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A Hybrid Approach Using Fuzzy AHP-TOPSIS Assessing Environmental Conflicts in the Titan Mining Industry along Central Coast Vietnam

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Received: 1 July 2019; Accepted: 18 July 2019; Published: 22 July 2019

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Abstract: Environmental conflict management gains significance in rational use of natural resources, ecosystem preservation and environmental planning for mineral mines. In Central Coast Vietnam, titan mines are subject to conflicting use and management decisions. The paper deals with an empirical research on applying a combination of the fuzzy Analytic Hierarchy Process (AHP) and the fuzzy Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) to measure environmental conflicts emerging as a result of titan mining in Vietnam. The methodology used in the paper combines the fuzzy AHP and the fuzzy TOPSIS to rank environmental conflicts and propose conflict prevention solutions in the titan mining industry of Ky Khang coastal commune (Ky Anh district, Central Coast Vietnam). Data was collected by using a questionnaire with 15 locals, 8 communal authorities, 2 district authorities, and 12 scientific experts on titan mining, environmental geology, and sustainability management. The result shows that, titan mining conflicts with the eight criteria of economic sectors at five alternative sites including beach, protected forest, agricultural area, settlement area, and industrial area. The conflicts between titan mining and forestry, agriculture, settlements, fishing and aquaculture are highly valued. The beach area shows most environmental conflict as a result of titan mining, followed by the agricultural area and settlement area. Based on the empirical findings, legal and procedural tools such as environmental impact assessments, strategic environmental assessments, integrated coastal zone management, marine spatial planning, and multi-planning integration advancing environmental management for titan mines in Vietnam are suggested.

Keywords: fuzzy AHP; fuzzy TOPSIS; titan mining; environmental conflict; Ky Anh; Vung Ang Economic Zone; Central Coast Vietnam

1. Introduction

Environmental conflicts, which originate as a result of environmental pollutions, resource use competition, and social conflicts, emerge when stakeholders take part in activities with contradictory interests, values, power, perceptions, and goals. Environmental conflicts cover different issues: Biodiversity conflicts [1–3], coastal zone conflicts [4–7], air pollution conflicts [8], land use conflicts [9,10], and water conflicts [11–14]. Most recently, environmental conflict is considered in relation to economic, development and social issues in the context of global climate change [15,16]. Worldwide, environmental conflicts challenge the economic security at both local, regional, national, and global scales [17,18]. Particularly in coastal zones, environmental conflicts occur as a result of the negative impacts of environmental pollution by sectors and activities. The most sensitive and conflictive sectors are mining, land use, shrimp farming, fossil fuels, biomass, and hydropower plants [18–20]. In the mineral mining industry, environmental conflicts result from inadequate public information, stereotypes in decision making, the potential of problems to disappear, technical solutions, and archaic techniques [21]. Effective tools such as integrated coastal zone management (ICZM), marine spatial planning (MSP), and multi-planning integration advancing coastal zone management are recommended to address environmental conflicts in coastal areas [22–24].

The potential of mathematical models in environmental conflict analysis is internationally recognized. The General Algebraic Modelling System (GAMS) is applied to analyze coastal land conflicts [25]. The Analytic Network Process (ANP) is combined with the Driver-Pressure-State-Impact-Response (DPSIR) model to address conflict [26]. Applying multiple-criteria decision-making (MCDM) to environmental decision-making allows defining optimal specifications to be applied to environmental conflicts. For example, the Analytic Hierarchy Process (AHP) is used to evaluate open pit coal production [27]. Intuitionistic fuzzy set (IF) and AHP is combined to select best drilling mud for drilling operations [28]. Fuzzy Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) is applied to select best compromise alternatives for water resource use [29]. AHP is integrated with Fuzzy TOPSIS to assess the conservation priority for six alternatives sites of a coastal area [30]. Integrating Delphi and Fuzzy AHP-TOPSIS allow weighting criteria and prioritizing heat stress indices in surface mining. In this case, Delphi extracts criteria based on the advantages of occupational health experts and selected criteria are weighed using the most suitable heat stress index based on Fuzzy TOPSIS [31].

This paper aims applying a hybrid approach using a combination of fuzzy AHP and fuzzy TOPSIS to measure environmental conflicts emerging as a result of titan mining along the Central Coast Vietnam. This area has an abundant potential for mineral mining of titanium and zircon [32]. Four key titan mining sites currently exist in this area: the Ky Khang mine (Ha Tinh province), Nhat Le (Quang Binh), De Gi (Binh Dinh), and Nhum (Binh Thuan) [33]. Titan mining contributes significantly to the local economy; however, it causes environmental problems. Most of titan mining sites are open pits with environmental pollution, degraded mangrove ecosystems, negatively affected human health and local livelihoods. Also, land use and land cover changes (LULCC) are evidenced: Vegetation cover is cutoff, and is replaced by temporary transportation infrastructure for large vehicles such as excavators, containers, and trucks. The environmental problems related to mining activities causing conflicts between stakeholders as well as conflicts between the titan mining industry with agriculture, forestry, infrastructure, and heritage sites are intense and result in major social conflicts.

The rest of the paper is organized as follows: Section 2 introduces a combination of the fuzzy AHP and fuzzy TOPSIS methodology; the results for a case analysis are indicated in Section 3 including ranking environmental conflicts and proposing conflict prevention solutions; finally, conclusion and recommendation are drawn in Section 4.

2. Methodology

2.1. Study Area

Ky Khang is one of seven coastal communes of the Ky Anh district (Ha Tinh province, Vietnam), located in the northeast of the district (Figure 1). The commune has a coastline of approximately 5 km, a total area of 26.3 square kilometers, and a total population of about 7000 people [34]. While Ky Khang contains one of four key titan mines along the Central Coast, the commune also is a key agricultural area in the Ha Tinh province with 728 hectares of agricultural land area [35]. The local economy mainly relies on vegetable and rice crop production, aquaculture, and titan mining. The titan mine covers 759 hectares. The mining permit is issued by the Ha Tinh Mineral and Trading Corporation since 1997 [33]. Ky Khang borders the Vung Ang Economic Zone (EZ), which is one of the seven key coastal economic zones prioritized by the Vietnamese Government for the period 2016–2020. Over 350 enterprises operate in the Vung Ang EZ, targeting steel smelting, thermal power plants, electricity generation, and deep-water port services. This industrial package puts fishermen's livelihood and sea water quality under pressure. An environmental incident rises from Vung Ang EZ in 2016, attracting both domestic and international attention, is the "Formosa environmental disaster". This problem came from a large source of toxic waste produced by the Formosa Ha Tinh Steel Corporation. The disaster, which spread over the coast of Central Vietnam including the Ha Tinh, Quang Binh, Quang Tri and Thua Thien-Hue provinces, killed sea fish, shrimp, clam, and coral reefs [36,37]. Moreover, in the Ky Anh district, Ky Khang is the commune most seriously damaged by natural disasters such as tropical storms and coastline erosion [35]. Combined natural disasters, environmental disasters and environmental pollutions raise environmental conflicts between the titan mining industry and the other economic sectors (agriculture, aquaculture, fishing, tourism, and forestry).

