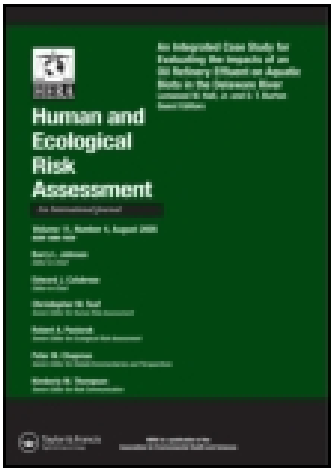

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Risk Assessment of Desertification for Binh Thuan Province, Vietnam

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ABSTRACT

Vietnam is one among five ranked countries with high-risk injury due to the phenomenon of climate change. Geographically, Binh Thuan, a coastal province, is located in the Southern Centre area. Currently, natural disasters have become more frequent, particularly drought. Desertification has become more serious. Besides the natural causes as described above, there are several affected by human activities such as high population and poverty, inappropriate cultivating technique, deforestation, ill-adopted legal framework, weak management capacity, lack of adequate knowledge, and a lack of awareness in local population. To assess risks of desertification for the Binh Thuan province (Vietnam), a risk assessment model based on a Leopold matrix was applied. As a result, a model of cause and effect showed six degrees of impacts of environmental and social conditions on the socioeconomic developments from very highly to very unlikely significance. Risk assessment allows for a general figure of various impacts of desertification on the socioeconomic developments in Binh Thuan, Vietnam.

Key Words: assessment matrix, Binh Thuan province, climate change, desertification, risk assessment, Vietnam.

INTRODUCTION

Global warming includes sea-level rise (SLR) at a global average rate of 1.8 (1.3 to 2.3) mm per year from 1961 to 1992 and about 3.1 (2.4 to 3.8) mm per year from 1993 to 2003 (IPCC 2007). Anthropogenic warming has likely had influences over other aspects of climate, such as temperature extremes and wind patterns, putting stress/changes on physical and biological systems (IPCC 2007).

Tropical areas such as Vietnam are being affected by desertification. Vietnam is one of the countries in southeast Asia that is increasingly being affected by climate change. During the period 1958–2007 the average temperature increased by 0.5–0.7°C. By 2050, an increase of another 0.4°C is expected as compared to the

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Table 1. Sea-level rise from 2020 to the end of the 21st century in Southern Centre of Vietnam.

	Year								
	2020	2030	2040	2050	2060	2070	2080	2090	2100
	Sea-level rise (cm)								
Low emission scenario (B1)	11	17	23	28	35	42	50	57	65
Medium emission scenario (B2)	12	17	23	30	37	46	54	64	75
High emission scenario (A1F1)	12	17	24	33	44	57	71	86	100

Source: MONRE (2009).

2020 average temperature. During the period 1993–2008, the sea level increased on average by 3 mm per year. In addition, an increase of 28 to 33 cm is projected. Typhoons will move more southwards and increase both in frequency and in intensity (MONRE 2009). Climate change and SLR scenarios for Vietnam in the 21st century are developed based on different Intergovernmental Panel on Climate Change (IPCC) compliant emission scenarios (IPCC 2007), namely, low (B1), medium (B2), and high (A1F1) for the Southern Centre and other regions of Vietnam (Table 1) (MONRE 2009). Drought in Vietnam is not characterized by catastrophes such as malnutrition, famine, or environmental refugees as they now occur in sub-Saharan Africa. Nevertheless, Vietnam has a record of frequent drought periods. One of the longest in recent times occurred in 1998. This resulted in severe damage to 11 main crops (hundred thousand hectares of rice, coffee, tea, and fruits were affected), forest fires, dry water reservoirs, intrusion of sea water, and lack of fresh water (MONRE 2003). Drought affects 45% of Vietnam's agricultural land (9.34 million hectares out of 21 million hectares of agricultural land and forests). Of these, 30% (7.84 million hectares) is severely degraded.

