ISSN 2162-5298 (Print)
ISSN 2162-5301 (Online)

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Journal of Environmental Science and Engineering A

Volume 2, Number 8, August 2013

From Knowledge to Wisdom

Journal of Environmental Science and Engineering A

Volume 2, Number 8, August 2013 (Serial Number 20)

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Publication Information:
Journal of Environmental Science and Engineering A (formerly parts of Journal of Environmental Science and Engineering ISSN 1934-8932, USA) is published monthly in hard copy (ISSN 2162-5298) and online (ISSN 2162-5301) by David Publishing Company located at 16710 East Johnson Drive, City of Industry, CA 91745, USA.

Aims and Scope:
Journal of Environmental Science and Engineering A, a monthly professional academic journal, covers all sorts of researches on environmental management and assessment, environmental monitoring, atmospheric environment, aquatic environment and municipal solid waste, etc..

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Abstracted/Indexed in:
Googel Scholar
CAS (Chemical Abstracts Service)
Database of EBSCO, Massachusetts, USA
Chinese Database of CEPS, Airiti Inc. & OCLC
Cambridge Science Abstracts (CSA)
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Subscription Information:
Price (per year):
Print $600, Online $480
Print and Online $800

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Journal of Environmental Science and Engineering A

Volume 2, Number 8, August 2013 (Serial Number 20)

Contents

Environmental Economics

Journal of Environmental Science and Engineering A 2 (2013) 469-475
Formerly part of Journal of Environmental Science and Engineering, ISSN 1934-8932

Physico-chemical Characteristics of a Gold Mining Tailings Dam Wastewater

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Received: May 13, 2013 / Accepted: July 05, 2013 / Published: August 20, 2013.

Abstract: The study was conducted on the status of the quality of wastewater from the tailings dam of Central Africa Gold Limited in Bibiani, Ghana, to ascertain the level of contamination of the wastewater. The tailings dam stores process effluent from the gold extraction plant. Wastewater samples taken from the tailings dam were analyzed for physico-chemical characteristics. Arsenic, iron and cyanide were identified as the major pollutants in the tailings dam wastewater with average concentrations of 4.5, 25.2 and 11.1 $mg \cdot L^{-1}$, respectively. Arsenic, iron and free CN^- (cyanide) concentrations in the process effluent exceeded the Ghana EPA discharge limits of 0.2, 2 and 0.2 $mg \cdot L^{-1}$, respectively. High conductivity, total dissolved solids, sulphate and ammonium were found in the wastewater studied. The tailings dam serves as a natural reservoir that removes most of the total suspended solids and the turbidity, resulting in the improvement in the aesthetic appeal of the wastewater. Nonetheless, arsenic, iron and cyanide concentrations were still high and hence the wastewater cannot be discharged into the environment without prior treatment.

Key words: Cyanide, heavy metals, physico-chemical characteristics, gold mine wastewater, tailings dam.

1. Introduction

Mining activities are important sources of contamination of the environment [1]. Mining operations use water for mineral processing, metal recovery, dust control and supply of water needs of workers on site [2]. Typically, mine process effluent is collected and stored in tailings impoundment before being treated and released to surface water if necessary. Water pollution by mining poses serious threat to the health of the local communities (e.g., reproduction disorders and mortality) as well as the environment. Biodiversity may also be decreased by pollution due to mining. The contaminants include heavy metals, cyanide, phosphate, carbonates, sulphides, sulphates, arsenic and its complexes, nitrogen and its compounds [3-5]. Some heavy metals, such as zinc, copper, chromium, iron and manganese are essential for metabolic functioning in small amounts, but, in elevated quantities, these elements become toxic [6, 7]. The effect of metal pollution is long-lasting, as these pollutants are non-biodegradable [8, 9]. Although regulated mines have greatly improved their environmental performance, there still exist potential health and environmental threat.

In many developing countries, industries dispose of their effluents without adequate characterization, quantification and treatment due to lack of adequate legislation and law enforcement, as well as due to economic and technological constraints [10, 11]. An important step in the selection of a treatment system is to study the physical and chemical characteristics of the wastewater stream in question [12]. The study of a wastewater stream’s characteristics will help to

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identify contaminants present in the wastewater and provides information on the treatment required to meet the regulatory limits for discharge.

The objective of this study is to characterize the tailings dam effluent of Central Africa Gold Limited in Bibiani (Ghana), thereby generating reliable data for planning and design of an effluent treatment system. To do this, effluent from the tailings dam were collected and analyzed to determine the levels of physical-chemical parameters, and the heavy metals and cyanide concentrations. The effluent quality was assessed to determine its level of compliance with the Ghana EPA standard [13] for industrial effluent disposal.

2. Materials and Methods

2.1 Study Area

The study was carried out in the concession of CAG (Central african gold) at Bibiani in the Western Region of Ghana. CAG operates an open pit, underground mine and tailings reclamation. The concession area falls within the wet semi-equatorial climatic zone of Ghana. The area is approximately 55.7 km^2. The wastewater from the gold processing plant is stored in a tailings dam, located within the concession (Fig. 1). Several constructed seepage ponds and bore holes are used as monitoring points for the detection of leakages from the tailings dam into the ground water. Rivers Mpokwampa, Mensin, Kyirayaa and Pamunu are located within the concession. The Mensin River is the principal river draining the CAG concession.

2.2 Wastewater Sampling

Sampling, sample preparation, documentation and sampler cleaning were performed in accordance with procedures described in American Public Health Association [14]. The plastic sample bottles were cleaned thoroughly using a detergent, 10% HNO_3, triple-rinsed with distilled water and finally