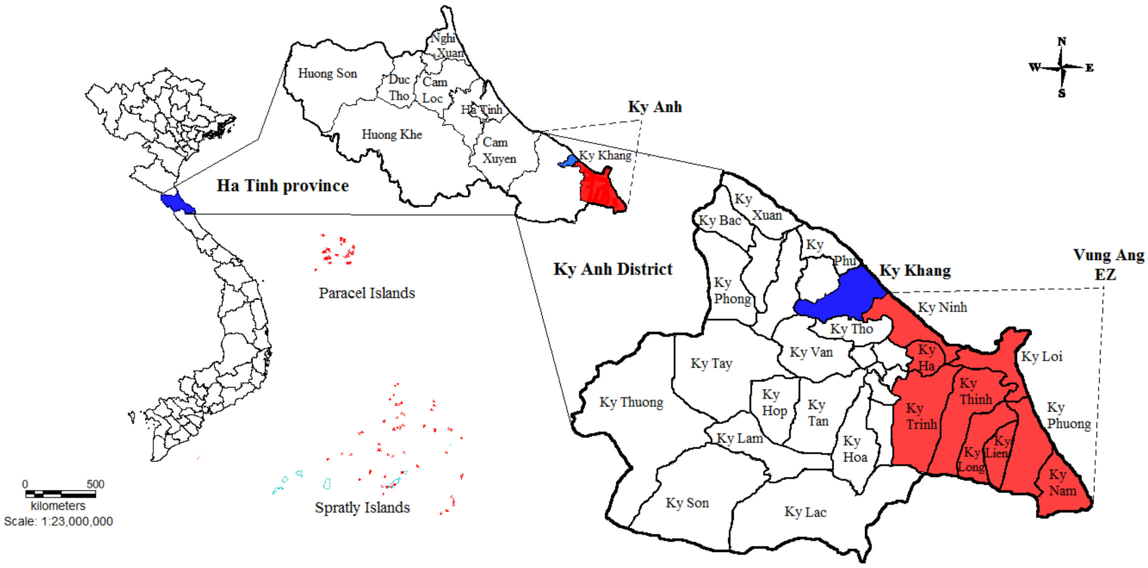

Figure 1. Location of Ky Khang and Vung Ang EZ in the Ky Anh district (Ha Tinh, Vietnam).

2.2. *A Combination of Fuzzy AHP and Fuzzy TOPSIS*

2.2.1. Fuzzy AHP

The AHP is one of the most common Multi-Criteria Decision Making (MCDM) instruments to deal with quantifiable and intangible criteria, which reflect the relative importance of the alternatives based on constructing a pair-wise comparison matrix [38–40]. Fuzzy AHP was developed to determine the weights of multiple criteria [41]. While the traditional AHP faces limitations on information imprecision and vagueness for decision making, the fuzzy AHP solves these problems of imprecision using linguistic variables, which are used to represent the relative importance between each pair of criteria [42]. Five linguistic variables corresponding with their fuzzy numbers are presented in Table 1.

Table 1. Linguistic variables and fuzzy numbers [42].

Linguistic Variables	Fuzzy Numbers
Extreme importance (EXI)	(7; 9; 9)
Very strong importance (VSI)	(5; 7; 9)
Strong importance (SI)	(3; 5; 7)
Moderate importance (MI)	(1; 3; 5)
Equal importance (EI)	(1; 1; 1)

The process of Fuzzy AHP is structured in four steps [41]. Let $X = \{x_1, x_2 \ldots\ x_n\}$ be an object set and $G = \{g_1, g_2 \ldots\ g_m\}$ be a goal set. According to the extent analysis method [42], each object x_i is evaluated by performing an extent analysis for each goal, g_i. Therefore, m extent analysis values for each object can be obtained by using following notation: $M_{gi}{}^1, M_{gi}{}^2 \ldots M_{gi}{}^m$.

Step 1. The fuzzy synthetic extent value (S_i) with respect to the ith criterion is calculated in the following way:

$$S_i = \sum_{j=1}^{m} M_{g_i}^j \otimes \left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^j\right]^{-1} \quad (1)$$

With:

$$\sum_{j=1}^{m} M_{g_i}^j = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j\right), \sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^j = \left(\sum_{i=1}^{n} l_i, \sum_{i=1}^{n} m_i, \sum_{i=1}^{n} u_i\right),$$

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^j\right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i}\right)$$

where: l is the lower limit value; m is the most promising value; u is the upper limit value.

Step 2. The degree of possibility of $S_2(l_2, m_2, u_2) \geq S_1(l_1, m_1, u_1)$ is defined as:

$$V(S_1 \geq S_2) = \sup_{y \geq x}\left[\min\left(\mu_{M_1}(x), \mu_{M_2}(y)\right)\right] \quad (2)$$

where: x and y are the values on the axis of membership function of each criterion.

$$\mathrm{V}(S_1 \geq S_2) = \left\{\begin{array}{c} 1\ if\ m_1 > m_2 \\ 0\ if\ l_2 > u_1 \\ (l_2 - u_1)/(l_2 - u_1 + m_1 - m_2)\ otherwise \end{array}\right\} \quad (3)$$

Step 3. The possibility that a convex fuzzy number S is greater than k convex fuzzy numbers $S_i \left(i = \overline{1,k}\right)$ is defined as:

$$V(S \geq S_1, S_2, \ldots S_n) = V[(S \geq S_1), (S \geq S_2), \ldots, (S \geq S_n)] = \min V(S \geq S_i); \left(i = \overline{1,n}\right) \quad (4)$$

Step 4. Calculate the normalized weight vectors W′

$$W\prime = (d\prime(A_1), d\prime(A_2), \ldots, d\prime(A_n))^T \quad (5)$$

where: $d\prime(A_i) = \min V(S_i \geq S_t)$; $i = \overline{1,n}$; $t = \overline{1,n}$; and $i \neq t$

The normalized weight vectors W' is generated according to the pairwise comparisons of the criteria of the involved respondents. As far as the important the corresponding criterion is concerned, the higher the weight, the more important the corresponding criterion.

2.2.2. Fuzzy TOPSIS

The fuzzy TOPSIS was developed based on the attribute of the shortest and the longest distance from the positive ideal solution and the negative ideal solution [43]. The best alternative has the shortest distance to the positive ideal solution, and the longest distance from the negative ideal solution. The classical TOPSIS assumes that individual preferences are assigned with crisp values. However, one should consider uncertainty and imprecision in the environmental practices. Fuzzy TOPSIS is more feasible because it incorporates the fuzzy environment uncertainty in decision making.

The process of Fuzzy TOPSIS used in this study follows six steps [43].

Step 1. Calculate the aggregate fuzzy ratings for the solutions.