Vietnam's natural area is approximately 33 million hectares, of which the land area is about 31 million hectares. Land is an invaluable resource as an important environmental component. Moreover, land is a kind of nature supporting humans to develop agriculture, forestry, and food security. However, over decades, the awareness and understanding of the Vietnamese people is still limited. Abuse and exploitation have led to land degradation, desertification, and loss of part or all of the features of production, making more fertile soils in the beginning, but after a period of time arable lands become "a problem" (VFF 2011).

Regionally and provincially, drought mainly occurs in the southern part of Central Vietnam. Binh Thuan, Ninh Thuan, and Khanh Hoa provinces are the most severely affected (MONRE 2003). Poverty, political instability, deforestation, overgrazing of animals and even the outdated irrigation methods can reduce the productivity of the land. Thus, the anti-desertification effort in Vietnam combats deforestation and operates to overcome land degradation, drought, and desertification.

As was pointed out in the United Nations Convention to Combat Desertification definition of desertification (UNCCD 2007), the desertification process is "the degradation in the arid, semi-arid, and dry sub-humid areas resulting from various factors, including climatic variations and human activities." Therefore, desertification assessment should take into account both "climatic" conditions and "human"

elements. Future directions for research would also support the current policy and anticipate the risks in the region. Unfortunately, Binh Thuan province suffers from desertification under the influence of climate change but there is a lack of local and provincial scenarios pertaining to the effects of desertification and how to deal with the issue.

To assess risks of desertification on the socioeconomic development of Binh Thuan province, Vietnam, an assessment matrix of cause and effect model was applied.

METHODS

Risk is defined, as "the chance of something happening that will have impacts on objectives" (Committee 2004). Based on the results from Delphi analysis and Leopold matrix (Gobin *et al*. 2011) after Bisset (1989), this section defines the environment and society of the districts of Tuy Phong and Bac Binh and how the province of Binh Thuan as a whole has been affected as the result of global climate change and desertification including the varying degrees of impact and on sequences.

Delphi, internationally, is a method that is widely used to map scientific consensus (Hai *et al*. 2009; Hugé *et al*. 2009; Hai 2010). A Leopold matrix is widely used to assess risks for development projects among individuals from different perspectives (Bisset 1989; FAO 1996; ADB 1997). The matrix is used to facilitate the interactive participation of varied and conceivably hierarchical and antagonistic experts and to capitalize on stakeholders' knowledge and opinions as valid input to research in an inexact research area (Bunting 2010). The matrix is a semi-qualitative environmentalimpactassessment method pioneered in the last century (Leopold 1971). In fact, the main issue is to assign a level to the severity of a probability of an occurrence. These levels can be further used to determine the acceptability of the (remaining) risk. The intersections of rows and columns are completed by each expert to indicate the magnitude and the importance (from 1 to 10) of the impact of each activity on each socioeconomic aspect (Box 1) (Bisset 1989).

To assess risks, models (Figures 1 and 2) of a risk assessment matrix were applied as a tool that allows viewing the probable risks in terms of the cause and effect of desertification in Binh Thuan province.

First, shown in Figure 1 (a matrix: 5×5) are the following main steps to assess the risks (Sidharth 2010):

1. The matrix is based on two criteria:
   a. Likelihood: the probability of a risk (cause);
   b. Consequences: the severity of the impact or the extent of damage caused by the risk (effect).
2. Likelihood of occurrence (cause): Based on the likelihood of the occurrence of a risk the risks can be classified into one of the five categories:
   a. Definite: A risk that is almost certain to show up during project execution. In terms of percentages the risk is more than 80% and likely to cause problems;
   b. Likely: Risks that have 61–80% probability of occurrence can be grouped as likely;

1. Identify all socio-economic activities (located across the top of the matrix) that are part of desertification;

2. Under each of the proposed socio-economic activities, place a slash at the intersection with each environmental condition on the side of the matrix if an impact is possible;

3. Having completed the matrix, in the upper left-hand corner of each box with a slash, a number from 1 to 10 is placed to indicate the magnitude of the possible impact: 10 represents the greatest magnitude of impact and 1 the least (no zeroes). Before each number + is placed if the impact would be beneficial. In the lower right-hand corner of the box a number from 1 to 10 is placed to indicate the importance of the possible impact; 10 represents the highest importance and 1 the least (no zeroes).