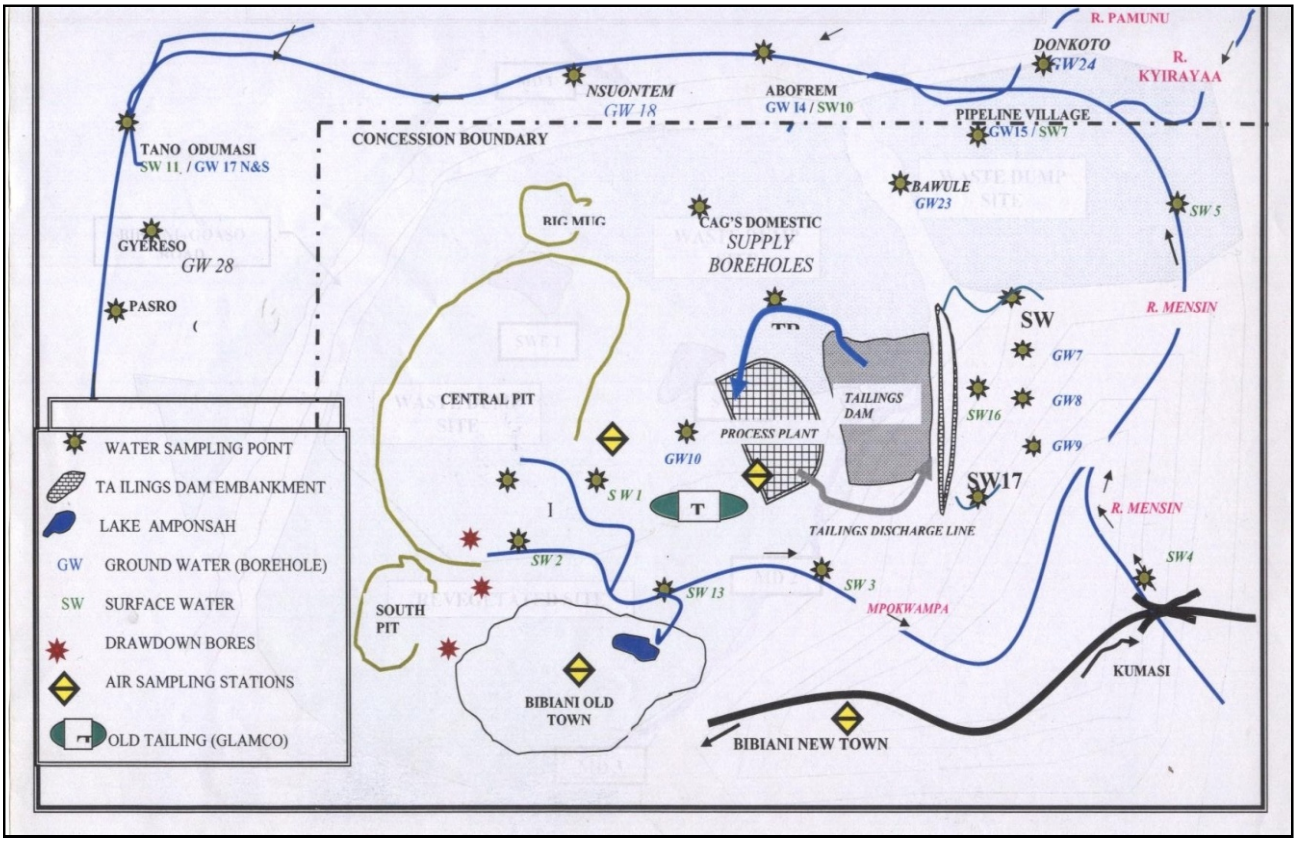

Fig. 1 Schematic drawing of water, wastewater and air sampling sites with respect to streams and rivers downstream.

triple-rinsed with the sample. Samples were collected daily from the tailings dam (Fig. 1) and transported to the environmental laboratory of the company in an ice chest containing ice cubes for analysis within 2 h to 4 h after collection. Samples for heavy metals analysis were filtered and acidified with 0.1 mol HNO_3 before storing in a refrigerator.

2.3 Wastewater Characterization

2.3.1 Analytical Quality Assurance

For all the methods that required the use of the spectrophotometer, both reagent blanks and sample blanks were used. The purpose of using blanks was to negate the effect of background interferences. When the absorbance was not zero for a particular parameter, the value was subtracted in order to obtain accurate determination of the parameter concerned. By blanking the instrument, it was assured that any reading obtained was exclusively due to the component of interest and not due to irrelevant chemicals in solution. Standard solutions were prepared for the COD (chemical oxygen demand) analysis. Before any measurement was done, instruments were calibrated using standard solutions. All field meters and equipment were checked and calibrated according to the manufacturers' specification. Preservation and handling of samples were done in accordance with procedures described in APHA [14]. All analyses were performed in triplicate.

2.3.2 Wastewater Analysis

In order to characterize the wastewater, the following parameters were measured in the tailings dam wastewater samples: temperature, pH, EC (electrical conductivity), turbidity, TSS, TDS (total dissolved solids), DO (dissolved oxygen), SO_4^{2-} (sulphate), NH_4^+ (ammonium), NO_3^- (nitrate), PO_4^{3-} (phosphate), COD, heavy metal ions (i.e., arsenic (As) and iron (Fe)) present in significant concentrations and free CN^- (cyanide).

Temperature, pH, EC and TDS of the samples were determined onsite using a multi-parameter ion specific meter (Hanna instrument, combo). The DO was measured onsite with an oxygen meter (WTW field meter OXI 330). The turbidity was measured onsite using a Hanna turbidity meter, while the TSS was measured in the laboratory using a HACH spectrophotometer (DR 500) at a wavelength of 810 nm.

COD was determined in the laboratory according to procedures described by the standard methods for the examination of water and wastewater [14]. The concentrations of PO_4^{3-}, SO_4^{2-}, NO_3^- and NH_4^+ were determined in the laboratory using the HACH spectrophotometer (DR 5000) at wavelengths of 420, 450, 410 and 425 nm, respectively. The arsenic concentration in samples was determined by the graphite furnace method using an AAS (atomic absorption spectrometer). For heavy metal analysis of the samples, the direct air acetylene flame method using an AAS was used. The cyanide concentration was measured in the laboratory using Microquent cyanide test kits.

2.4 Statistical Analysis

Standard statistical analysis was conducted using Excel and the Statistical Package for the Social Sciences (SPSS 17.0) software for windows [15, 16]. The SPSS software was used to perform DSA (descriptive statistical analysis) of the data.

3. Results and Discussion

This study showed that most of the quality parameters of the tailings dam effluent that were measured did not meet the permissible limits set by the Ghana EPA [13, 17] for industrial effluent and the WHO guidelines for use of wastewater in agriculture and aquaculture [18].

3.1 Physical Characteristics of the Tailings Dam Wastewater

The level of TDS (total dissolved solids) in the wastewater studied was 1,144 $mg \cdot L^{-1}$ (Table 1). This was above the 50 $mg \cdot L^{-1}$ prescribed by both the WHO recommended guideline value and Ghana EPA for effluent discharge into the environment. The tailings dam is an effective settler, as evident from the low levels of suspended solids and turbidity measured in the dam wastewater as compared with the levels found in the process effluent (data not shown). The removal of TSS and turbidity in the tailings dam eliminates the need for filtration prior to treatment.

The temperatures were found to be below the Ghana EPA maximum permissible limit of 40 °C [17] throughout the study. The temperatures of the process effluent (data not shown) remained relatively stable during the study period, resulting in a fairly stable temperature of the tailings dam wastewater. This can be attributed to a well-controlled process temperature of the gold extraction plant. The lower mean tailings dam wastewater temperature measured can be attributed to the heat loss to the surrounding air and dissipation as a result of a larger surface area in the tailings dam.

Apart from the unacceptably high levels of physical parameters such as TDS of the wastewater, high arsenic, iron and cyanide concentrations of the wastewater (Table 1) pose a serious environmental concern due to the toxicity of these elements.

3.2 Chemical Characteristics of the Tailings Dam Wastewater

The pH recorded in this study for the tailings dam wastewater (Table 1) could be described as slightly alkaline and was within the Ghana EPA standards (6-9) for effluent discharge into the environment. Although the pH of the process effluent was relatively high (data not shown), the tailings dam wastewater pH gradually decreased over time due to neutralization of the alkaline environment by rainwater and possibly also as a result of carbon dioxide uptake [19, 20]. The production of NO_3^- and SO_4^{2-} from the biodegradation of cyanide and thiocyanate [21] may have contributed to the lower pH value observed in the tailings dam. The result suggests that this wastewater exerts no negative effect on the environment as far as the pH is concerned.

The high values of the EC measured throughout the study period is due to the presence of electrolytes, such as Fe^{3+}, SO_4^{2-}, PO_4^{3-} and NO_3^- in the wastewater (Table 1). The EC values of the tailings dam effluent were high, probably due to increased concentration as a result of evaporation loses in the tailings dam.

Wastewater containing biodegradable organic matter decreases the DO of the receiving water due to

Table 1 Descriptive statistics of the tailings dam wastewater characteristics.