If $x_{ijt} = \left(e_{ijt}, f_{ijt}, g_{ijt}\right)$, $i = \overline{1,n}$, $j = \overline{1,m}$, $t = \overline{1,l}$ is the fuzzy aggregated rating of solution A_i, by decision maker D_t, with respect to each criteria C_j. The fuzzy aggregated rating $x_{ij} = \left(e_{ij}, f_{ij}, g_{ij}\right)$, is given by:

$$x_{ij} = \frac{1}{l} \otimes \left(x_{ij1} \oplus x_{ij2} \oplus \ldots \oplus x_{ijt} \oplus \ldots \oplus x_{ijl}\right) \tag{6}$$

where: $e_{ij} = \frac{1}{l}\sum_{t=1}^{l} e_{ijt}$, $f_{ij} = \frac{1}{l}\sum_{t=1}^{l} f_{ijt}$, and $g_{ij} = \frac{1}{l}\sum_{t=1}^{l} g_{ijt}$

Step 2. Calculate normalized fuzzy decision matrix.

Data is normalized to obtain a comparable scale using linear scale transformation. Suppose $r_{ij} = \left(a_{ij}, b_{ij}, c_{ij}\right)$ is the mean of alternative solutions i for criterion j. The normalized value x_{ij} can be calculated as:

$$x_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*}\right), j \in B \tag{7}$$

$$x_{ij} = \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}}\right), j \in C \tag{8}$$

where: $a_j^- = \min_i a_{ij}$, $c_j^* = \max_i c_{ij}$, $i = \overline{1,n}$, $j = \overline{1,m}$

Step 3. Construct the weighted normalized matrix.

The weighted-normalized value G_i is given by multiplying the normalized value x_{ij} of the decision matrix by the weight assigned to the criterion j.

$$G_i = x_{ij} \otimes w_j,\ i = \overline{1,n},\ j = \overline{1,m} \tag{9}$$

Step 4. Determine the fuzzy positive ideal and negative ideal solutions.

The positive ideal solution maximizes the benefit criteria and minimizes the cost criteria; whereas the negative ideal solution maximizes the cost criteria and minimizes the benefit criteria. The positive and negative ideal solutions are found out in the following way:

$$\mathrm{A}^+ = \left[\mathrm{A_j}^+\right]_{1j} = \left[\mathrm{v_{jmax}}\right]_{1j} \tag{10}$$

$$\mathrm{A}^- = \left[\mathrm{A_j}^-\right]_{1j} = \left[\mathrm{v_{jmin}}\right]_{1j},\ j = \overline{1,m} \tag{11}$$

Calculate the distance/separation from:
* Positive Ideal Separation (d^+):

$$d_i^+ = \sqrt{\sum_{i=1}^{n} \left(G_i - A^+\right)^2} \tag{12}$$

* Negative Ideal Separation (d^-):

$$d_i^- = \sqrt{\sum_{i=1}^{n} \left(G_i - A^-\right)^2} \tag{13}$$

where: d_i^+ and d_i^- are the distances of each alternative A_i from positive and negative ideal solutions.

Step 5. Calculate the Relative closeness coefficient (CC) to the ideal solution.

$$CC_i = \frac{d_i^-}{d_i^+ + d_i^-};\ 0 < CC_i < 1;\ i = \overline{1, n} \quad (14)$$

$CC_i = 1$ if $A_i = A^+$; $CC_i = 0$ if $A_i = A^-$

Step 6. Rank alternatives

The rank of considered alternatives can be decided, according to the descending order of closeness coefficient (CC). When the closeness coefficient is closer to 1 the corresponding solution is the optimal one.

2.2.3. Data Collection

The hybrid approach using Fuzzy AHP-TOPSIS provides a quantitative logical and systematic framework to identify critical issues, attach relative priorities to those issues, choose best compromise alternatives, and facilitate communication towards general acceptance [29,44]. This paper considered 8 criteria, representing the main economic sectors of Ky Khang, and 5 different alternative sites, representing conflict hotspots. Fuzzy AHP is combined with Fuzzy TOPSIS to estimate weights of the criteria and to prioritize alternative sites according to the intensity of environmental conflicts. Data on weighting sector criteria and prioritizing alternatives sites in the Ky Khang commune are collected using a questionnaire with 15 locals, 8 communal authorities, 2 district authorities, and 12 scientific experts on titan mining, environmental geology, and sustainability. Data were collected during a field trip in March 2018. All respondents inhabit in the study area (locals and authorities) or are knowledgeable about the study area and about scientific problems related to titan mining. The questionnaire allows inventory the opinion of the respondents on the pair wise comparison matrix by using Likert 5 scale, indicating five pre-coded responses with the neutral point (point 3) being neither agree nor disagree. Respondents took about 30 min to complete the questionnaire.

3. Results

3.1. Determining Criteria of Sectors and Alternative Sites

In the considered case study, in the area of Ky Khang, couples of environmental conflicts between the titan mining industry and other economic sectors are found across conflict hotspots. These couples are indicated by criteria in Fuzzy AHP model. Conflict hotspots are defined by alternative sites in Fuzzy TOPSIS model. It is supposed that conflicts occur based on eight criteria (C_j) and are responsible for five alternatives sites (A_i). The eight criteria entail agriculture (C1), aquaculture (C2), fishing (C3), salt production (C4), tourism (C5), forestry (C6), settlement (C7), and industry (C8) (Figure 2). Five alternatives sites include the beach (A1), a protected forest area (A2), an agricultural area (A3), a settlement area (A4), and an industrial area (A5). Since titan mining is popular along the coast, it conflicts with the eight criteria of sectors at the five alternatives sites. Impacts concern land use and competition with other sectors, use of fresh water during mining process, and emission of pollutants to air, soil and sediments. Consequently, mining destroys protection forests near the coast, reduces both surface and underground water quality and quantity, increases salinity, and destroys beaches.

In beach area (A1), titan mining impacts aquaculture, fishing, and tourism negatively by destroying beaches, eroding the coastline, and changing landscapes visually. Parts of titanium dumps were filled by clastic sedimentary rocks. Sand dunes have changed leaving hollow pits and deep holes. New sandy dunes of 6–10 m have appeared, consisting of silky sand, and being mobile by the wind. Mining leaves disposal sites and reservoirs over large areas.

Building infrastructure in a protected forest (A2) needs cutting trees, takes aquaculture ponds and mangrove farms, and kills sea fishes as a results of environmental pollution.

Titan mining takes arable land and decreases crop yields in agricultural area (A3). It causes competition spatially between titan mining and areas for salt production and decreases the quality and the yields of the salt due to pollutants. Crops on the fields and houses are flooded by sand. Mining damages soil surface: A large amount of soil and rocks are removed from the ground and leave holes behind. Surface water is polluted by overflowing acid effects, toxic pollutants and water-soluble solids release from deposits and sediments. Mine waste discharges sediments in rivers and streams.