Box 1. Instructions for a Leopold matrix (Leopold 1971).

Likelihood (Causes) \ Consequences (Effects)	**Negligible** *(Impact on the function, or its objectives is negligible. Routine procedures would be sufficient to deal with the consequences/ Minimal resource impost)* **(1)**	**Minor** *(Would threaten an element of the function. May cause small delays or have minor impact on quality)* **(2)**	**Moderate** *(Would necessitate significant adjustment to the overall function and require corrective action. May have a negative impact)* **(3)**	**Major** *(Would threaten goals and objectives; requires close management)* **(4)**	**Severe** *(Would stop achievement of functional goals and objectives)* **(5)**
Almost certain *(expected to occur in most circumstances)* **(5)**	Medium 5	High 10	High 15	Very high 20	Very high 25
Likely *(will probably occur in most circumstances)* **(4)**	Medium 4	Medium 8	High 12	High 16	Very high 20
Possible *(might occur at some time)* **(3)**	Low 3	Medium 6	High 9	High 12	High 15
Unlikely *(could occur at some time)* **(2)**	Low 2	Medium 4	Medium 6	Medium 8	High 10
Rare *(may occur in exceptional circumstances)* **(1)**	Low 1	Low 2	Low 3	Medium 4	Medium 5

Note: Risk level

Low	Medium	High	Very high
Normal control and monitoring measures sufficient	Requires identification and control of all contributing factors by monitoring conditions and reassessment of project milestones	Substantial delay project schedule, significant impact on technical performance or cost, and requires close management attention	Would prevent achievement of objectives, cause unacceptable cost overruns or schedule slippage and requires close executive attention

Figure 1. A model of risk assessment matrix (Sidharth 2010).

Not significant	NS	0.0 – 0.3	May be ignored and no further action required
Very low	VL	0.4 – 1.2	
Low	L	1.3 – 2.5	Ensure safe process
Moderate	M	2.6 – 4.2	Refers to risk
High	H	4.3 – 6.7	Monitor control measures
Very high	VH	6.8 – 10.0	Avoid as much and as soon as possible

		Socio-economic activities									
		Insignificantly impact	Minor impact		Illness impact		Major impact		Significant impact	High significant impact	significant impact
Environmental and social factors	Certain	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
	Almost certain	0.9	1.8	2.7	3.6	4.5	5.4	6.3	7.2	8.1	9.0
	Very likely	0.8	1.6	2.4	3.2	4.0	4.8	5.6	6.4	7.2	8.0
	Probable	0.7	1.4	2.1	2.8	3.5	4.2	4.9	5.6	6.3	7.0
	Likely	0.6	1.2	1.8	2.4	3.0	3.6	4.2	4.8	5.4	6.0
		0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
	May happen	0.4	0.8	1.2	1.6	2.0	2.4	2.8	3.2	3.6	4.0
	Improbable	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3.0
	Unlikely	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0
	Very unlikely	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0

Figure 2. A model of risk assessment matrix applied in this study.

c. Occasional: Risks that have a near 41–60% probability of occurrence;
d. Seldom: Risks that have a low probability (21–40%) of occurrence but cannot be ruled out completely;
e. Unlikely: Rare and exceptional risks, which have 1–20% probability of occurrence.

3. Rank of consequences (effect): The consequences of a risk can be ranked and classified into one of the following five categories, based on how severe the damage can be:
   a. Not impact: Risks that will cause a near negligible amount of damage to the overall progress of the project (1–20% probability of occurrence);
   b. Marginal: If a risk will result in some damage, but the extent of damage is not likely to make much of a difference to the overall progress of the project (21–40% probability of occurrence);
   c. Moderate: Risks that do not impose a great threat, but yet a sizable damage can be classified as moderate (41–60% probability of occurrence);
   d. Critical: Risks with significantly large consequences that can lead to a great amount of loss are classified as critical (61–80% probability of occurrence);
   e. Catastrophic: These are the risks that can make the project completely unproductive and unfruitful, must be a top priority during risk management (81–100% probability of occurrence).

