000 ha [25]. Based on the agricultural report issued by the Agriculture and Food Agency, Taiwan's abandoned arable land in 2009 comprised a total area of 140,516.06 ha, which accounted for 17.3% of the arable land [26]. Taiwan's fallow agricultural land in 2011 comprised approximately 200,000 ha, which accounted for 20% of the arable land [27]. Wise [28] proposed that ecosystems and forest expansion can reduce the CO_2 concentration in the atmosphere. Taiwan's current situation is favorable for the implementation of plain afforestation and the promotion of policies on the reuse of fallow agricultural land, which will be conducive to achieving carbon sequestration [29] and an integrated planning for mitigating CO_2 emissions [30].

The aforementioned description indicated that Taiwan features long-day conditions, a large area of idle agricultural land, and considerable experience in community development, and diverse subsidy policies are implemented in Taiwan. These conditions are highly suitable for promoting the use of solar power and plain afforestation. The purpose of this study was to apply the Delphi method and fuzzy logic theory to establish a quantified assessment model, which can be used to evaluate the effectiveness of promoting solar power and plain afforestation policies in a community. Therefore, we adopted a case study to describe the application function of the assessment model. This model can be used by the community for the self-evaluation of policy effectiveness, and serve as a reference for governmental management departments to amend policies and assess the quality of community development.

2. Research model and literature review

We integrated the Delphi method and fuzzy logic theory to establish an assessment model. First, the Delphi method involving group decision skills was adopted as the foundation for quality analysis, and then fuzzy logic theory, which quantifies human semantic technology, was used to complete the model framework. During the course of this study, Delphi experts assisted with developing the assessment model. The following subsections describe how the model was constructed.

2.1. Framework of the research model

The framework of this study was divided into two sections, the Delphi process and the fuzzy logic inference system. The Delphi process involves the operating procedures used during expert group decision-making. The main purpose of using the Delphi process was to obtain the data required for establishing the fuzzy logic inference system. These data were parameters and information necessary for model construction, such as input criteria, fuzzy sets, a fuzzy set range, membership function, and if-then rules, which are components that enable the developed model to possess inference functions. The framework of the research model developed in this study is shown in Fig. 1.

2.2. Delphi method

The Delphi method is an expert group decision-making model. The expert group includes experts or professionals from the industry, academia, and government departments [31]. The group decision-making process used in the Delphi method is divided into four steps: (a) Experts who are professionals with practical work experiences in related research domains (preferably professional managers with 10 or more years of experience, CEOs, scholars, and civil servants) are selected. The invited experts must not know who the other invited members are to avoid influencing the objectivity of their opinions; (b) The topic that requires exploration and the relevant information required for the study are employed to design the questionnaire, which can then be distributed by mail or through interviews; (c) After receiving the returned data, the distinct opinions of the experts are organized and subsequently used to design a new questionnaire. (d) Steps (b) and (c) are repeated until the experts reach a consensus regarding the designed questionnaire. In general, employing interviews can reduce the number of times Steps (b) and (c) are repeated.

The Delphi method has been widely adopted to explore various topics. Studies have been conducted on environment-related topics such as environmental impacts on the Galapagos Islands [32], the development of a sustainable building assessment scheme [33], competition in the European electricity markets [34], Delphi-based change assessment in ecosystem service values [35], the development of agrienvironmental indicators [36], and the assessment of the impacts of forest management [37]. The Delphi method has also been applied in other areas, which include the systematic review of methodological criteria [38], the forecasting of financial markets [39], the determinants of adolescents' ineffective and improved coping with cyberbullying [40], humanistic care indicators for residents in nursing homes [41], and the identification and assessment of future challenges for supply chain security [42]. Thus, the Delphi method has been applied in diverse fields as a prediction tool for investigating various research topics.

2.3. Fuzzy logic theory

The rapid development of information technology prompted the innovative development and application of artificial intelligence (AI) products. Modern AI products have been widely applied in the aerospace industry, military weapons, transportation tools, industrial control [43], agriculture, and medical and household items. Current theories that can be used to develop AI products include fuzzy logic theory, neural fuzzy logic, the artificial neural network, the expert system, and genetic algorithms. The products in which fuzzy logic theory has been applied include drones, robots, and washing machines. Fuzzy logic is distinctive because it can apply expert fuzzy logic inference systems to convert technologies that cannot easily use mathematical models to develop control systems, into a control model that exhibits humanized thinking abilities.