Also, titan mining affects negatively buildings, heritage sites, and tourism infrastructures in the settlement area (A4). In industrial area (A5), titan mining and other industrial activities emit pollutants in the environment, which stress both locals and tourists. Mining machines, pumps and transport cause noise, which directly affects residents and tourists.

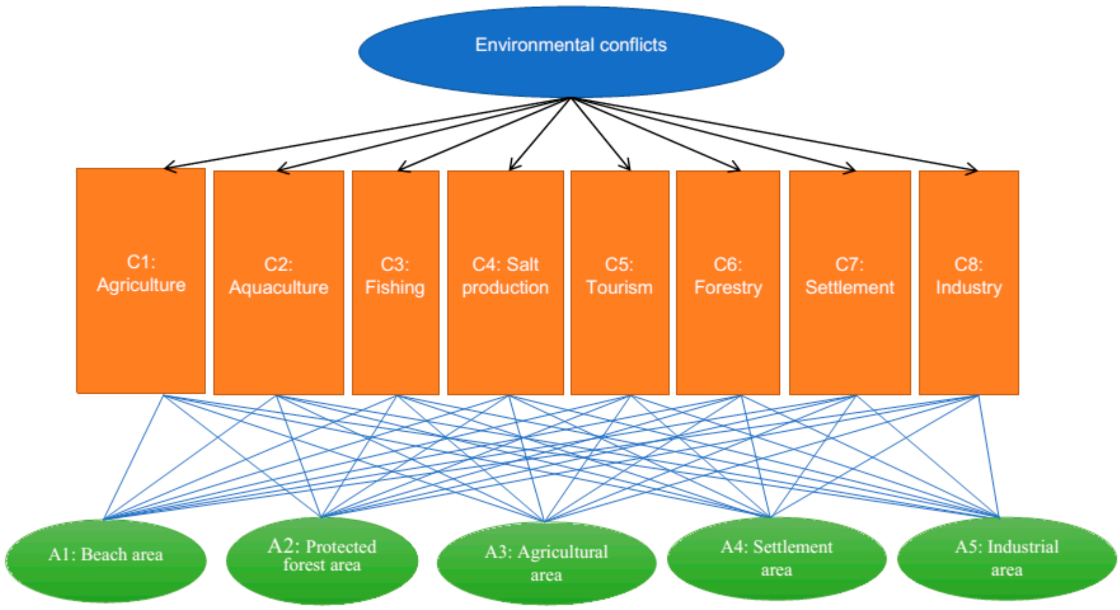

Figure 2. Decision tree on environmental conflicts with 8 criteria of sectors (C_j) in 5 alternative sites (A_i).

3.2. Levels of Environmental Conflict and Priority Alternative Sites to Implement Conflict Prevention Solutions

3.2.1. Weighting Criteria

The opinions of the different involved respondents (37 in total), collected by means of a questionnaire, were used to generate the pairwise comparisons of the criteria and determine the final importance levels represented in the decision matrices. The respondents determine the level of environmental conflicts between the titan mining industry with other economic sectors for five alternative sites. The evaluation of 5 decision matrices on 8 criteria is presented in Table 2. For example, comparing C1 and C2, C1 is considered of "very strong importance" compared to C2 for DM1 (value in the 4th column and in the 2nd raw). Consequently, the reciprocal value is assigned when C2 is compared to C1 for the same DM (3rd column, 7th raw).

Equations (1) and (2) are used to calculate the levels of the comparison between two fuzzy numbers based on the decision matrix. The relationship between a fuzzy number which is higher than the remaining fuzzy numbers, is calculated using Equations (3) and (4). Table 3 shows the results of priority weighting of the criteria based on the Equation (5). Forestry shows the highest score (0.131), which indicates titan mining has the most significant impacts on the forest plantations. Also, the conflicts between titan mining and agriculture, settlements, fishing and aquaculture are highly valued: agriculture shows the second weight score (0.129), followed by settlements (0.128), fishing (0.127), and aquaculture (0.125).

Table 2. Evaluation of decision matrix (DM).

Criteria of Sectors	Decision Matrices	C1	C2	C3	C4	C5	C6	C7	C8
C1 (Agriculture)	DM1	EI	VSI	EI	MI	MI	SI	EXI	SI
	DM2	EI	SI	MI	VSI	VSI	(MI)	(SI)	SI
	DM3	EI	SI	EI	SI	EXI	SI	SI	VSI
	DM4	EI	(MI)	MI	SI	SI	(SI)	(SI)	(MI)
	DM5	EI	MI	EI	SI	VSI	(SI)	(MI)	(MI)
C2 (Aquaculture)	DM1	(VSI)	EI	(SI)	(MI)	EI	EI	VSI	MI
	DM2	(SI)	EI	(MI)	SI	SI	(SI)	(VSI)	MI
	DM3	(SI)	EI	(MI)	MI	EXI	EI	SI	VSI
	DM4	MI	EI	SI	VSI	SI	(SI)	(SI)	(MI)
	DM5	(MI)	EI	(MI)	MI	MI	(VSI)	(VSI)	(SI)
C3 (Fishing)	DM1	SI	EI	EI	EI	MI	SI	EXI	VSI
	DM2	MI	(MI)	EI	SI	VSI	(SI)	(SI)	SI
	DM3	MI	EI	EI	SI	SI	MI	SI	VSI
	DM4	(SI)	(MI)	EI	MI	EI	(VSI)	(SI)	(SI)
	DM5	MI	EI	EI	MI	SI	(SI)	(SI)	(MI)
C4 (Salt production)	DM1	MI	(MI)	EI	EI	MI	SI	EXI	VSI
	DM2	(SI)	(VSI)	(SI)	EI	MI	(VSI)	(EXI)	(MI)
	DM3	(MI)	(SI)	(SI)	EI	SI	(SI)	EI	MI
	DM4	(VSI)	(SI)	(MI)	EI	(MI)	(EXI)	(VSI)	(SI)
	DM5	(MI)	(SI)	(MI)	EI	MI	(EXI)	(VSI)	(SI)
C5 (Tourism)	DM1	EI	(MI)	(MI)	(MI)	EI	MI	VSI	SI
	DM2	(SI)	(VSI)	(VSI)	(MI)	EI	(EXI)	(EXI)	(SI)
	DM3	(EXI)	(EXI)	(SI)	(SI)	EI	(VSI)	(SI)	(MI)
	DM4	(SI)	(SI)	EI	MI	EI	(EXI)	(VSI)	(SI)
	DM5	(MI)	(VSI)	(SI)	(MI)	EI	(EXI)	(EXI)	(VSI)
C6 (Forestry)	DM1	EI	(SI)	(SI)	(SI)	(MI)	EI	SI	MI
	DM2	SI	MI	SI	VSI	EXI	EI	(MI)	VSI
	DM3	EI	(SI)	(MI)	SI	VSI	EI	SI	SI
	DM4	SI	SI	VSI	EXI	EXI	EI	MI	MI
	DM5	VSI	SI	SI	EXI	EXI	EI	MI	SI
C7 (Settlement)	DM1	(VSI)	(EXI)	(EXI)	(EXI)	(VSI)	(SI)	EI	(MI)
	DM2	VSI	SI	SI	EXI	EXI	MI	EI	EXI
	DM3	(SI)	(SI)	(SI)	EI	SI	(SI)	EI	EI
	DM4	SI	SI	SI	VSI	VSI	(MI)	EI	EI
	DM5	VSI	MI	SI	VSI	EXI	(MI)	EI	EI
C8 (Industry)	DM1	(MI)	(SI)	(VSI)	(VSI)	(SI)	(MI)	MI	EI
	DM2	(MI)	(SI)	(SI)	MI	SI	(VSI)	(EXI)	EI
	DM3	(VSI)	(VSI)	(VSI)	(MI)	MI	(SI)	EI	EI
	DM4	MI	MI	SI	SI	SI	(MI)	EI	EI
	DM5	SI	MI	MI	SI	VSI	(SI)	EI	EI