Parameters	Range	Mean (± SD)	GH EPA standards
Temperature (°C)	26.0-28.5	26.7 (± 1.46)	40.0
DO ($mg \cdot L^{-1}$)	0.9-7.1	2.9 (± 0.75)	5.0
pH	8.1-8.3	-	6.0-9.0
EC ($\mu S \cdot cm^{-1}$)	2,160-2,650	2,334(± 125)	750
Turbidity (NTU)	1.2-5.8	4.8 (± 2.5)	75.0
TDS ($mg \cdot L^{-1}$)	992-1,349	1,144 (± 66.9)	50.0
TSS ($mg \cdot L^{-1}$)	41-96	71 (± 12)	1,000
Cyanide ($mg \cdot L^{-1}$)	8.3-12.4	11.1(± 3.5)	0.2
As ($mg \cdot L^{-1}$)	3.89-5.21	4.5 (± 2.1)	0.2
Fe ($mg \cdot L^{-1}$)	22.6-29.2	25.2 (± 3.0)	2.0
SO_4^{2-} ($mg \cdot L^{-1}$)	320-560	450 (± 30.0)	250
NH_4^+ ($mg \cdot L^{-1}$)	60.0-88	74 (± 9.5)	1.5
NO_3^- ($mg \cdot L^{-1}$)	1.5-3.6	2.6 (± 0.5)	11.5
PO_4^{3-} ($mg \cdot L^{-1}$)	2.1-7.8	4.8 (± 1.5)	2.0
COD ($mg \cdot L^{-1}$)	92-150	130 (± 8.5)	250

microbial oxygen consumption in the water. The average DO values obtained (Table 1) were below the minimum EPA standard for industrial effluent [13]. The lower DO values recorded for the tailings dam wastewater (Table 1) during the study can be attributed to the poor aeration of the tailings dam, the low oxygen holding capacity of the wastewater in the dam as a result of the high tropical temperature [22] and the (bio) chemical oxidation of the sulphide ore minerals [23, 24].

The high levels of COD recorded for the wastewater may be attributed to the oxygen that is mainly required for the oxidation of both organic and inorganic compounds. The wastewater can thus be classified as inorganic with a high load of non-biodegradable compounds.

Nitrate is the most oxidized form of nitrogen compounds in water and wastewater and causes algal blooming, resulting in eutrophication in surface water [25, 26]. The tailings dam wastewater shows low levels of nitrate (Table 1), but the ammonium, phosphate and sulphate concentrations, on the other hand, were higher than the Ghana EPA standards (Table 1).

Contamination of the wastewater with heavy metals was the consequence of the processing method and the type of gold-bearing ore processed. Comparison of measured arsenic and iron concentrations to EPA standards for industrial effluent [13] indicates high iron and arsenic concentrations (Table 1). The high arsenic concentration in the tailings dam wastewater may partly be attributed to evaporation of water in the tailings dam. Furthermore, the arsenic concentration is also influenced by the pH of the wastewater. At low pH, most of the arsenic will be adsorbed onto ferric hydroxide particles and settle to the bottom of the dam [27]. However, the pH of the tailings dam was not low enough to lead to the natural adsorption of arsenic onto the TSS and accumulation by TSS settling in the dam. Consequently, the soluble arsenic concentration in the liquid phase in the dam remained high, and far exceeded the EPA discharge limit for industrial effluent [13].

The cyanide contamination was due to its use as a process chemical. The lower concentrations of cyanide measured in the tailings dam wastewater may be attributed to the natural removal processes, mainly volatilisation, complexation and biodegradation [20]. Naturally occurring microbial action causes transformation of cyanide to NH_3 (ammonia). The cyanide reacts with the sulphide minerals and partially oxidise sulphur intermediates to produce thiocyanate [21]. Although the biodegradation of cyanide reduces the free cyanide concentration, it results in the formation of by-product, such as cyanate, thiocyanate, sulphate, ammonia, nitrate and elevated metal concentrations [21]. Thiocyanate is less toxic and more stable than cyanide [28]. The rate of natural conversion of cyanide to NH_3 largely depends on environmental conditions and may not produce an effluent of desirable quality that meets discharge regulations [27]. In the case of the tailings dam at Bibiani, the continuous discharge of fresh tailings into the dam may impede the rate at which the natural cyanide transformations occur.

4. Conclusions

The tailings dam wastewater quality of the Central Africa Gold Limited was studied. Almost all the parameters measured were found to exceed the permissible limit set by the Ghana EPA and the WHO guideline values. Iron, arsenic and cyanide were identified as the most toxic constituents. The wastewater from the tailings dam cannot be discharged into the environment without prior treatment. Any treatment technology for this wastewater must focus on these contaminants.

The study showed that the tailings dam is an effective settler, removing over 99% of TSS and the turbidity. Due to continuous loading of the tailings dam with fresh process effluent, the rate of biodegradation of cyanide and organic matter may be low. However, the dam is able to contain the toxic effluent and prevent pollution of the environment with heavy metals and cyanide.

Acknowledgment

This work was financially supported by the Government of Ghana through the annual Book and Research Allowance. The authors are grateful to the Central African Gold Limited for providing laboratory facilities. We further acknowledged the Rector of Kumasi Polytechnic, Professor Nicholas Nicodemus Nana Nsowah-Nuamah for his encouragement.

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Journal of Environmental Science and Engineering A 2 (2013) 476-486
Formerly part of Journal of Environmental Science and Engineering, ISSN 1934-8932

Application of Livelihood Vulnerability Index to Assess Risks from Flood Vulnerability and Climate Variability—A Case Study in the Mekong Delta of Vietnam

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Received: April 28, 2013 / Accepted: July 22, 2013 / Published: August 20, 2013.

Abstract: An Giang province in the Mekong Delta is the most vulnerable province the impact of flooding and climate variability. Thousand of households are at risk due to severe annual floods. This study applied the LVI (livelihood vulnerability index) to estimate flood vulnerability of Phu Huu and Ta Danh villages in An Giang province. Data on socio-demographics, livelihoods, health, social networks, physical, financial and natural resources, natural disasters and climate variability were collected from a survey of 120 households in each village. From these data the LVI of each village was calculated. Results show that the overall LVI of Phu Huu village, located in the early flooded zone, is higher than that of Ta Danh village, located in the late flooded zone. The analysis also indicated that this practical method can be applied for other purposes such as to monitor vulnerability, evaluate development programs or policy effectiveness by incorporating with scenario comparison.

Key words: An Giang province, Mekong Delta, livelihood vulnerability index, flood and climate variability.

1. Introduction

River deltas, with their dense populations and food production systems, are the most important regions in many countries. However, due to their locations at the end of river basins, floods usually occur with large volumes of water from upstream catchments. Although the water level rise and flow velocity are not as high as at upstream sloping lands, floods in the deltas usually last many days or even many months each year. Such flood types cause damage over a large area and influence the livelihoods of a great number of people. Under climate change with the possibility of higher rainfall variability, the heavily populated mega deltas are expected to be at greatest risk of increased river and coastal flooding [1].

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To estimate climate change vulnerability the LVI (livelihood vulnerability index) was developed by using multiple indicators to assess exposure to natural disasters (including floods) and climate variability, social and economic characteristics of households that affect their adaptive capacity, and current health, food, and water resource characteristics that determine their sensitivity to climate change impacts [2]. The LVI analysis was first applied in Mozambique [2], then in other countries: Nepal, Ghana, Trinidad and Tobago, and in other studies [3-7].

In the Vietnamese Mekong Delta, flooding is a recurring seasonal event. About 2.7 million ha of land are located in flood-prone areas and thousands of villagers are vulnerable to floods [8-10]. Additionally, floods are associated with climate variability and flooding in this delta will become more serious in the future, and are expected to increase in duration, number, and frequency [11, 12].