Fuzzy logic theory originated from the fuzzy sets concept proposed by Professor Zadeh [44]. Fuzzy sets further advanced the traditional concept of noncontinuous crisp sets such as crisp set {0, 1}. This set is a combination of two elements, 0 and 1. However, fuzzy sets are composed of infinite continuous values between 0 and 1, rather than simply a set comprising 0 and 1. The data attributes of crisp set {0, 1} represent two distinct absolute meanings such as 0 and 1, right and wrong, positive and negative, and high and low. By contrast, the data attribute of fuzzy sets involve membership functions that explain the degree to which data approach 0 or 1. Thus, the objects that are designed by crisp sets can accept only correct data values such those obtained using the traditional binary arithmetic method, which cannot analyze and process data containing unquantified matter. Because the computation of fuzzy sets is based on the principle of membership function, fuzzy sets can accept inaccurate data and the fuzzy semantics of natural human languages [45,46]. In 1996, Zadeh proposed that fuzzy logic may be equated to computing with words, delineating the ability of fuzzy logic to quantify and process human language semantics.

Current quantified values or units with which humans are familiar include Arabic numerals, kg, m, L, and lumen; these are either defined by or derived from the research findings of relevant scholars. After the fuzzy logic theory was defined by Zadeh [47], it was widely used in

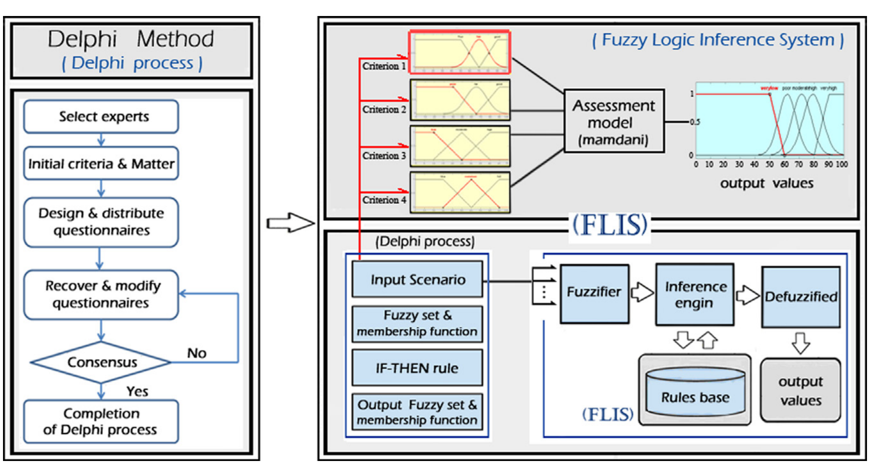

Fig. 1. Research model framework.

quantified decision analysis and practical applications in various fields. In addition, fuzzy logic can process and compute data of various attributes; for example, it can compute quantified semantics such as good, ordinary, and bad as well as high, medium, and low, or perform mixed computing on precise values such as weight (kg), length (m), height (m), and the amount of water (L). Unlike traditional calculation methods, this computing approach is capable of simultaneously processing various data.

Studies have applied fuzzy logic theory on various environmental topics including the determination of a nuclear power plant location [48], the evaluation of environmental sanitation [49], greenhouse gas emission trading [50], sustainable energy crop selection [51], thermo-economic optimization applied to small waste water treatment plants [52], environmental quality indices [53], environmental monitoring [49], and solar energy demonstration zones [21]. These studies have demonstrated that fuzzy logic is highly adaptive and reliable. In addition, fuzzy linguistics can be used to convert a scenario into inference information that would facilitate practical analyses and applications.

2.4. Fuzzy logic theory and the Delphi method

This study applied fuzzy logic theory that has AI functions and the Delphi method involving expert group decision making to establish an assessment model. The purpose was to obtain objective and reliable expert data that enable the model established using fuzzy logic to possess humanized thinking function. Furthermore, previous studies on the methodology of fuzzy logic and the Delphi method were examined, including content presentation personalization and media adaptation in tourism Web sites [54], the effect of renewable energy applications on Taiwan buildings [23], the adjustment of statistical time series predictions [55], collaborative product design and optimal selection [56], the construction of road safety performance indicators [57], and the evaluation of hydrogen production technologies [58]. These studies have indicated that combining the Delphi method and fuzzy logic theory is beneficial in the exploration of various problems and knowledge to enhance the rigor of research studies.

3. Establishing the fuzzy logic inference system

We applied the following steps by using MATLAB software to establish a fuzzy logic inference system (FLIS): (a) determine the output model (Mamdani is a continuous output model and Sugeno is a noncontinuous output model); (b) confirm the input criteria; (c) determine the fuzzy sets and membership function of each criterion, and quantify interval values; and (d) establish an if-then rules base. After completing these steps, the FLIS can achieve the inference function. Among the steps, the if-then rules base is similar to a human brain that is capable of performing corollary thinking, information computing, quantification, and decision analysis. The quantification procedure used for processing FLIS data is described as follows: (a) scenario is inputted, which includes inaccurate data values such as high, medium, and low expressed in a human language, or accurate data values; (b) a fuzzifier is used; (c) an inference engine is used; and (d) the output value is quantified. Thus, the FLIS transforms the human cognition of a scenario into usable and comprehensible information.