Where: EXI = extreme importance; VSI = very strong importance; SI = strong importance; MI = moderate importance; EI = equal importance; the terms in brackets "()" indicate the reciprocal of them.

Table 3. Priority weighting matrix.

V	S(C1)	S(C2)	S(C3)	S(C4)	S(C5)	S(C6)	S(C7)	S(C8)	d′	Weight (w)	Ranking
S(C1)≥	-	0.97	0.99	1.00	1.00	0.96	0.98	1.00	0.96	0.129	2
S(C2)≥	1.00	-	1.00	1.00	1.00	0.99	1.00	1.00	0.99	0.125	5
S(C3)≥	1.00	0.98	-	1.00	1.00	0.97	0.99	1.00	0.97	0.127	4
S(C4)≥	0.98	0.94	0.96	-	1.00	0.93	0.95	0.99	0.93	0.121	7
S(C5)≥	0.95	0.91	0.93	0.98	-	0.89	0.92	0.96	0.89	0.116	8
S(C6)≥	1.00	1.00	1.00	1.00	1.00	-	1.00	1.00	1.00	0.131	1
S(C7)≥	1.00	0.99	1.00	1.00	1.00	0.98	-	1.00	0.98	0.128	3
S(C8)≥	0.99	0.96	0.98	1.00	1.00	0.94	0.96	-	0.94	0.123	6

Where: C1 = Agriculture; C2 = Aquaculture; C3 = Fishing; C4 = Salt production; C5 = Tourism; C6 = Forestry; C7 = Settlement; C8 = Industry.

3.2.2. Final Ranking of the Alternatives

The opinions of the respondents are provided for eight criteria and potential options in five alternative sites. The linguistic variables are converted into triangular fuzzy numbers: S = (VL, L, M, H, VH), VL (Very low) = (0, 0, 0.2), L (Low) = (0, 0.2, 0.4), M (Medium) = (0.2, 0.4, 0.6), H (High) = (0.4, 0.6, 0.8), VH (Very high) = (0.6, 0.8, 1.0) (Table 4). Formula (6) allows evaluating the five decision matrices on the level of conflict. Formulas (7) and (8) are used to standardize the criteria. Formula (9) allows determining the value of the ratio weighted normalized and the distances of each alternative to the positive and negative ideal points. The values of separation from positive solution (d^+) and Separation from negative solution (d^-) are calculated by using Formulas (10)–(13). Values of closeness coefficient (CC) are calculated from values of d^+ and d^- by means of formula (14). The weighted normalized decision matrices indicate the highest and the lowest weighted values belong to forestry and tourism respectively ($w_{(C6)}$ = 0.131; $w_{(C5)}$ = 0.116) (Table 5).

Table 4. Evaluation of decision matrix and average values of five alternative sites.

Alternative Sites	Decision Matrices	C1	C2	C3	C4	C5	C6	C7	C8
A1 (Beach area)	DM1	L	VH	H	H	M	M	L	VL
	DM2	VL	VH	VH	VH	H	M	VL	L
	DM3	VL	VH	VH	H	M	VH	VL	L
	DM4	VL	L	L	M	VL	M	M	VL
	DM5	M	VH	VH	VH	VH	H	M	H
A2 (Protected forest area)	DM1	L	M	H	L	L	M	VL	VL
	DM2	L	H	L	VL	H	VH	L	VL
	DM3	L	VL	VL	L	M	VH	M	M
	DM4	L	M	L	M	VL	VH	M	L
	DM5	L	M	M	VL	H	VH	VL	VL
A3 (Agricultural area)	DM1	M	M	L	M	VL	L	VL	L
	DM2	VH	M	L	M	M	M	VH	L
	DM3	VH	M	VL	L	VL	L	H	M
	DM4	VH	M	M	H	L	M	L	L
	DM5	VH	H	H	VL	M	L	L	L
A4 (Settlement area)	DM1	VL	L	M	VL	L	L	H	L
	DM2	M	VL	VL	M	M	H	VH	M
	DM3	M	L	L	M	L	M	VH	M
	DM4	M	L	M	L	L	L	VH	M
	DM5	H	VL	VL	M	L	M	VH	M
A5 (Industrial area)	DM1	M	M	VH	M	M	VH	VL	VL
	DM2	VL	VL	VL	VL	VL	L	VH	VH
	DM3	VL	VL	M	L	L	M	VH	VH
	DM4	L	VL	M	M	L	VL	M	VH
	DM5	VL	L	L	H	VL	VL	H	VH

Where: DM1.5 is decision matrices; C1 = Agriculture; C2 = Aquaculture; C3 = Fishing; C4 = Salt production; C5 = Tourism; C6 = Forestry; C7 = Settlement; C8 = Industry.

Table 5. Weighted normalized decision matrices.

Criteria of Sectors	A1 (Beach Area)			A2 (Protected Forest Area)			A3 (Agricultural Area)			A4 (Settlement Area)			A5 (Industrial Area)			Weight (w)
C1	0.04	0.13	0.35	0.00	0.22	0.43	0.57	0.78	1.00	0.22	0.39	0.61	0.04	0.13	0.35	0.129
C2	0.55	0.77	1.00	0.23	0.41	0.64	0.27	0.50	0.73	0.00	0.14	0.36	0.05	0.14	0.36	0.125
C3	0.52	0.76	1.00	0.14	0.33	0.57	0.14	0.33	0.57	0.10	0.24	0.48	0.24	0.43	0.67	0.127
C4	0.52	0.76	1.00	0.05	0.19	0.43	0.19	0.38	0.62	0.14	0.33	0.57	0.19	0.38	0.62	0.121
C5	0.44	0.69	1.00	0.31	0.56	0.88	0.13	0.31	0.63	0.06	0.38	0.69	0.06	0.25	0.56	0.116
C6	0.35	0.57	0.78	0.57	0.78	1.00	0.09	0.30	0.52	0.17	0.39	0.61	0.17	0.30	0.52	0.131
C7	0.08	0.21	0.42	0.08	0.21	0.42	0.21	0.38	0.58	0.58	0.79	1.00	0.38	0.54	0.75	0.128
C8	0.09	0.22	0.43	0.04	0.13	0.35	0.04	0.26	0.48	0.17	0.39	0.61	0.52	0.70	0.91	0.123