An Giang province is located at the upper part of the Vietnamese Mekong Delta and is the most vulnerable province to floods. For instance, the 2000's flood killed 134 inhabitants, destroyed 151,867 houses, and caused a damage cost of about US $42 million [13]. After the 2000's flood, despite the effort of local governments, especially in improvement of "structural measures" and "concrete measures", including investment in dikes, local people still suffer from flood damage every year [14]. Recently, the flood in 2011 caused severe losses in infrastructure and agriculture [15]. Most of the An Giang population is engaged in agriculture, typically in rice cultivation, with over 20% living in flood-prone areas and income below the poverty line [15]. Therefore, there is a major concern that floods will cause rural poverty as it poses a major threat to people's livelihoods and properties through destructive impacts on infrastructure and the environment as well as disturbance to livelihood activities.

This study aims to improve understanding of people's livelihoods and vulnerability in flood-prone areas of An Giang province. It is based on an empirical study of livelihood assets and application of LVI. The LVI analysis is designed to provide development organizations and local policy makers with a practical method to understand demographic, social and other related factors contributing to flood vulnerability at the community or district levels.

2. Materials and Methods

This study adopted the Sustainable Livelihood Framework [16] to guide the assessment of livelihood vulnerability to floods. The SLF (sustainable livelihood framework) where vulnerability context is a major determinant of sustainability of livelihood assets as it directly influences livelihood strategies, institutional process, and livelihood outcomes of the community [17, 18]. Under the context of SLF the vulnerability level of a community determines the impacts of floods and climatic conditions on people's livelihood assets and strategies.

2.1 Constructing LVI

This study aimed to calculate the level of vulnerability under impacts of extreme floods and climate variability in two flooded villages of An Giang province by applying the LVI developed by Hahn [2]. Indicators, or sub-components, of community vulnerability to flood impacts are grouped into 10 major components presented in Table 1. These components, classified under 5 different livelihood assets of HHs (households) in the SLF: human, physical, social, natural, financial capitals, comprise of health, knowledge and skills, livelihood strategy, land, natural resources, natural disasters and climate variability, socio-demographic, social networks, housing and production means, and finance and incomes. Each major component includes several indicators or sub-components developed based on available data collected through household surveys on flood impacts in An Giang province.

2.2 Calculating the LVI

In this study the LVI was calculated by applying a balanced weighted average approach [2, 19]. Each sub-component contributes equally to the overall index even though each major component comprises of different numbers of sub-components. A simple method with equal weights was applied for all major components. Because each sub-component is measured on a specific scale, it was therefore normalized as an index. For this purpose the equation used in the human development index to calculate the life expectancy index [20], and in LVI to assess risks [2] was applied:

$$index_{sv} = \frac{S_v - S_{\min}}{S_{\max} - S_{\min}} \quad (1)$$

where, S_v is the value of sub-component for village *v;* S_{min} and S_{max} are the minimum and maximum values,

Table 1 Capitals, major components and sub-components comprising the livelihood vulnerability index.

Capitals	Major component	Sub-component/indicator
Human	Health	Percentage of HHs with ill family member (s)
		Percentage of HHs with family member (s) getting illness due to flood
	Knowledge & skills	Percentage of unlettered HH heads
		Percentage of HH heads just passed primary school
	Livelihood strategies	Percentage of HHs without any training to cope with flood
		Average agric. livelihood diversity [1/ (No. of agric. activities + 1)]
		Percentage of HHs depending on agriculture as major source of income
		Percentage of HHs without non-farm activities affected by flood
		Percentage of jobless HHs during flood season
		Percentage of HHs exploring natural resources during flood season
		Percentage of HHs do fishing during flood season
Natural	Land	Percentage of landless HHs
		Percentage of HHs with small farm (0.1-0.5 ha)
	Natural resources	Percentage of HHs that do not cultivate the 3rd crop
		Percentage of HHs depending on or exploiting natural resources
		Percentage of HHs depending on or doing fishing during flood
	Natural disasters and climate variability	Average number of severe floods in the past 10 years
		Average of death/injury due to floods in past 10 years
		Percentage of HHs that do not receive flood warning
		Mean standard deviation of monthly average water level in last 5 years 2007-2011
		Mean standard deviation of monthly average precipitation in last 5 years 2007-2011
Social	Socio-demographic conditions	Dependency ratio
		Percentage of HH female heads
		Average HH family member
	Social networks	Percentage of poor HHs
		Percentage of HHs receiving helps due to flood
		Percentage of HHs that have not been member of any organization
Physical	Housing & production means	Percentage of HHs without solid house
		Percentage of HHs with house affected by flood (partially to totally submerged)
		Percentage of HHs without access to production means
Financial	Finance and incomes	Percentage of HHs borrowing money
		Percentage of HHs with annual net HHs income lower than US $ 1,000
		Percentage of HHs without income during flood season

Note: HH (s) = Household (s).

respectively, from data of that sub-component in both villages.

After normalizing sub-component values, the value of each major component was calculated by Eq. (2):

$$M_{vj} = \frac{\sum_{i=1}^{n} index_{svi}}{n} \qquad (2)$$

where, M_{vj} is value of major component j for village v; $index_{svi}$ represents the value of sub-component s indexed by i of major component M_j; and n is the number of sub-components in major component M_j.

These ten major component values were directly used in Eq. (3) or aggregated to five values for livelihood assets [H (Human capital), N (Natural capital), S (Social capital), P (Physical capital) and F (Financial capital)] before used in Eq. (4) to obtain the weighted average of LVI:

$$LVI_v = \frac{\sum_{j=1}^{10} w_{M\,j} M_{vj}}{\sum_{j=1}^{10} w_{Mj}} \qquad (3)$$

$$LVI_v = \frac{w_H H_v + w_N N_v + w_S S_v + w_P P_v + w_F F_v}{w_H + w_N + w_S + w_P + w_F} \quad (4)$$

where, LVI_v is the livelihood vulnerability index of village v; w_{Mj} is weight value of major component j; w_H, w_N, w_S, w_P, w_F are weight value of asset H, N, S, P, F, respectively. The LVI is ranged from 0 to 1; 0 denoting least vulnerable and 1 denoting most vulnerable.

2.3 Study Area and Household Surveys

The study and surveys were carried out at two villages, Phu Huu and Ta Danh, in a flood-prone area in An Giang province (locations in Fig. 1), the most flood affected province in the Mekong Delta. The province has a total area of 353,676 ha, of which 297,872 ha are agricultural lands with mainly rice crops. The provincial population is 2,273,150 people of which 72% live in rural areas. People living in flood-prone areas are poorer than those living in non-flooded areas. These two villages are situated in different zones. The Phu Huu village is located in an early-flooded zone with seasonal floods from early July to October, whereas the Ta Danh village is located in late-flooded zone with seasonal floods from late July to November.

Phu Huu is a densely populated village in An Phu district (Fig. 1) with 4,460 HHs, of which 1,160 HHs (26%) are poor. The village has a total natural area of about 4,000 ha, of which 3,555 ha are used for agricultural production. The major crops are rice, groundnuts and beans. The village is rich with natural resources, especially fish from river during flood season. During the last 10 years, irregular floods often occurred and caused huge damage in both economic and non-economic sectors.