By using the Delphi process, we obtained the key data required for the various stages of constructing the FLIS. We invited nine Delphi experts including one chairperson (with more than 15 yr of professional experience) of the community development association, three volunteers (with 10 yr of experience) who promote community environmental protection development, two people from governmental departments, and three scholars. We spent 8 mo completing the procedures required in the Delphi process. In addition, the Delphi experts unanimously agreed that the four criteria, namely citizen participation; proenvironmental behaviors; electricity difference/mo; and the land area of afforestation (mm) are the crucial factors that should be used to evaluate the effectiveness of community-promoted policies on solar power and plain afforestation.

3.1. Definition of fuzzy sets, fuzzy range, and membership function

In this study, we used the Delphi process to define fuzzy sets, membership function, and fuzzy range. The definition of fuzzy sets and fuzzy range based on each criterion is shown in Table 1. The fuzzy sets of the two criteria of citizen participation and proenvironmental behaviors were established by using the ratio of community residents participating in activities as the evaluation standard. Therefore, the words *enthusiastic, average,* and *scant,* and *passionate, general,* and *cold* were adopted for the fuzzy linguistics of citizen participation and proenvironment behaviors, respectively. The fuzzy range of the fuzzy sets was defined as values in the range of 0–100%. For the electricity difference/mo criterion, we adopted the rate of electricity saved monthly from families who participated in implementing solar power policies as an evaluation standard. Therefore, the words *high, medium,* and *low* were adopted in fuzzy linguistics, and the fuzzy range of the fuzzy sets was in the range of 0–50%. Regarding the land area of afforestation criterion, the willingness of farmers who own fallow agricultural land in the community to participate in the implementation of plain afforestation policies was used as the evaluation standard. Thus, the words *high, medium,* and *low* were adopted for fuzzy linguistics; the fuzzy range definition of the fuzzy sets ranged from 0% to 100%. To understand the effectiveness of the community's assistance with policy promotion, *very good, good, average, bad,* and *very bad* were assigned as fuzzy linguistics for the final step of output value in the FLIS. The fuzzy range of the fuzzy sets was defined as values in the range of 0–100%.

Because we did not explore the precision control of the fuzzy logic controller, selecting distinct membership functions will not influence the final assessment results. In general, triangle membership function and gauss membership function are commonly adopted in decision evaluation. To understand the corresponding relations between input and output continuity, in addition to adopting the Mamdani model of the FLIS, we employed the gauss membership function as the membership function of each criterion and the output. By using the Delphi

Table 1
Fuzzy sets and fuzzy range of each criterion.

	Range (fuzzy sets)	Output (Fuzzy sets)
Citizen participation	1–100% (*enthusiastic, average, scant*)	
Proenvironmental behaviors	1–100% (*enthusiastic, average, scant*)	Very good (85 or above)
		Good (70–84)
Electricity difference/month	1–50% (*high, medium, low*)	Average (55–69)
		Bad (40–54)
Land area of afforestation	1–100% (*high, medium, low*)	Very bad (39 or below)
Note	The range can be defined using the default value (0–1) in the MATLAB software; the purpose of defining the fuzzy range was to facilitate practical applications	

process, the parameters for the various stages were completely defined to satisfy the requirements of current situations.

3.2. The relation between input scenario and quantified output value

The four criteria used in this study were citizen participation, proenvironmental behaviors, electricity difference/mo, and the land area of afforestation. Because the fuzzy set of each criterion is formed by three types of scenarios such as *enthusiastic, average,* and *scant* or *passionate, average,* and *cold*, using the four criteria can yield 81 scenarios (3*3*3*3). These 81 scenarios were used to evaluate the effectiveness of promoting renewable energy and

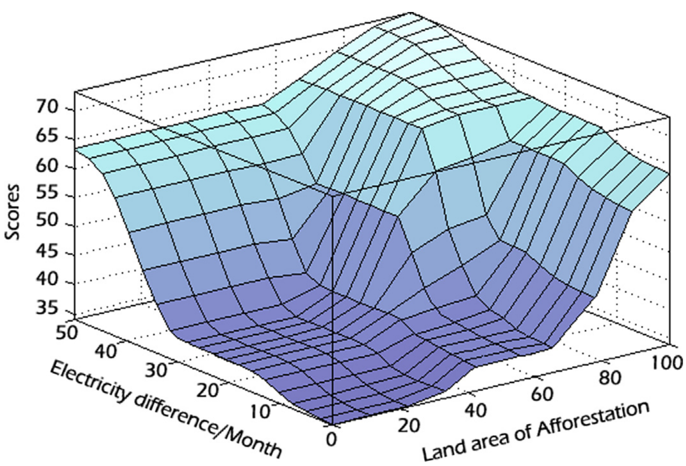

Fig. 2. 3D mapping of electricity difference/mo and the land area of afforestation.

afforestation policy by the community. Although these 81 scenarios were mixed with imprecise fuzzy linguistics, each scenario was transformed using the FLIS (which is a complex inference model) into clear quantified output value. For example, regarding citizen participation, an *enthusiastic* scenario is represented by using numbers 80 or above, whereas an *average* scenario is represented by using a number of approximately 50. A scenario with 70 is difficult to categorize; it could be categorized as *enthusiastic* or *average*. In FLIS computations, membership function and the inference rules base are applied to determine whether the scenario is *enthusiastic* or *average*. Subsequently, the scenario is converted into quantified values.