Second, therefore, to assess risks in terms of the cause and effect of desertification in Binh Thuan province based on the results of Gobin *et al.* (2011) from the Leopold matrix such as magnitude of impacts of environmental and social factors on socioeconomic activities and these principles above, a similar model matrix (10×10) was applied as a tool (Figure 2). In principle, Figure 2 (and Figure 3 as the results) is the same as using numbers as Figure 1. The matrix is based on two criteria, that is, environmental and social factors (causes: from certain to very unlikely) and socioeconomic activities (effects: from insignificant impact to very high significant impact). In this figure, there are six degrees of impacts from "not significant: $0 \rightarrow 0.3$ scores" to "very high: $6.8 \rightarrow 10$ scores" with its solutions from "may be ignored and no further action required" to "avoid as much as possible."

RESULTS AND DISCUSSION

The desertification processes in Vietnam are drought, land degradation, deforestation, and sand movement (MARD 2004). However, how do the phenomena affect the province of Binh Thuan and the districts of Tuy Phong and Bac Binh from a research point of view?

To understand what are the current problems in the province, Figures 3 and 4 describe in more detail the risk assessment for climate change and desertification on the provincial and districts' socioeconomic development. These include:

1. Certain environmental and social factors impact very highly (6.8–10 scores) on socioeconomic activities such as:
   - Rainfall $\rightarrow$ rice (6.8 score) and supply water for agriculture (7.1 score);

			Agricultural activities														Water supply		Income		Expenditure		Migration	
			Cultivated area							Raising animals														
			Rice	Vegetable	Sweet potatoes	Cotton	Dragon fruit	Cassava	Maize	Buffaloes	Cattle	Goats	Shrimp aquaculture	Fresh water fish aquaculture	Raising sheep	Mode of production	Agriculture	Eating	Agriculture	Industry	Health	Food	In migration	Out migration
Physical	Geographical and natural position of the territory		3.9	3.9	3.0	4.6	4.8	2.4	2.7	2.3	2.2	2.8	4.0	3.2	3.7	4.4	6.5	5.3	4.7	3.8	3.6	2.6	4.5	4.6
	Geology		2.0	1.9	1.8	2.1	2.2	1.8	1.6	0.9	0.9	0.7	1.9	1.2	1.0	2.5	3.7	3.4	1.8	2.1	1.2	0.5	1.9	1.9
	Soil composition		5.8	5.5	4.9	5.3	5.1	4.3	4.5	1.0	1.1	1.5	1.5	1.1	1.2	4.8	4.0	2.2	3.6	1.2	0.9	0.4	1.3	1.5
	Land use/ land cover		5.4	5.3	4.7	5.5	5.3	4.4	4.8	4.3	4.4	4.5	3.2	2.8	4.4	5.1	4.1	2.2	4.6	2.0	1.4	1.1	2.3	2.4
	Topography		5.8	4.5	4.5	4.7	4.9	3.9	3.4	2.3	2.8	2.8	4.1	4.0	3.5	5.4	6.2	4.9	3.5	2.6	1.9	1.0	2.4	3.0
	Rainfall		6.8	5.9	4.9	5.1	5.3	4.5	4.7	2.9	2.7	2.7	4.7	4.0	3.1	5.7	7.1	6.0	4.9	2.3	3.3	2.5	2.2	1.9
	Water resources	Surface water	6.6	4.9	4.1	4.5	4.7	2.8	3.8	3.9	3.6	2.8	6.3	6.3	3.1	5.7	7.6	6.8	5.4	4.1	4.2	3.7	3.6	3.4
		Ground water	2.0	2.1	2.3	3.0	3.0	1.3	1.3	1.3	1.2	1.2	3.2	2.2	2.2	3.4	3.8	6.4	2.7	3.2	3.2	3.1	2.3	1.9
	Sunshine duration		5.4	5.0	4.5	5.6	5.6	3.7	4.4	1.7	2.1	2.2	2.6	1.8	2.8	3.2	4.7	3.7	3.8	1.5	4.0	2.6	1.3	1.4
	Period of sunny, dry days		6.2	6.3	5.0	5.2	5.4	4.4	5.2	4.6	4.3	4.3	3.8	3.6	4.5	4.1	6.7	5.8	5.3	2.7	4.7	4.2	2.2	2.4
	Temperature		5.2	5.4	4.6	5.2	5.3	3.8	4.2	4.7	4.6	4.1	4.8	4.5	4.8	4.3	5.1	4.0	3.5	2.3	4.4	3.4	1.8	1.6