Ta Danh village in the Tri Ton district (Fig. 1) has 1,805 HHs of which 450 HHs (25%) are poor and 115 HHs (6%) were resettled in the flood-protected-residential polders. The village has a total natural area of about 5,040 ha, of which 969 ha are used for rice production with three crops per year. Livestock, including cattle, pig, chicken and especially duck raising in the paddy fields after harvesting or during a flood, is another

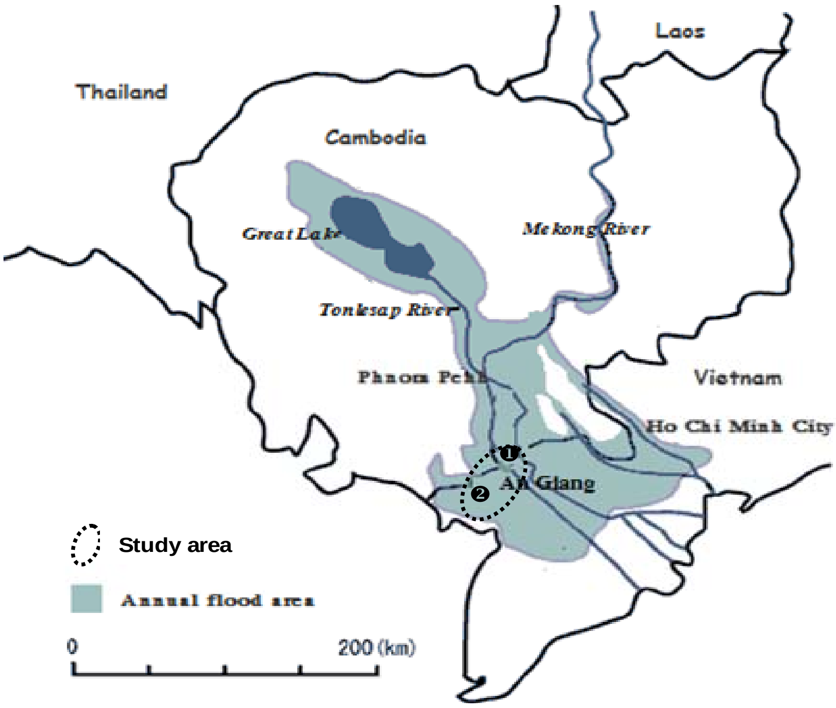

Fig. 1 Location of the study area in An Giang province, Mekong Delta, Vietnam.

Note on study area: (1) Phu Huu village of An Phu district in early flooded zone; (2) Ta Danh village of Tri Ton district in late flooded zone.

source of income. This village is known as one of the predominant villages for rice production in the flood-prone area

Households to survey were selected by wealth-ranking stratification, approximately 120 HHs with 40 poor, 40 medium and 40 better-off HHs in each village. Two other criteria were living in the area most vulnerable to flood and belonging to different social groups. Interviews were conducted by staff from Can Tho University, the major university in the Mekong Delta, and local partners in the province. The survey questionnaire was based on sub-components or indicators presented in Table 1. Ten focus group discussions, each comprising of 7-10 household heads from different social groups, were organized to gather information at community level.

3. Results and Discussion

The flooding in 2011 was the worst in An Giang province of the past few years. It killed 23 people and caused damages of US $49 million to the economy, including US $10.5 million in agriculture. However, our surveys in the Ta Danh and Phu Huu villages were implemented in June before the peak of this flood in September, therefore respondents might not reflect these damages in their answers to some indicators.

LVI values of all 31 sub-components, 10 components and 5 capitals are presented in Table 2. The overall LVI of Phu Huu village is 0.488 which makes Phu Huu’s livelihoods moderately vulnerable to flooding and climate variability. This value is higher than the overall LVI of 0.432 of Ta Danh village. In the following section, vulnerability assessments for all 5 capitals, and respective major components are discussed in details.

3.1 Human Capital Vulnerability

The human capital index of Phu Huu village (0.428) is higher than that of Ta Danh (0.374) due to its slightly higher health, knowledge and skills, and livelihood strategy indexes (Table 2). The greater Health index of Phu Huu village is caused by higher proportion of households with family member getting illness due to flood (6% vs. 3% in Ta Danh village). Phu Huu village also has greater knowledge and skills index than Ta Danh village (0.664 vs. 0.588). This is caused by higher index of unlettered household heads of Phu Huu village (0.419 vs. 0.194), and higher index of household heads just passed primary school (0.653 compared with 0.630). In terms of livelihood strategies, Phu Huu village has higher vulnerability index than Ta Danh village (0.443 vs. 0.386) due to high numbers of households depending on agriculture as major source of income, without non-farm activities and jobless during flood season.

The details indicated that the higher Human capital index of Phu Huu village are mainly from these sub-components: percentage of unlettered HH heads, percentage of HHs depending on agriculture as major source of income and percentage of HHs without non-farm activities affected by flood. This result shows that interventions such as improvement of education level, diversification of income sources, and engaging into more non-farm activities can reduce the vulnerability to flooding and climate variability. Of these three interventions, the second and the third are more challenging because Phu Huu village is located in the early flooded zone, while the first does not relate much to the flood situation and hence can be done easier.

3.2 Natural Capital Vulnerability

Land is the most important asset and indicator of wealth, therefore in this study, landless or small farms owned by farmers are considered higher vulnerable to flood and climate change. Phu Huu village has slightly lower land ownership index than Ta Danh (0.277 vs. 0.294) because it has lower percentage of landless HHs (27% vs. 39%) although its percentage of small farm HHs is higher (29% vs. 19%). These percentages are partly caused by land resources (Ta Danh is larger and lower population density, therefore farm size is

Table 2 LVI of all sub-component values, major components and capitals for Phu Huu and Ta Danh villages.

Sub-component	Phu Huu	Ta Danh	Major component	Phu Huu	Ta Danh	Capitals	Phu Huu	Ta Danh
% of HHs with ill family member (s)	0.057	0.031	Health	0.029	0.016	Human	0.428	0.374
% of HHs with family member(s) getting illness due to flood	0.000	0.000						
% of unlettered HH heads	0.419	0.194	Knowledge & skills	0.664	0.588			
% of HH heads just passed primary school	0.653	0.630						
% of HH heads without any training to cope with flood	0.921	0.940						
Average agric livelihood diversification [1/(number of agric. livelihood activities + 1)]	0.063	0.063	Livelihood strategies	0.443	0.386			
% of HHs depending on agriculture as major source of income	0.951	0.842						
% of HHs without non-farm activities affected by flood	0.829	0.752						
% of jobless HHs during flood season	0.350	0.330						
% of HHs exploring natural resources during flood season	0.106	0.008						
% of HHs do fishing during flood season	0.358	0.320						
% of land less HHs	0.269	0.395	Land	0.277	0.294	Natural	0.339	0.286
% of HHs with small farm (0.1-0.5 ha)	0.285	0.193						
% of HHs that do not cultivate the 3rd crop	0.825	0.752	Natural resources	0.430	0.384			
% of HHs depending on exploiting natural resources	0.106	0.080						
% of HHs depending on or doing fishing during flood	0.358	0.320						
Average number of severe floods in the past 10 years	0.040	0.030	Natural disasters and climate variability	0.309	0.224			
Average number of death/injury due to floods in the past ten years	0.089	0.059						
% HHs that do not receive flood warning	0.095	0.072						
Mean standard deviation of monthly average water level in last 5 years 2007-2011	0.758	0.395						
Mean standard deviation of monthly average precipitation in last 5 years 2007-2011	0.562	0.562						
Dependency ratio	0.309	0.257	Socio-demographic conditions	0.408	0.372	Social	0.554	0.484
% of female HH heads	0.485	0.493						
Average HH family member	0.486	0.348						
% of poor HHs	0.350	0.391						
% of HHs receiving helps due to flood	0.772	0.554	Social networks	0.846	0.708			
% of HHs that have not been member of any organization	0.919	0.861						
% of HHs without solid house	0.626	0.592	Housing and production means	0.618	0.414	Physical	0.618	0.414
% HHs with house affected by flood (partially to totally submerged)	0.732	0.126						
% of HHs without access to production means	0.496	0.525						
% HHs borrowing money	0.515	0.488	Finance & incomes	0.616	0.519	Financial	0.616	0.519
% HHs with annual net income lower than US $ 1,000	0.829	0.683						
% HHs without income during flood season	0.505	0.385						
Overall LVI (weighted average of human, natural, social, physical, financial capitals)								
LVI—Phu Huu	0.488							
LVI—Ta Danh	0.409							