Fig. 2 presents the 3D mapping of the input and output of the two criteria: electricity difference/mo and the land area of afforestation. The 3D map shows that obtaining a high evaluation value requires a high ratio of farmers who possess fallow lands and are willing to participate in plain afforestation, and a high ratio of families must be willing to invest in the installation of a solar power system. In addition, Fig. 3 indicates that when community residents demonstrate enthusiastic participation and passionate proenvironmental behaviors, high scores were obtained. This suggests that farmers are willing to participate in plain afforestation and citizens are willing to install a solar power system in their home, thus indicating that satisfactory policy effectiveness was observed in the entire community.

The four criteria used in this study can produce 81 combinations of scenarios. Based on the conversion result obtained after the FLIS model quantified these 81 scenarios, we found that the optimal effectiveness of the plain afforestation and solar power policies received a score of 90.6. By contrast, the least favorable effectiveness yielded a score of 26.3 (Table 2). Each input scenario corresponded to

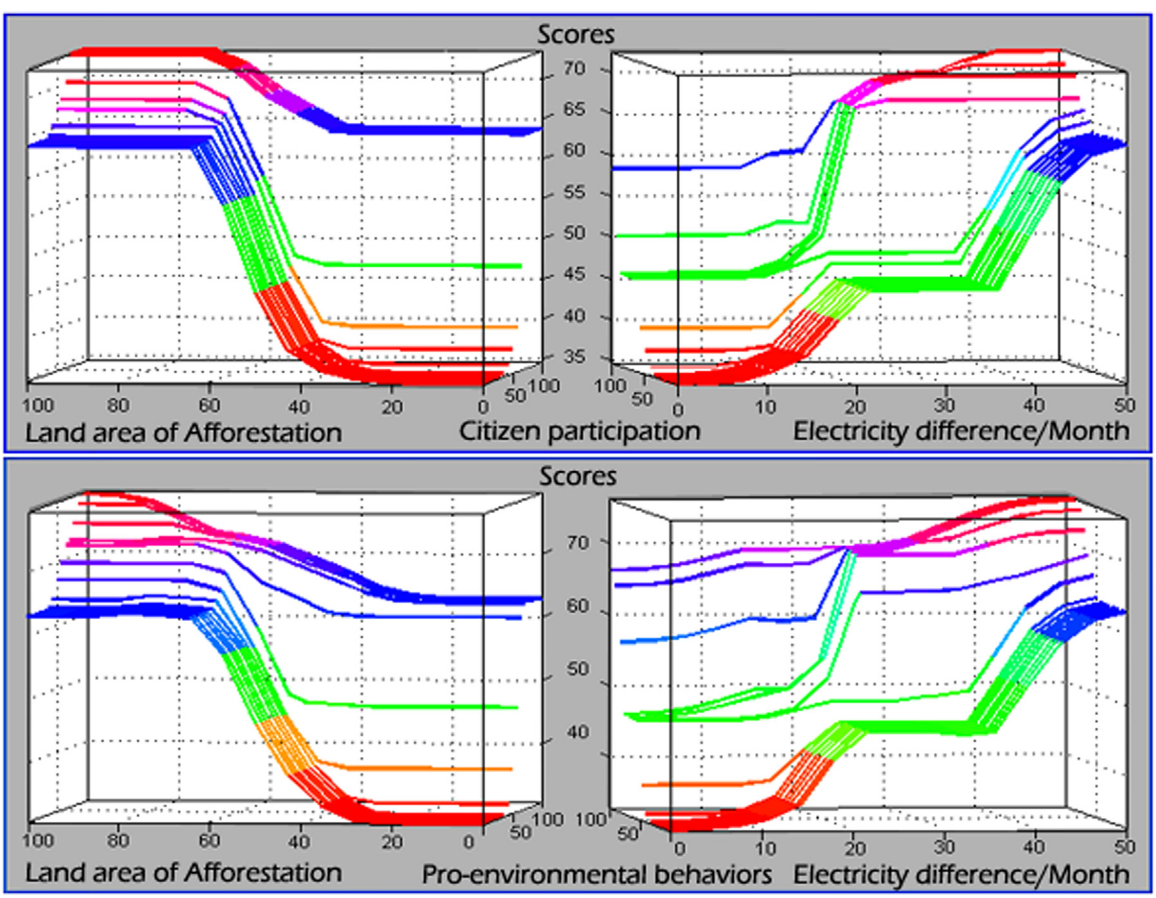

Fig. 3. 3D mapping of input and output.

a quantified output value. Figs. 2 and 3 indicated that the FLIS can transform complex human cognition into information that can be easily understood and accepted. The Delphi-fuzzy model established in this study is capable of processing scientific inference and quantification algorithms. In addition, the Delphi-fuzzy model is a highly objective and adaptive assistive decision-making tool that can facilitate subsequent maintenance and applications.