The ideal solution comprises all of best values possible of criteria, whereas the negative ideal solution consists of all worst value possible of criteria. Calculated separation from negative ideal solution (d^-) indicates beach area (A1), agricultural area (A3) and settlement area (A4) have the highest scores (0.56, 0.46, and 0.44 respectively); whereas they get lowest scores for separation from positive ideal solution (d^+) (7.47, 7.58, and 7.60 respectively). According to closeness coefficient, the beach area (A1) shows most environmental conflict as a result of titan mining ($CC_{(A1)}$ = 0.0703), followed by the agricultural area ($CC_{(A3)}$ = 0.0575), and settlement area ($CC_{(A4)}$ = 0.0549) (Table 6). Since the worst alternative sites have farthest distance from the ideal solution and the shortest distance from the negative ideal solution, it is necessary to pay more attention on environmental conflicts in these alternative sites.

Table 6. Final ranking alternatives.

(a) Separation from Positive Ideal Solution (d^+)									
Alternative Sites	**Criteria of Sectors**								d^+
	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	
A1 (Beach area)	0.98	0.90	0.90	0.90	0.92	0.93	0.97	0.97	7.47
A2 (Protected forest area)	0.97	0.95	0.96	0.97	0.93	0.90	0.97	0.98	7.62
A3 (Agricultural area)	0.90	0.94	0.96	0.95	0.96	0.96	0.95	0.97	7.58
A4 (Settlement area)	0.95	0.98	0.97	0.96	0.96	0.95	0.90	0.95	7.60
A5 (Industrial area)	0.98	0.98	0.94	0.95	0.97	0.96	0.93	0.91	7.61
(b) Separation from Negative Ideal Solution (d^-)									
Alternative Sites	**Criteria of Sectors**								d^-
	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	
A1 (Beach area)	0.03	0.10	0.10	0.10	0.09	0.08	0.04	0.04	0.56
A2 (Protected forest area)	0.04	0.06	0.05	0.03	0.07	0.10	0.04	0.03	0.42
A3 (Agricultural area)	0.10	0.07	0.05	0.05	0.05	0.05	0.05	0.04	0.46
A4 (Settlement area)	0.05	0.03	0.04	0.05	0.05	0.06	0.10	0.06	0.44
A5 (Industrial area)	0.03	0.03	0.06	0.05	0.04	0.05	0.07	0.10	0.43

Where: C1 = Agriculture; C2 = Aquaculture; C3 = Fishing; C4 = Salt production; C5 = Tourism; C6 = Forestry; C7 = Settlement; C8 = Industry; Closeness coefficient (CC): $CC_{(A1)}$ = 0.0703; $CC_{(A2)}$ = 0.0521; $CC_{(A3)}$ = 0.0575; $CC_{(A4)}$ = 0.0549; $CC_{(A5)}$ = 0.0534; Final ranking of alternatives: Level 1 (A1); level 2 (A3); level 3 (A4); level 4 (A5); level 5 (A2).

4. Conclusions

The paper presents empirical research on environmental conflicts emerging as a result of recent development of titan mining industry along the Central Coast Vietnam. The considered Ky Khang coastal area is located in an economically fast developing area. The resources are subject to conflicting use and management decisions. Coastal zone conflicts are fueled by a combination of other conflicts, which demonstrates the unique character of environmental conflicts along coast. Titan mining is a major problem resulting in most serious impacts on the ecosystems and the environment along coasts. Mining destroys protected forest areas, erodes coastlines, affects the ground water level, increases salinity and modifies natural landscapes. The risk of environmental conflicts between socio-economic groups along the coast increases during the mineral exploitation period.

A combination of Fuzzy AHP and Fuzzy TOPSIS shows its advantages in connecting decision makers with conflicting objectives to reach consensus. The systematic and logical approach is a strength since it allows solving complex multi-person and multi-criteria decision problems by weighting environmental conflicts and relating them to alternative sites. The model contributes to the group decision-making process taking into account the affected sites surrounding the titan mines. Determining the intensity of the conflicts and the alternative sites in which titan mining occurs is imperative. According to the results of this study, titan mining affects most seriously the forests. Since only few forests are left along the coast, environmental conflicts are obvious for protected forests. The raising of beach tourism, agricultural production, and housing all demand more space and compete with titan mining. Therefore, it is necessary to pay more attention to solutions mitigating conflicts in these sites.

To the best of our knowledge, till now no previous study has identified the ranks of environmental conflicts and the priorities of conflict prevention solutions in the case of coastal areas of Vietnam. Therefore, the paper makes an attempt to discuss management implications for environmental conflicts in mineral mines for Vietnam. These environmental conflicts are at risk of escalation and intensification in case they are not managed well [44–46]. The findings of this study suggested decisions should use decision science in identifying priority of prevention solutions for each environmental conflict hotspot. In the titan mine of studied Ky Khang, key issues of environmental conflicts concern climate change, biodiversity, environmental air quality, forestry, fresh water, and land resources. Environmental conflicts raise in Ky Khang and in the Vung Ang EZ because of the limited land areas and freshwater resources. Surface water is salinized by the mine activities and useless for agri- and aquaculture. Air is polluted by smoke, toxic gases and dust from the mining activities and electricity generation. While agriculture, forestry, aquaculture, salt production, tourism, heritage preservation, and human health all are affected by titan mining, the couple of conflicts titan mining—forestry should be considered most carefully in the study area. Managing environmental conflicts pertains to the available tools and approaches, and recommendations arising from these study results provide a scientific basis for policy-makers to mitigate the negative impacts of the conflicts. Since environmental conflicts dovetail in political, economic, social and ecological contexts, their management should focus on integrated measures [47,48]. Environmental impact assessments (EIA) and strategic environmental assessments (SEA) are important legal and procedural tools to manage the environment, in particular with regard to the current and intended development [49,50]. Moreover, integrated coastal zone management (ICZM), marine spatial planning (MSP), and multi-planning integration advancing coastal zone management are favorable to titan mines along coasts. In reality, there is lack of planning for natural resource use in the Central Coast Vietnam [35,51]. Consequently, resources in this area are depleted and risks of conflicts between economic groups using these natural resources are common. Over-all, conflicts will likely become more severe and serious as long as resources decline both in quality and quantity and environmental pollution increases. Developing natural resources and environmental management strategies and models of sustainable consumption of resources according to a sustainable development strategy are required. Potential conflicts are identified, and preventive measures are proposed.