usually larger) and natural conditions (Ta Danh is located in the deeply flooded zone), and partly due to the development history (recently Ta Danh village became destination of landless people due to improved accessibility, living conditions and labor demand while Phu Huu has been developed many years ago).

In terms of natural resources, Phu Huu village has higher index than Ta Danh village (0.430 vs. 0.384) mainly due to higher percentage of HHs that do not cultivate third crop (83% vs. 75%). Other sub-components, percentage of households depending on or exploiting natural resources (11% vs. 8%) and percentage of HHs depending on fishing (36% vs. 32%) also contribute partly to this higher index.

Phu Huu village also has higher index on natural disasters and climate variability than Ta Danh village (0.309 vs. 0.224) because of its location in the earlier flood zone. The major sub-component contributing to this higher index is the mean standard deviation of monthly average water level in last 5 years (0.758 vs. 0.395). Other sub-components as number of severe floods (4 vs. 3), number of deaths/injuries due to floods (12 vs. 8), and percentage of HHs that do not receive flood warning (9.5% vs. 7.2%) also contribute a small part to this higher index.

As a result, the weighted average of three components indices, i.e., the vulnerability index of Natural capital of Phu Huu village is higher than that of Ta Danh village (0.339 vs. 0.286) due to its higher values of the natural resources and natural disasters, although its land index is slightly lower. This difference reflects the high vulnerability due to its location in the early flooded zone.

3.3 Social Capital Vulnerability

Phu Huu village has higher dependency ratio and average HH size than Ta Danh (0.309 vs. 0.257, and 4.43 vs. 3.73, respectively) but slightly lower percentage of female HH head (48.5% vs. 49.3%) and lower percentage of poor household (35% vs. 39%). These four sub-components generate a higher socio-demographic component index (0.408 vs. 0.372). It also has a higher social networks index (0.846 vs. 0.708) because of a higher percentage of HHs receive help due to flood (77.2% vs. 55.4%), and a higher percentage of HHs that have not been member of any organization (91.9% vs. 86.1%). These results indicate a need for strengthening community networks and local organizations such as Woman Union, Farmer Associations, Red Cross, etc. at the village level to reduce social capital vulnerability. The weighted average of socio-demographic and social networks components, i.e., the Social vulnerability index of Phu Huu village is higher than that of Ta Danh (0.554 vs. 0.484). This higher index does not relate to the location of Phu Huu village in early flood zone and can be improved by social programs.

3.4 Physical Capital Vulnerability

Survey results show a higher percentage of HHs without solid houses in Phu Huu village (62.6% vs. 59.2%). The percentage of HHs with houses affected by flood (partly to totally submerged) was 73% in Phu Huu village and 13% in Ta Danh village. 49.6% of Phu Huu HHs reported that they did not have access to production means such as a water pump, sprayer, boat or fishing nets) compared to 52.5% in Ta Danh village. The combination of these three sub-components provides a higher Physical vulnerability index for Phu Huu village (0.618 vs. 0.414). This higher index depends to the HH economy in Phu Huu village that could be influenced by its location in the early flooded zone.

3.5 Financial Capital Vulnerability

In Phu Huu village, 51.5% of HHs have to borrow money during flood season, while that percentage in Ta Danh is 48.8%. Phu Huu village also has a higher percentage of HHs without income during the flood season and net income below US $ 1,000 (50.5% vs. 38.5% and 82.9% vs. 68.3%, respectively). These three sub-components generate higher financial

Table 3 LVI by wealth group in PH (Phu Huu) and TD (Ta Danh) villages.

Household assets	Index by wealth groups in PH			Index by wealth groups in TD		
	Better-off (*n* = 32)	Poor (*n* = 38)	Mix group (*n* = 120)	Better-off (*n* = 32)	Poor (*n* = 40)	Mix group (*n* = 120)
Human	0.298	0.435	0.428	0.267	0.393	0.374
Natural	0.295	0.355	0.339	0.244	0.295	0.286
Social	0.402	0.555	0.554	0.347	0.495	0.484
Physical	0.583	0.648	0.618	0.332	0.441	0.414
Financial	0.442	0.621	0.616	0.369	0.562	0.519
Overall LVI	0.378	0.499	0.488	0.309	0.428	0.409

vulnerability index of Phu Huu village than that of Ta Danh (0.616 vs. 0.519).

In this study, we only present the LVI of better-off, poor, and mixed groups by using data obtained from better-off, medium-income and poor HHs. However, the LVI of the medium group was not calculated separately because the wealth identification of household surveys was insufficient. These data in Table 2 and mix group in Table 3 are for all respondents, i.e., combination of all better-off, poor and medium (without proper wealth identification). LVI and capital indexes by wealth group (Table 3) confirm that the poor group is most affected and the better-off group is least vulnerable in both Phu Huu and Ta Danh villages. Apparently better-off HHs are experienced people, having stable jobs and high levels of knowledge and skill, whereas poor HHs are usually landless or small farm people who are facing with financial deficit, having poor production means and possessing low quality houses that are easily damaged by floods. The indexes of better-off, poor and mixed groups are 0.378, 0.499 and 0.488 in Phu Huu village and 0.309, 0.428 and 0.409 in Ta Danh village respectively. These show closer values between the mixed and poor groups (0.01-0.02 differences), but much lower values of better-off group (about 0.1 lower than other groups). This reflects the wealth structure in these two villages with a small group at better-off level compared with the majority at medium and poor levels.

Overall, Phu Huu village has higher LVI than Ta Danh village (0.488 vs. 0.409), indicating relatively greater vulnerability to flood and climate variability. The results of ten major components are presented collectively in a spider diagram (Fig. 2) with scale in 0.1 unit increments, from 0 (less vulnerable) at the center of the web to 0.9 (most vulnerable) at the outside edge. The diagram reflects well that Phu Huu village is more vulnerable in most components, in particular housing and production means, finance and incomes and social networks and; whereas Ta Danh village is slightly more vulnerable in land component. With the same trend, the diagram in Fig. 3 shows that Phu Huu village is more vulnerable in all capitals compared with Ta Danh village, with high difference in physical, financial and social capitals. These results indicate clearly which capitals should be taken into account for reducing livelihood vulnerability of these villages.