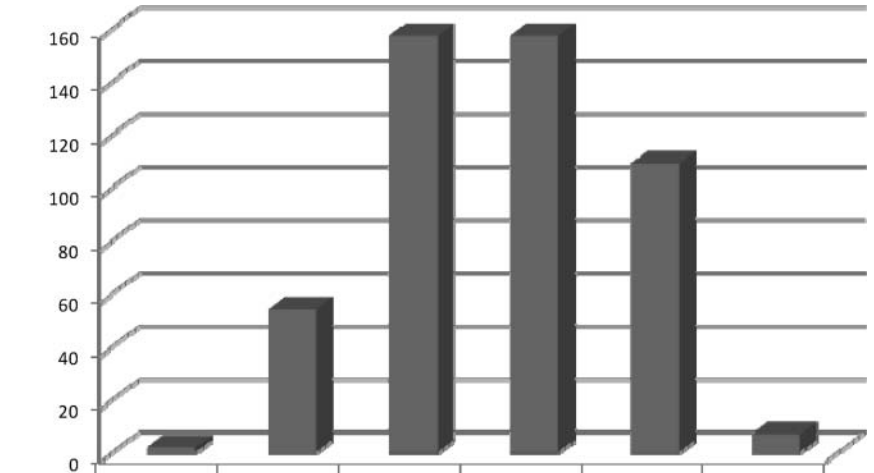
Figure 3. Risk assessment for climate change and desertification in Binh Thuan province. *(Continued)*

		Agricultural activities														Water supply		Income		Expenditure		Migration	
		Cultivated area							Raising animals														
		Rice	Vegetable	Sweet potatoes	Cotton	Dragon fruit	Cassava	Maize	Buffaloes	Cattle	Goats	Shrimp aquaculture	Fresh water fish aquaculture	Raising sheep	Mode of production	Agriculture	Eating	Agriculture	Industry	Health	Food	In migration	Out migration
	Humidity	5.2	5.3	4.3	4.3	5.1	3.7	4.1	2.7	2.6	2.3	2.1	2.3	3.4	3.6	4.5	3.3	3.1	1.8	4.1	1.9	1.0	0.9
	Wind/wind direction	1.7	1.9	1.4	1.1	1.3	1.1	1.5	1.3	1.3	1.1	0.8	0.6	1.3	2.4	1.6	1.1	1.2	0.7	2.8	0.6	0.3	0.3
	Wind speed	3.3	2.7	1.7	2.7	3.2	2.0	3.4	1.0	0.9	0.8	0.7	0.5	1.0	2.4	1.7	1.2	1.9	0.9	2.1	1.0	0.7	0.6
	Hazard/risk	4.1	4.0	3.9	3.2	3.7	3.6	3.1	2.7	2.6	2.6	4.2	3.8	2.3	4.5	3.8	3.8	4.4	2.7	3.2	2.9	3.4	3.8
Socio-economic	Population density	3.6	3.2	1.9	2.2	2.2	2.2	2.2	2.5	2.7	2.8	2.1	2.5	1.9	3.9	4.7	6.8	4.4	3.1	4.1	3.1	5.1	5.4
	Social awareness	2.6	2.6	2.1	2.5	2.8	2.8	2.7	2.1	2.2	2.2	3.3	2.8	2.5	5.7	2.7	3.4	3.7	3.7	4.0	3.6	3.2	3.4
	Land use planning	6.0	5.5	5.1	5.0	5.2	4.9	5.1	4.5	4.5	4.4	5.0	4.7	4.1	6.6	6.0	4.8	5.5	3.5	1.9	1.3	5.1	4.6
	Forestry	3.1	2.1	1.7	1.6	1.6	2.7	2.5	1.3	1.2	1.9	1.9	1.2	1.5	3.3	4.5	3.9	3.6	2.7	1.9	1.2	2.6	2.0
	Conversion of forest	2.3	1.6	1.4	1.3	1.4	2.1	1.9	1.3	1.3	1.6	0.9	0.8	1.0	3.9	3.1	2.7	2.2	2.1	1.9	1.2	1.9	1.4
	Titanium mining	1.4	1.4	1.5	0.9	1.0	0.7	0.7	0.6	0.8	1.1	2.6	2.4	1.2	3.8	2.3	2.7	2.0	5.2	2.5	1.8	2.9	2.5
	Aquaculture	3.6	1.9	1.6	1.4	1.3	0.9	0.9	0.7	0.7	1.1	7.1	6.5	0.8	4.5	3.6	2.6	4.9	2.1	2.8	2.7	2.4	2.2
	Irrigation	6.5	4.9	3.3	3.8	3.5	2.7	3.3	1.4	1.3	1.5	4.2	4.3	1.4	6.4	7.4	6.1	6.2	2.3	2.3	1.4	2.2	2.2