Author Contributions: Conceptualization, M.T.D., A.T.N. and L.H.; Data Curation, Q.T.T.; Formal Analysis, D.T.N. (Dinh Tien Nguyen); Investigation, Q.T.T., H.G.D., D.T.N. (Duyen T. Nguyen) and H.T.D.; Methodology, A.T.N., T.K.N. and H.T.T.P.; Project Administration, M.T.D., H.G.D. and D.T.N. (Duyen T. Nguyen); Resources, Q.T.T. and D.T.N. (Duyen T. Nguyen); Software, T.K.N. and H.G.D.; Validation, D.T.N. (Dinh Tien Nguyen); Visualization, H.T.D.; Writing—Original Draft, M.T.D., A.T.N., H.T.T.P., D.T.N. (Dinh Tien Nguyen) and L.H.; Writing—Review & Editing, A.T.N. and L.H.

Funding: This research was funded by the Vietnam national project code DTDLCN.31/16.

Acknowledgments: The authors would like to thank locals, district and communal authorities, and scientists who were most collaborative in completing the questionnaire, and in providing discussion opportunities.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Lu, Y.; Fu, B.; Chen, L.; Ouyang, Z.; Xu, J. Resolving the conflicts between biodiversity conservation and socioeconomic development in China: Fuzzy clustering approach. *Biodivers. Conserv.* **2006**, *15*, 2813–2827. [CrossRef]
2. Young, J.C.; Marzano, M.; White, R.M.; McCracken, I.; Redpath, S.M.; Carss, D.N.; Quine, C.P.; Watt, A.D. The emergence of biodiversity conflicts from biodiversity impacts: Characteristics and management strategies. *Biodivers. Conserv.* **2010**, *19*, 3973–3990. [CrossRef]
3. Meng, H.H.; Zhou, S.S.; Li, L.; Tan, Y.H.; Li, J.W.; Li, J. Conflict between biodiversity conservation and economic growth: Insight into rare plants in tropical China. *Biodivers. Conserv.* **2019**, *28*, 523–537. [CrossRef]
4. Cadoret, A. Conflict dynamics in coastal zones: A perspective using the example of Languedoc-Rousillon (France). *Coast. Conserv.* **2009**, *13*, 151. [CrossRef]
5. Bramatia, M.C.; Musellab, F.; Allevaa, G. What drives environmental conflicts in coastal areas? An econometric approach. *Ocean Coast. Manag.* **2014**, *101*, 63–78. [CrossRef]
6. Stepanova, O. Conflict resolution in coastal resource management: Comparative analysis of case studies from four European countries. *Ocean Coast. Manag.* **2015**, *103*, 109–122. [CrossRef]
7. Rempis, N.; Alexandrakis, G.; Tsilimigkas, G.; Kampanis, N. Coastal use synergies and conflicts evaluation in the framework of spatial, development and sectoral policies. *Ocean Coast. Manag.* **2018**, *166*, 40–51. [CrossRef]
8. Solomon, N.; Birhane, E.; Gordon, C.; Haile, M.; Taheri, F.; Azadi, H.; Scheffran, J. Environmental impacts and causes of conflict in the Horn of Africa: A review. *Earth-Sci. Rev.* **2018**, *177*, 284–290. [CrossRef]

9. Barry, M.B.; Dewar, D.; Whittal, J.F.; Muzondo, I.F. Land Conflicts in Informal Settlements: Wallacedene in Cape Town, South Africa. *Urban Forum* **2007**, *18*, 171–189. [CrossRef]
10. Pape, R.; Löffler, J. Climate change, land use conflicts, predation and ecological degradation as challenges for reindeer husbandry in Northern Europe: What do we really know after half a century of research? *AMBIO* **2012**, *41*, 421–434. [CrossRef]
11. Zeitoun, M.; Mirumachi, N. Transboundary water interaction I: Reconsidering conflict and cooperation. *Int. Environ. Agreem. Politics Law Econ.* **2008**, *8*, 297. [CrossRef]
12. Strauß, S. Water conflicts among different user groups in South Bali, Indonesia. *Hum. Ecol.* **2011**, *39*, 69–79. [CrossRef]
13. Gunasekara, N.K.; Kazama, S.; Yamazaki, D.; Oki, T. Water conflict risk due to water resource availability and unequal distribution. *Water Resour. Manag.* **2014**, *28*, 169–184. [CrossRef]
14. Yuling, S.; Lein, H.; Chen, X. Water conflicts in Hetian District, Xinjiang, during the Republic of China period. *Water Hist.* **2016**, *8*, 77–94. [CrossRef]
15. Abrahams, D.; Carr, E.R. Understanding the connections between climate change and conflict: Contributions from geography and political ecology. *Curr. Clim. Chang. Rep.* **2017**, *3*, 233–242. [CrossRef]
16. Pearson, D.; Newman, P. Climate security and a vulnerability model for conflict prevention: A systematic literature review focusing on African agriculture. *Sustain. Earth* **2019**, *2*, 2. [CrossRef]
17. Brock, L. Environmental Conflict Research—Paradigms and Perspectives. In *Environmental Change and Security: International and European Environmental Policy Series*; Carius, A., Lietzmann, K.M., Eds.; Springer: Berlin/Heidelberg, Germany, 1999; pp. 37–53.
18. Klaus, R. Agrarian development and conflicts of land utilization in the coastal plains of Calabria (South Italy). *GeoJournal* **1986**, *13*, 27–35.
19. Sebastiani, M.; González, S.E.; Castillo, M.M.; Alvizu, P.; Oliveira, M.A.; Pérez, J.; Quilici, A.; Rada, M.; Yáber, M.C.; Lentino, M. Large-scale shrimp farming in coastal wetlands of Venezuela, South America: Causes and consequences of land-use conflicts. *Environ. Manag.* **1994**, *18*, 647–661. [CrossRef]
20. Pérez-Rincón, M.; Vargas-Morales, J.; Crespo-Marín, Z. Trends in social metabolism and environmental conflicts in four Andean countries from 1970 to 2013. *Sustain. Sci.* **2018**, *13*, 635–648. [CrossRef]
21. Carpenter, S.L.; Kennedy, W.J.D. Environmental conflicts in mineral development. *Miner. Environ.* **1980**, *2*, 159–164. [CrossRef]
22. McKenna, J.; Cooper, J.A.G.; O'Hagan, A.M. Coastal erosion management and the European principles of ICZM: Local versus strategic perspectives. *Coast. Conserv.* **2009**, *13*, 165–173. [CrossRef]
23. Tuda, A.O.; Stevens, T.F.; Rodwell, L.D. Resolving coastal conflicts using marine spatial planning. *Environ. Manag.* **2014**, *133*, 59–68. [CrossRef] [PubMed]
24. Zhao, X.; Jia, P. Multi-planning integration advancing coastal zone management: A case study from Hainan Island, China. *Coast. Conserv.* **2018**, 1–7. Available online: https://link.springer.com/article/10.1007/s11852-018-0667-0 (accessed on 30 June 2019). [CrossRef]
25. Rudianto Tantu, A.G. An analysis of coastal land conflict in the North of Jakarta coastal area: (A general algebraic modelling system approach). *Coast. Conserv.* **2014**, *18*, 69–74. [CrossRef]
26. Chuang, Y.H.; Yu, R.F.; Chen, W.Y.; Chen, H.W.; Su, Y.T. Sustainable planning for a coastal wetland system with an integrated ANP and DPSIR model for conflict resolution. *Wetl. Ecol. Manag.* **2018**, *26*, 1015–1036. [CrossRef]
27. Bascetin, A. A decision support system using analytical hierarchy process (AHP) for the optimal environmental reclamation of an open-pit mine. *Environ. Geol.* **2007**, *52*, 663–672. [CrossRef]
28. Sadiq, R.; Tesfamariam, S. Environmental decision-making under uncertainty using intuitionistic fuzzy analytic hierarchy process (IF-AHP). *Stoch. Environ. Res. Risk Assess.* **2009**, *23*, 75–91. [CrossRef]
29. Afshar, A.; Mariño, M.A.; Saadatpour, M.; Afshar, A. Fuzzy TOPSIS Multi-Criteria Decision Analysis applied to Karun Reservoirs System. *Water Resour. Manag.* **2011**, *25*, 545–563. [CrossRef]
30. Pourebrahim, S.; Mokhtar, M.B. Conservation priority assessment of the coastal area in the Kuala Lumpur mega-urban region using extent analysis and TOPSIS. *Environ. Earth Sci.* **2016**, *75*, 348. [CrossRef]
31. Asghari, M.; Nassiri, P.; Monazzam, M.R.; Golbabaei, F.; Arabalibeik, H.; Shamsipour, A.; Allahverdy, A. Weighting criteria and prioritizing of heat stress indices in surface mining using a Delphi Technique and Fuzzy AHP-TOPSIS Method. *Environ. Health Sci. Eng.* **2017**, *15*, 1. [CrossRef]