4. Case study

4.1. Case summary

Hunei District in Kaohsiung City was used as a case for analysis in this study. This district has a total area of 20.1615 km^2, populated with 29,289 community people (i.e., 10,193 households). According to the Hunei District Office, the surface area of its agricultural land is approximately 591 ha, of which 290–310 ha is fallow. The surface area of aquaculture land is approximately 750 ha, and 600 households engage in husbandry farming. Hunei District has received numerous awards from governmental management departments for the participation of its residents in community development. The chairperson of the Hunei District was one of the Delphi experts invited to participate in this study. The chairperson has over 20 yr of practical experience in community development and the district received community development subsidies from the public sector almost every year. In recent years, Hunei District has promoted environmental protection policies (e.g., air-quality improvement) and hosted events such as the Love for the Earth, Let's GO! Hunei District has engaged in promoting environmental seed teachers for years while occasionally holding events related to environmental protection. Overall, these events have substantially enhanced public participation. Fig. 4 presents a picture of the Hunei community map and residents participating in community activities. Selecting this community as the case study is effective for exploring the potential benefits and disadvantages related to community-based policy promotions.

Table 2
The FLIS assessment of the case study.

Criteria	Optimal	Least favorable	Hunei community
Citizen participation	Enthusiastic	Scant	Average
Pro-environmental behaviors	Passionate	Cold	Average
Electricity difference/month	High	Low	Low
Land area of Afforestation (mm)	High	Low	Low
Quantified output value	90.6	26.3	64.6

4.2. Case study

Van der Schoor and Scholtens [59] found that the development of a shared vision, level of activities, and type of organization are critical factors for determining the strength of the 'local network' when local community energy initiatives make contributions. For years, the residents of Hunei District have enthusiastically participated in community development. To evaluate the effectiveness of the solar power and plain afforestation policies promoted in this district, we spent 3 mo conducting interviews and surveys. The results showed that until August 2014, of the 308 ha of fallow agricultural land in Hunei District, only one farmer participated in plain afforestation (his fallow land was approximately 0.7 ha). In addition, a household with 750 ha aquaculture land applied for replacement subsidies for only 20 solar water wheels. If 1 ha of land requires five solar water wheels, then a household with 750 ha aquaculture land would need 3750 solar water wheels. For implementing solar power, most of the residents installed solar power heaters; few families invested in installing solar power systems. These data were processed using the Delphi process to obtain the input value for the case study, as shown in Table 2. The evaluation results of using the FLIS indicated that the corresponding output value was 64.6. The FLIS generated an optimal effectiveness value of 90.6, and the least favorable effectiveness value was 26.3 (Table 2). The evaluated case study obtained a score of 64.6, which means that the effectiveness of promoting solar power and plain afforestation policies in the case community was unsatisfactory.

4.3. Case evaluations and comparisons

The number of farmers who participated in plain afforestation and the number of families that installed solar power systems indicated unsatisfactory effectiveness. However, as shown in Fig. 3, the assessment result of the FLIS presented a high output value when residents demonstrated high citizen participation and increased proenvironmental behaviors. This implies that the fuzzy logic model evaluated the basic condition of the event, as well as considered the development potential and overall cognition. Thus, for this case study, the evaluation of the FLIS was satisfactory, meaning that the problems

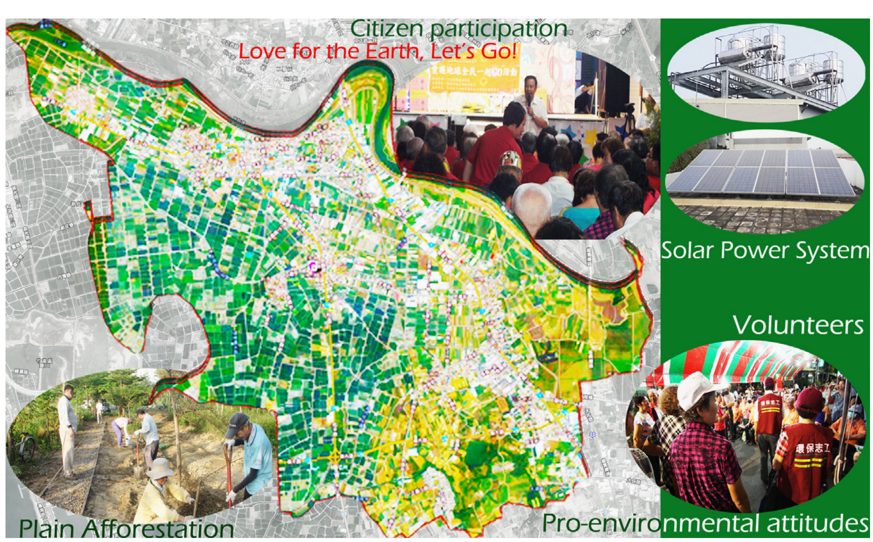

Fig. 4. Hunei District map and photos of residential participation in proenvironmental activities.