Figure 3. (Continued)

		Agricultural activities														Water supply		Income		Expenditure		Migration	
		Cultivated area							Raising animals														
		Rice	Vegetable	Sweet potatoes	Cotton	Dragon fruit	Cassava	Maize	Buffaloes	Cattle	Goats	Shrimp aquaculture	Fresh water fish aquaculture	Raising sheep	Mode of production	Agriculture	Eating	Agriculture	Industry	Health	Food	In migration	Out migration
	Hydroelectricity/reservoir	4.7	3.9	2.5	3.0	2.8	2.0	2.3	1.4	1.5	1.6	3.1	3.6	1.4	5.3	6.6	4.8	4.4	3.6	2.0	1.3	3.0	4.4
	Immigrant-resettlement from developing projects	2.8	2.6	2.3	1.6	1.8	2.2	2.3	2.2	2.3	2.3	1.6	2.3	1.5	5.2	4.6	5.2	3.6	1.8	3.5	2.8	5.3	5.3
Ecological	Dunes	2.1	2.7	3.2	2.8	2.8	2.1	1.7	1.3	1.3	1.5	2.6	2.6	1.7	3.8	3.2	2.8	2.7	1.6	2.5	1.6	1.3	1.4
	Forest	2.2	1.9	1.7	1.8	1.8	1.7	1.5	2.6	2.5	3.0	1.1	1.2	2.1	5.5	5.2	4.7	3.3	1.9	3.1	1.3	1.9	1.5

Figure 3. (Continued)



	0.0 – 0.3	0.4 – 1.2	1.3 – 2.5	2.6 – 4.2	4.3 – 6.7	6.8 – 10.0
Frequency	2	54	157	157	109	7
%	0.4%	11.1%	32.3%	32.3%	22.4%	1.4%

Figure 4. Results (sum of all scores and its percentage) of risk assessment in the province.

- Surface water → supply water for agriculture (7.6 score—the highest value) and eating (6.8 score);
- Population density → supply water for eating (6.8 score);
- Aquaculture → shrimp (7.1);
- Irrigation → supply water for agriculture (7.4 score).

These figures show that environmental conditions of rainfall, surface water, population density, aquaculture, irrigation affect agricultural activities, and water supply. Most importantly, rice and water supply for agriculture and eating are severely affected by surface water and rainfall. Moreover, the meteorological effects (*e.g.,* rainfall, sunshine duration, period of sunny, and dry day) impact on agriculture and the associated human–environmental and socioeconomic situation of the population. The slowly progressing character of increasing drought episodes allows establishing management options for an adaptation to drought. Most importantly, rice and water supply for agriculture and eating are extremely affected by surface water and rainfall. The provincial average rainfall is 1500 mm, about 76% of the national average rainfall. Especially, the lowest rainfall, about 700 mm, is over the districts of the case areas of Bac Binh and Tuy Phong.

2. Certain environmental and social factors impact highly (4.3–6.7 scores) on socioeconomic activities:
   - Almost all the physical factors (*e.g.,* soil characteristics, topography, rainfall, surface water, groundwater, sunshine duration, and humidity) affect agricultural activities, water supply, and migration. Land use/land cover, period of sunny and dry days, and temperature factors appear mostly in such activities;

- Land use planning is perceived as the most important factor, since it impacts all human activities (*e.g.*, agriculture, water supply, income, expenditure, and migration).