32. MONRE (Ministry of Natural Resources and Environment). *Basic Contents of Survey on Geology, Environmental Geology and Disasters of Geology in Coastline of Vietnam*; General Department of Geology and Minerals of Vietnam: Hanoi, Vietnam, 2001; 463p. (In Vietnamese)
33. DGM (Department of Geology and Minerals of Vietnam). *Report on Mineral Resources in Coastal Provinces*; Department of Geology and Minerals of Vietnam: Hanoi, Vietnam, 2016; 365p. (In Vietnamese)
34. KAG (Ky Anh Government). *Socio-Economic Development of Ky Anh*; Official Report; KAG: Ky Anh, Vietnam, 2019; 78p. (In Vietnamese)
35. Nguyen, A.T.; Vu, D.A.; Vu, P.V.; Nguyen, T.N.; Pham, T.M.; Nguyen, H.T.T.; Le, H.T.; Nguyen, T.V.; Hoang, L.K.; Duc Vu, T.; et al. Human ecological effects of tropical storms in the coastal area of Ky Anh (Ha Tinh, Vietnam). *Environ. Dev. Sustain.* **2017**, *19*, 745–767. [CrossRef]
36. PMV (Prime Minister of Vietnam). *"Decision 1880/Q-TTg on the Compensation to the Provinces of Ha Tinh, Quang Binh, Quang Tri, and Thue Thien-Hue Following the Marine Environmental Incident"*; PMV: Ha Noi, Vietnam, 2016. (In Vietnamese)
37. PMV (Prime Minister of Vietnam). *"Decision 309/Q-TTg on the revision of Decision 1880/Q-TTg on September 29 2016 Regarding the Compensation for the Provinces of Ha Tinh, Quang Binh, Quang Tri, and Thue Thien-Hue following the Marine Environmental Incident"*; PMV: Ha Noi, Vietnam, 2017. (In Vietnamese)
38. Saaty, R.W. The analytic hierarchy process—What it is and how it is used. *Math. Model.* **1987**, *9*, 161–176. [CrossRef]
39. Vargas, L.G. An overview of the analytical hierarchy process and its applications. *Eur. J. Oper. Res.* **1990**, *48*, 2–8. [CrossRef]
40. Carnero, M.C. Multicriteria model for maintenance benchmarking. *Manuf. Syst.* **2014**, *33*, 303–321. [CrossRef]
41. Chang, D.Y. Applications of the extent analysis method on fuzzy AHP. *Eur. J. Oper. Res.* **1996**, *95*, 649–655. [CrossRef]
42. Pourjavad, E.; Mayorga, R.V. A hybrid approach integrating AHP and TOPSIS for sustainable end-of-life vehicle strategy evaluation under fuzzy environment. *Wseas Trans. Circuits Syst.* **2016**, *15*, 216–223.
43. Hwang, C.L.; Yoon, K. *Multiple Attribute Decision Making: Methods and Applications*; Springer: Berlin/Heidelberg, Germany, 1981; 225p, ISBN 978-3-642-48318-9.
44. Yasmi, Y.; Schanz, H.; Salim, A. Manifestation of conflict escalation in natural resource management. *Environ. Sci. Policy* **2006**, *9*, 538–546. [CrossRef]
45. Taylan, O.; Bafail, A.O.; Abdulaal, R.M.S.; Kabli, M.R. Construction projects selection and risk assessment by fuzzy AHP and fuzzy TOPSIS methodologies. *Appl. Soft Comput.* **2014**, *17*, 105–116. [CrossRef]
46. Sirisawat, P.; Kiatcharoenpol, T. Fuzzy AHP-TOPSIS approaches to prioritizing solutions for reverse logistics barriers. *Comput. Ind. Eng.* **2018**, *117*, 303–318. [CrossRef]
47. Tyagi, M.; Kumar, P.; Kumar, D. A hybrid approach using AHP-TOPSIS for analyzing e-SCM performance. *Procedia Eng.* **2014**, *97*, 2195–2203. [CrossRef]
48. Sun, L.; Zhu, D.; Chan, E.H.W. Public participation impact on environment NIMBY conflict and environmental conflict management: Comparative analysis in Shanghai and Hong Kong. *Land Use Policy* **2016**, *58*, 208–217. [CrossRef]
49. Rincón-Ruiz, A.; Rojas-Padilla, J.; Agudelo-Rico, C.; Perez-Rincon, M.; Vieira-Samper, S.; Rubiano-Paez, J. Ecosystem services as an inclusive social metaphor for the analysis and management of environmental conflicts in Colombia. *Ecosyst. Serv.* **2019**, *37*, 100924. [CrossRef]
50. Koornneef, J.; Faaij, A.; Turkenburg, W. The screening and scoping of environmental impact assessment and strategic environmental assessment of carbon capture and storage in the Netherlands. *Environ. Impact Assess. Rev.* **2008**, *28*, 392–414. [CrossRef]
51. Nguyen, A.T.; Vu, A.D.; Dang, G.T.H.; Hoang, A.H.; Hens, L. How do local communities adapt to climate changes along heavily damaged coasts? A Stakeholder Delphi study in Ky Anh (Central Vietnam). *Environ. Dev. Sustain.* **2018**, *20*, 749–767. [CrossRef]