were related to policies and not to the residents of the community. After obtaining the evaluation result, we found that the solar power and plain afforestation policies were difficult to implement because public power plants only purchase solar power that is obtained from solar systems built on legitimate buildings. Thus, solar power systems can be installed only on the top floor or the roof of buildings. In brief, most residents are not motivated to invest in a solar power system because of limited space for solar panel installation and insufficient power efficiency. Regarding plain afforestation, satisfying the threshold for obtaining subsidies is extremely difficult. For example, if farmers wish to apply for plain afforestation for 500 ha of their farmland, they must provide proof indicating that their land is fallow and is not classified as a specific agricultural area or excellent farmland, and they must also obtain agreement from neighboring land owners. In addition to these unfavorable regulations, the 20-yr grant term was reduced to 6 yr in relevant subsidy policies, which influenced the award incentives specified in the policies. Although the amount of subsidies for plain afforestation is higher than that received for owning a fallow land, the additional subsidy cannot fully cover the labor costs. Furthermore, management agencies have also failed to provide incentives for solving problems regarding farmers with future carbon rights.

Taiwan's economic transition has negatively influenced its agricultural economy. The majority of agricultural irrigation water has been used as industrial water, which severely dehydrated fertile farmlands, hindering farmers from growing crops to make a living. In the past, fallow agricultural land subsidies were provided to disadvantaged farmers; however, these subsidies are being criticized as inappropriate because government officials have come to consider providing subsidies for disadvantaged farmers as a favor. The decline in Taiwan's economic growth in recent years has prompted officials to prioritize eliminating these subsidies as a mean of reducing the country's financial burden. To address the aforementioned problems, we suggest relaxing the limitations on the installment of solar power systems, which can decrease the subsidy amount fir fallow lands and increase farmers' income. Related explanations are detailed as follows.

We formulated a hypothetical case in which policies are modified to enable the installation of a solar power system on the 308 ha of fallow agricultural land in Hunei District; the produced economic benefits and total amount of reduced CO_2 emissions are analyzed as follows [60]:

1. For 308 ha (1 (1 = 10,000 m^2), the surface area that can be used to install a solar power system is calculated using 80%. Therefore, the surface area that can be used for installing a solar power system is 308⁎10,000⁎0.8 m^2 = 2464,000 m^2.
2. In 2015, the electricity purchase price offered to public sectors is approximately US$0.18 per unit (the price of 1 unit of power is equivalent to the price of 1 kW h of power used for 1 h).
3. A 1 kW solar panel requires 10 m^2 of space. The installation cost is approximately US$1,666 per such unit. Because solar panels decrease in power generation efficiency each year causing transmission loss, the actual efficiency of generated power accounted for 60% in this study. The solar panel used in this study with surface area of 2,464,000 m^2 has a capacity of 246.4 MW.
4. Between 1981 and 2010, the annual average sunshine hours in Kaohsiung were approximately 2212.2 h [61]. We considered the effect of sunshine angle on power generation; therefore, the annual average sunshine hours were calculated using 60% of the actual hours. Thus, the annual direct sunshine hours were 2212.2 h*60% = 1,327.23 h which was approximately 1327.23 h. To simplify this value, we used 1300 h to compute the annual average sunshine hours.
5. For every 1 kW h of power that is produced in Taiwan, 0.614 kg of CO_2 is emitted [60].
6. The investment cost, annual sale price of electricity, profit (recovery period), and CO_2 emission reduction in the hypothetical case are shown in Table 3.

The results shown in Table 3 indicate that for the installation of a solar power system on 308 ha of fallow land, the investment cost can be returned in approximately 12 yr. The annual average power generated is 192,192 MW h kW h and, on average, 196,676 metric tons of CO_2 emissions can be reduced each year. Fig. 5 shows the FLIS evaluation results of the case example before and after policy implementation. Among these cases, Case 1 received a score of 46, which is the FLIS assessment result on general communities. The evaluation result of the FLIS regarding the original Hunei community was 64.6, which is relatively average despite that it is higher than that of Case 1. If policies allow a solar power system to be installed on the 308 ha of fallow land in Hunei District, the evaluation result obtained is 80.4. This value indicates that a high effectiveness will be observed in the Hunei community if solar systems are installed. In addition, each year, per ha of farmland has an average income of 112,320 USD/yr from selling electricity, which is beneficial for raising farmers' income and reducing the amount spent on subsidies for fallow agricultural land.