  Almost all water surface resources were used in the agriculture (about 84%) as the main cause of desertification. Consequently, the fresh water for eating and drinking is limited. Only 4.3% of the total water supply is for human life, but water quality is not guaranteed yet. More importantly, water without treatment is often a form of exploitation in mountainous or coastal areas where are shortages in the dry season.

3. Some environmental and social factors impact moderately (2.6–4.2 scores) on socioeconomic activities:
   - Almost all the physical factors (*e.g.*, land use, topography, rainfall, sunshine duration, period of sunny and dry days, temperature, and humidity), socioeconomic factors (*e.g.*, forestry, titanium mining, aquaculture, immigrant-resettlement from developing projects, irrigation, and hydroelectricity) affect agricultural activities, water supply, and income.
   - Geography and topography, surface water, groundwater, natural hazards (*e.g.*, landslide and erosion), population density, and social awareness appear mostly in these activities.

     Across the provinces, Binh Thuan is still considered a local water shortage area for the development of society and economy (Binh Thuan People's Committee 2011). Specifically, the rate of water use greater than the exploitation rate is 0.37 times (equivalent to 89,000 m^3 of water shortage a day). In particular, the water used in agriculture (726,710 m^3 a day) is 0.31 times is shortage. In general, it requires identification and control of all contributing factors by monitoring conditions and reassessment of project milestones.
4. Some environmental and social factors have a low impact (1.3–2.5 scores) on the socioeconomic activities:
   - The physical factors (*e.g.,* sunshine duration, period of sunny and dry days, temperature, humidity, soil composition, land use/land cover, topography, and rainfall) have little or no effect on migration. Socioeconomic factors (*e.g.*, forestry, titanium mining, aquaculture, immigrant-resettlement from developing projects, irrigation, and hydroelectricity) are thought to have little or no effect on agricultural activities, water supply, and income;
   - Geology, wind/wind direction, groundwater, hydroelectricity/reservoir, conversion of forest, forestry, population density, social awareness, titanium mining, aquaculture, irrigation, immigrant-resettlement from developing projects, dunes, and forest affect little on agricultural activities, income, expenditure, and migration.

     At the local level, water needs for socioeconomic development are still lacking—only meeting the demand for 88%. The towns of Phan Thiet, LaGi, and the districts of Tanh Linh, Ham Tan, and Duc Linh are the areas of water shortages (*i.e.*, 77,992 m^3, 8,917 m^3, 16,814 m^3, 9,000 m^3, and 37,121 m^3, respectively). In particular, there is lack of focus mainly in the city of Phan Thiet and the district of Duc Linh due to the high demand for water.

5. Some environmental and social factors have a very low impact (0.4–1.2 scores) on socioeconomic activities:
   - The physical factors (*e.g.*, geology and soil composition) have a very low effect on raising animals, income, and expenditure. Socioeconomic sectors such as forestry, conversion of forest, aquaculture, and titanium mining have a very low impact on agricultural activities such as cultivated area and raising animals;
   - Wind/wind direction and wind speed affect little on agricultural activities, water supply, income, expenditure, and migration.
6. Some environmental factors have a very unlikely effect, such as wind/wind direction (0.3 score—the lowest value) impacts on migration.

   The results (frequency and percentage) of risk assessment of climate change in Binh Thuan province are shown in Figure 4. Most impacts are concentrated on the levels from a low to high score (87%). In other words, most environmental and social factors affect socioeconomic activities in the case study area.

CONCLUSIONS

The Leopold matrix and a model (to assess risks) of cause and effect show six degrees (very highly, highly, moderately, low, very low, and very unlikely) of impacts of environmental and social conditions on the socioeconomic developments.

Rainfall, surface water, population density, aquaculture, and irrigation are the environmental conditions posing the highest risks to rice, supply water for agriculture, supply water for eating, and raising shrimp. Conversely, wind/wind direction does not significantly impact migration of people.

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