4. Conclusions

Practically, the assessment of livelihood vulnerability is complicated because there are many related aspects, dimensions, and factors such as natural resources, economic and social conditions, demography as mentioned in some reports [19, 21, 22]. This case study only focuses on some major components that influence HH assets by flood and climate variability. The sub-components used to construct the LVI in this study were based on the current conditions of our study sites, available data from HH surveys and focus group discussions. Therefore, they can only be used as references for other cases with different conditions and available

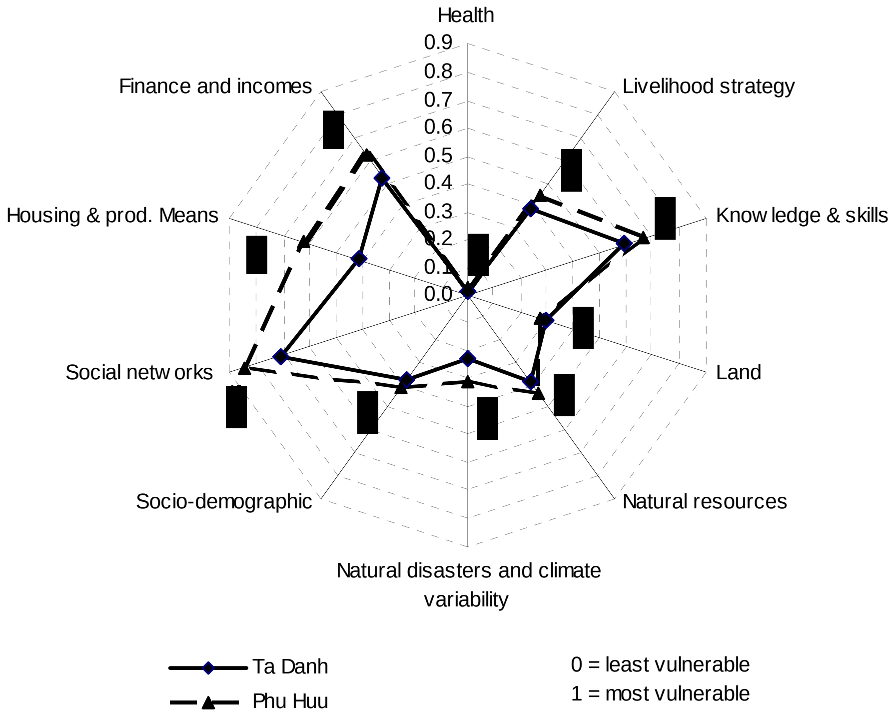

Fig. 2 Vulnerability diagram of major components of Phu Huu and Ta Danh villages.

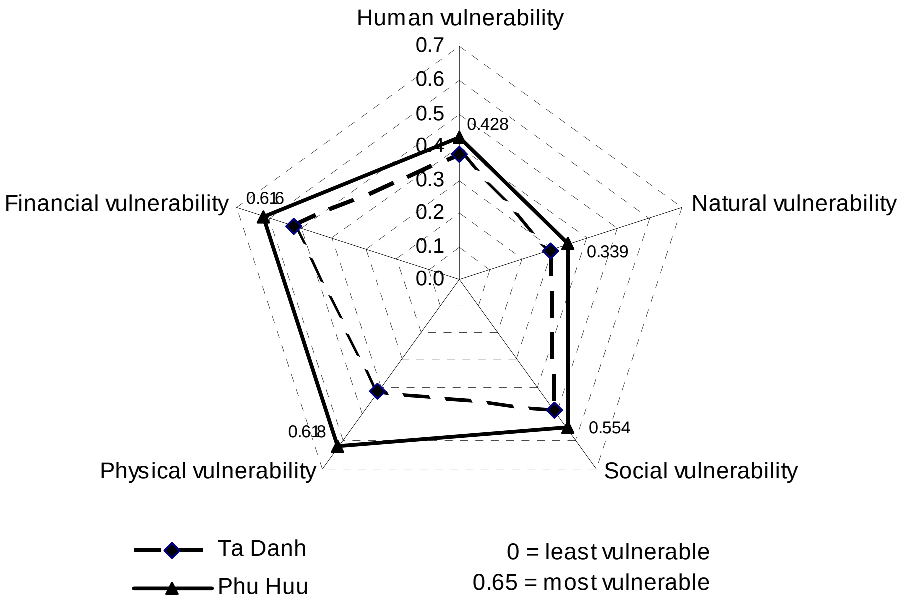

Fig. 3 Vulnerability diagram of five capitals of Phu Huu and Ta Danh villages.

data, and they can be updated or improved when situations are changed (e.g., better flood protection by dike or social programs implemented) or more information and data are available (e.g., more details on HH income possibilities or infrastructure improvement).

In general, our LVI analysis shows that Phu Huu village, located in the early flooded zone is more vulnerable to flood and climate variability then the Ta Danh village located in the late flooded zone. Hence, the LVI could arguably capture main characteristics of villages at different locations in flooded area and present a set of comparable and useful indexes to prioritize the supports needed to reduce their vulnerability.

Additionally, the analysis of LVI based on wealth also shows that the poor are the most susceptible to flood and climate variability. However, we did not include the wealth ranking questions in the survey but only based on the classification list provided by local authorities. Therefore, for future LVI analysis of wealth groups, it is proposed that wealth ranking will be include in the survey to assure proper correspondence of datasets.

Somehow the use of sub-components and indexes in the LVI approach simplifies the complex reality and there is no easy way to validate indices encompassed by unrelated sub-components. Directionality of sub-components is also arguable, for instance, in this study, higher percentages of female HH heads or of landless/small farm HHs increase community's vulnerability to flood. Moreover, in data interpretation, separating effects of flood and climate variability from other influencing factors is also a challenge and requires deep knowledge of local conditions, including natural resources, development level and socio-economic aspects. Culture of ethnic groups, that could be a sub-component of LVI, has not been included yet in this study.

In conclusion, the LVI analysis could be applied as a practical method to identify vulnerable communities, to understand factors contributing to vulnerability at community level and also to prioritize the potential interventions recommended to policy makers, local authorities and development organizations.

Acknowledgments

This paper is an output from projects funded by the Swedish government through Swedish international development cooperation agency (Sida) and delivered through the SUMERNET (sustainable Mekong research network) programme for the benefit of developing countries. The authors would like to express their sincere gratitude to these supporters. The authors also wish to acknowledge the generous support of all researchers and institutions, especially the leaders of An Giang Provincial CFSC (committee for flood and storm control), the village leaders and farmers in Phu Huu and Ta Danh villages who closely worked with them during study.

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Journal of Environmental Science and Engineering A 2 (2013) 487-493
Formerly part of Journal of Environmental Science and Engineering, ISSN 1934-8932

Contribution of Ground-Based Cloud Observation to Satellite-Based Cloud Discrimination

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Received: April 18, 2013 / Accepted: June 23, 2013 / Published: August 20, 2013.

Abstract: One of the biggest factors to deteriorate the satellite product quality is cloud coverage. Therefore, cloud masking process is important to improve the quality of various satellite products. However, satellite-based cloud discrimination algorithm has been developing and efficient ground-based cloud observations are necessary to validate satellite-based cloud discrimination. The purpose of this study is to develop the efficient ground-based cloud observation methodology using whole sky camera. This paper deals with methods how to discriminate cloud portions on whole sky image, how to apply the ground-based cloud observation to the validations for satellite products. For the cloud discrimination on whole sky image, we propose *SI* (sky index) and *BI* (brightness index) calculated from RGB (red, green and blue) channels. *SI* shows the extent of the blueness and gray scale and *BI* indicates the extent of the brightness. Sun, cloud and blue sky portions are divided by *SI* and *BI* threshold. As an application of ground-based cloud observation for the validation of satellite products, clouds portions discriminated from whole sky image are projected onto ground surface with map coordinate. We also examine to compare with cloud portions on whole sky images and MODIS (MODerate resolution imaging spectroradiometer) image as one of experiments. The proposed ground-based cloud observation method and its extension to satellite-based cloud discrimination should be connected to improve the quality of satellite products.