4.4. Analysis and suggestions for the evaluated case study

Since Taiwan acceded to the World Trade Organization (WTO) in 2002, the profits made from agricultural productions have not met their costs because of the free trade policy for agricultural products and price dumping of imported agricultural products. Consequently, farmers would rather receive grants than engage in farming. According to the Agricultural Department of the Dahu

Table 3
Benefit analysis of installing a solar power system on fallow agricultural land (308 ha; 1 ha = 10,000 mm).

Parameter data (unit)	Installation surface area (m^2)	10-m^2 Solar panel cost (US$)	Annual average daylight (h/y)	Sale Price of 1 kW h/10 m^2 (US$)	CO_2 emission for 1 kW h of electricity (kg)
	2464,000 m^2	1666 USD	1300 h/year	0.18 USD/h	0.614 kg/kW h
Investment cost (US$)	2464,000 m^2⁎(1666 USD/10 m^2) = 410,502 (Thousand USD)				
Electricity sale price (USD/yr)	2464,000 m^2⁎(1 kW h/10 m^2)⁎0.6⁎0.18 (USD/kW h⁎h)⁎1300(h/year) = 34,594,560 (USD/year)				
Investment recovery period (yr)	410,502 (Thousand USD)/34,594,560 (USD/year) = 11.866 (year); approximately 12 yr.				
Annual reduction in CO_2 (t)	2464,000 m^2⁎(1 kW h/10 m^2⁎0.614⁎1300 (h/year)⁎0.75 (kg/kW h⁎h) = 196,676,480 (kg/year) = 204,204 (t/year)				
Note	A 10-m^2 solar panel can generate approximately 1 kW *of power*; 85% was used as the actual efficiency. Thus, the actual power generated by a 10-m^2 solar panel is 0.6 kW h The amount of CO_2 emissions (kg) reducible per year = the annual amount of power generated by the solar panel⁎0.614 kg				

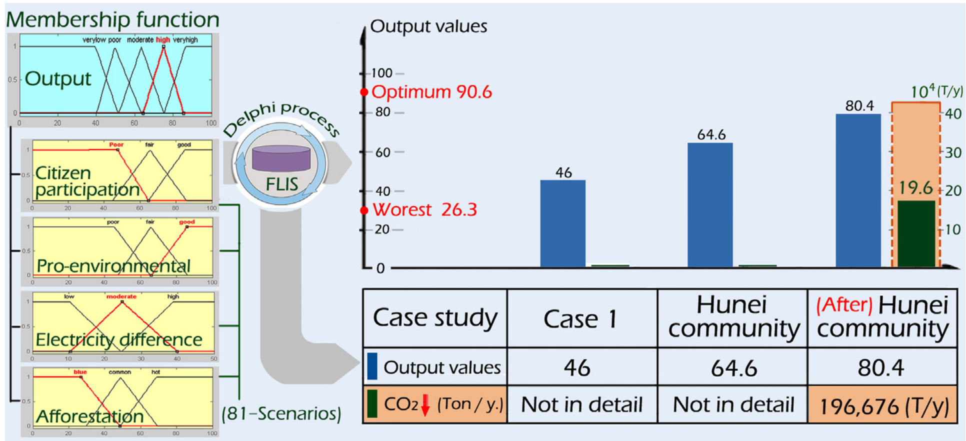

Fig. 5. FLIS evaluation results of the case study before and after policy implementation.

Table 4
The current status of solar power generation in the United States, China, Germany, Japan, Taiwan, and a case presented in this study.

Countries	Summary
United States	1. ISEGS (in the Californian Mojave Desert: 5.5 mi^2) [65] 2. Currently the world's largest solar power plant generating sufficient energy for providing electricity to 140,000 households. Its capacity is equivalent to 30% of the total solar power in the United States
China	1. Apple, SunPower, and Sichuan Shengtian New Energy Development Co., Ltd. (ground-mount) [66] 2. Two solar power plants with a total capacity of 40 MW are under construction. 3. The construction will be fully completed in the fourth quarter of 2015. The power plants are expected to produce 8000 MKVh of solar power annually.
Germany	1. Lieberose (ground-mount, with an area of 162 ha) [67] 2. Capacity: 53 MW 3. Annual production: 5300 MWh (equivalent to the annual consumption of 15,000 households) 4. Annual CO_2 emissions reduction: 35,000 tons
Japan	1. Kyocera Corporation and Century Tokyo Leasing Corporation (on a reservoir) [68] 2. Capacity: 2.9 MW 3. Annual production: 3300 MWh, supplying power to 920 general households
Taiwan	1. Subsidy policy: citizens and businesses (roof-mount) [64] 2. "Million Rooftop PVs" project 3. The installation of solar panels on the rooftops of one-third of residential buildings is expected to be completed by 2030 4. Capacity: 3100 MW by 2030 5. Annual production: 3,880,000 MWh by 2030
This study	1. Farmers (308 ha of fallow agricultural land are used in this case study) 2. Capacity: 246.4 MW 3. Annual production: 192,000 MWh

District Office, the current surface area of agricultural land in Taiwan is approximately 800,000 ha, of which 200,000 ha is fallow. Farmers receive subsidies of US$1,666 per hectare of fallow agricultural land annually. Moreover, 200,000 ha equals costs of approximately US$333.2 million, which is covered by taxpayers. Despite questioning the subsidies of fallow land by most people since 2002, an effective solution has yet to be determined. To solve the high CO_2 emission problem, the Taiwanese government promoted plain afforestation policies that allowed farmers to plant trees on agricultural land to absorb CO_2 from the atmosphere [62]. However, the effectiveness of this policy was unsatisfactory. Because the use of agricultural land in Taiwan is strictly controlled, agricultural land cannot be employed for other purposes even if it is fallow. Therefore, relevant policies must be amended to improve the lives of farmers and to develop solar energy on fallow land.

Zhao et al. [63] indicated that adjusting industrial structure, urban expansion control, and developing renewable energy are the main measures to achieving sustainable urban development. To sustainably reduce carbon emissions in cities, governments should consider the effectiveness of policy implementation when establishing energy-conservation policies in the future. The Taiwan Bureau of Energy, Ministry of Economic Affairs has initiated and subsidized the "Million Rooftop PVs" project, which is aimed at installing solar panels on the rooftops of one-third of residential buildings in Taiwan by 2030. Although this project provides a solution to conserving energy and reducing CO2 emissions in Taiwan, its goal can be achieved only at a slow rate. This study proposes to open fallow land for developing solar energy. Table 4 shows the current status of solar energy development in the United States, China, Germany, Japan, and Taiwan. The subsidies for producing solar energy in Taiwan are currently limited to installations on qualified buildings, a policy that differs substantially from that of other countries; thus, the current solar power policy in Taiwan is inefficient.

5. Conclusion

Taiwan's agricultural production lost its competitiveness since Taiwan joined the WTO in 2002. Thus far, fallow land has increased to over 200,000 ha in the past decade (excluding idled land without subsidies). If no effective policy to revitalize agriculture is established, fallow land would continue to increase. In this study, only 308 ha of a certain community's agricultural land, which accounted for only 0.15% of the total fallow land, was examined, and the immediate effect was superior to the currently promoted "Million Rooftop PVs" project. Taiwan's electronic industry is highly developed and comprises upstream, midstream, and downstream suppliers of solar energy materials and equipment. The electronic industry in Taiwan can develop solar energy; however, the industry is forced to transfer its technology to Japan because of the costs of land and other limitations of its use. According to this study, merely opening 15% of the fallow land for installing solar power systems can the goal of the "Million Rooftop PVs" project, which spans over 30 years, be achieved.

Although plain afforestation polices can facilitate the sequestration of CO_2 in the atmosphere, sufficient idle agricultural land is necessary for the policy to achieve a substantial effect. Our analysis of the case study on Taiwan's Hunei District verified that farmers' willingness to participate in plain afforestation is low. Three major reasons for this result were identified: (a) Minimal distinction was observed between the subsidies for plain afforestation and those for fallow agricultural land. (b) The policies failed to address the possession of carbon rights to future sequestrated CO_2 captured from forests on agricultural land and concerns pertaining to carbon emissions trading. (c) The majority of Taiwan's farmlands were divided as a result of inheritance or trade. Thus, numerous farmers own only a small area of farmland, which would cause root growth into neighboring lands when afforestation is implemented. To effectively promote plain afforestation policies, intensive farming-based management and operation should be devised, and a policy that addresses carbon rights and carbon trading concerns should be planned. Consequently, the goal of enhancing policy effectiveness and efficiently implementing policies that promote the reduction of CO_2 emissions can be achieved.

Regarding the policies on solar power systems, this study demonstrated that Taiwan possesses substantial experience in community development. Factors such as community citizen participation and proenvironmental behaviors are beneficial to promoting the use of solar power systems in communities. In addition, a comprehensive upstream and downstream supply chain of solar panel manufactures is available in Taiwan and the annual average sunshine hours are 900–1300 h. Taiwan's economic transition has resulted in a considerable amount of fallow agricultural land. Therefore, implementing solar power-related policies in Taiwan will be highly effective. Based on the analysis results of the case study (Table 3), flexible and practical policies can not only enhance the efficiency and effectiveness of policy promotions, but also facilitate the identification of favorable supporting policies. For instance, policies for solar power installation on agricultural lands, for financing equipment investments, and for encouraging citizens to obtain carbon rights that facilitate greenhouse gas reduction can be integrated to effectively enhance public participation and policy sustainability. Finally, the model established in this study can be used to investigate the core problems related to the aforementioned policies and, thus, serve as a valuable reference for policy management departments.

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