Key words: Cloud discrimination, whole sky camera, *SI* (sky index), *BI* (brightness index).

1. Introduction

Cloud observation and discrimination are essential to improve the quality of satellite products which are some physical values such incident solar radiation and PAR (Photosynthetic Active Radiation) etc.. After launching Terra and Aqua satellites, MODIS (MODerate resolution imaging spectroradiometer) has become to be a key sensor for generating various products with some physical values to understand global environmental change. However, cloud cover is one of the biggest factors to decrease the satellite product quality. The MOD35 is known as the cloud mask product in MODIS atmospheric field. It is indispensable to improve the quality of all MODIS products. The cloud mask aim to minimize the potential errors resulting from cloud contamination by labeling every pixel of data as either confident clear, probably clear, uncertain or confidently cloudy. However, even in case of clear sky by lidar/radar observation at ground level, many pixels are labeled as probably clear in four categories of MODIS cloud mask [1]. Furthermore, there are still some uncertainness in satellite-based cloud observation such as cloud motion, cloud coverage, cloud type and these effects. Therefore, the efficient ground-based cloud observation is necessary to contribute satellite-based cloud discrimination such existing Terra & Aqua/MODIS and under planning GCOM-C (global change observation mission-climate)/SGLI (second generation global imager) etc.. From such backgrounds, the ground-based cloud observation system has been

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developed by using whole sky camera in world widely instead of existing visual observation [2-5].

Here, the purpose of this study is to develop the efficient ground-based cloud observation methodology in order to contribute to satellite-based cloud discrimination and its validation. This paper mainly deals with methods how to discriminate the cloud portions on whole sky images and how to apply ground-based cloud discrimination to the satellite products using MODIS image as one of experiments. Through this experiment, the possibility of ground-based cloud observation is discussed.

2. Ground-Based Cloud Observation

2.1 Camera System

ADFC (automatic-capturing digital fisheye camera) is the instruments to take and accumulate the whole sky images. ADFC consists of digital camera (Nikon, Coolpix4500) with fisheye lens (Nikon, Fisheye Converter FC-E8), waterproof hard case and remote controlled cable connected to PC [6].

In order to decrease the influence for CCD (charge coupled device) saturation caused by the strong sun light, the neutral density filter with 10% transparency (FUJIFILM, ND1.0) puts between the digital camera and the fisheye lens. The camera is set up to take images at every two-minute interval by fixed exposure of the aperture as F2.8 and shutter speed as 1/500 s. In the case of this fixed exposure, these pixels of only sun and its circumference are saturated. The image has 2,204 pixels by 1,704 lines with RGB (red, green and blue) colors and JPEG (joint photographic experts group) (1/4 compressed) format instead of RAW or Tiff format to accumulate the large volume of image files. In this study, we already have confirmed that the almost no influences between JPEG (1/4 compressed) and RAW/Tiff formats after image processing. Also, DN (digital number) of RGB channels can be used instead of radiance by fixing aperture and exposure. The head of digital camera of ADFC is fixed to north direction and leveled to horizon.

2.2 Discrimination of Cloud, Blue Sky and Sun

The sky conditions consist of each state of sun, clouds and blue sky. In order to discriminate the sky conditions from whole sky images, we use two indices which show the levels of the blueness/grayscale and the brightness calculated from each image. Here, the method how to discriminate the sky conditions is described. Fig. 1 shows the flowchart to discriminate and classify cloud and blue sky portions from the whole sky image taken at the time (*t*).

In order to discriminate cloud and blue sky portions from the whole sky images, we propose *SI* (sky index) and *BI* (brightness index) which are calculated from RGB channels of the image. *SI* shows the blueness/grayscale and *BI* shows the brightness in pixels. *SI* and *BI* are expressed by Eqs. (1) and (2).

$$SI = \frac{DN_B - DN_R}{DN_B + DN_R} \quad (1)$$

$$BI = \frac{DN_B + DN_G + DN_R}{(2^n - 1) * 3} \quad (2)$$

where,

DN_B: digital number of Blue channel;
DN_G: digital number of Green channel;
DN_R: digital number of Red channel;
n: bit number of quantization level.

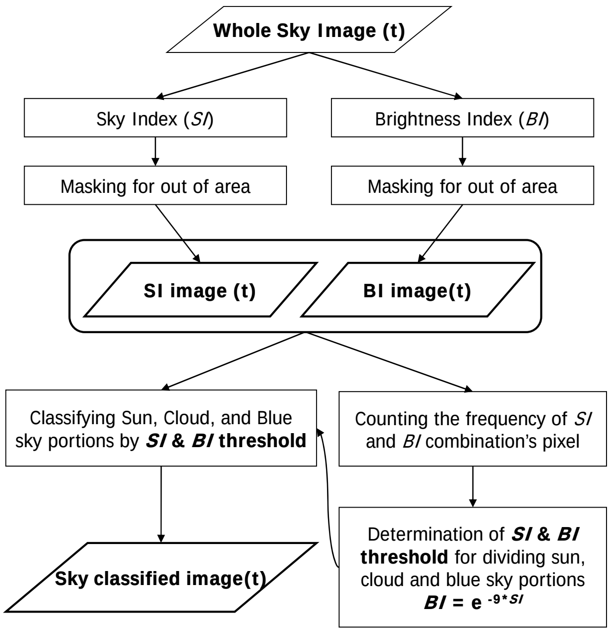


Fig. 1 The flowchart of cloud, blue sky and sun discrimination by whole sky images.

SI values have the range between -1.0 to 1.0. The blue sky portion in the RGB image has the higher digital number in blue channel and the lower digital number in red channel. On the other hand, the clouds show white or grey on the image. Thus, the higher value of *SI* shows bluer sky, the value of near zero shows the clouds and the sun. *BI* values are expressed by the range between 0 and 1.0. The bright pixels on the image show high *BI*. The pixels in the sun portion have $BI = 1$ and $SI = 0$.

Fig. 2 shows the frequency of *SI* and *BI* combination's pixel on one whole sky image taken at fair weather condition.

Two peaks can be seen as bright portions. They are cloud and blue sky. The low frequency can be seen between two peaks clearly as dark portion. Therefore, it seems that cloud and blue sky boundary can be identified by using low frequency's coordinates between the peaks of cloud and blue sky portions.

Fig. 3 shows the graph of *SI*&*BI* threshold curve for dividing cloud and blue sky portions. The whole sky images consisted of the sun, clouds and blue sky are classified by the threshold curve which was derived from two dimensions of *SI* and *BI* coordinates. The threshold curve for sky and cloud portions boundary was determined by counting the accumulated frequency of *SI* and *BI* combination's pixel from over 200 images taken around noon time for one year.

In this case, the threshold curve was used as $BI = e^{-9*SI}$. When the coordinates plot under the threshold curve, these are classified as cloud portion. The coordinates upper the curve are classified as blue sky portion. The sun portion on the image has the coordinates of $SI = 0$ and $BI = 1$. In this way, the sky classified image is generated by *SI* & *BI*.

3. Application of Ground-Based Cloud Discrimination to Satellite Products

As for the application of the cloud discrimination by ground-based cloud observation for validation of satellite products, it is necessary to overlay both whole sky image and satellite image. Here, we describe the method to project the cloud portions on whole sky image onto ground surface plane with map coordinates.

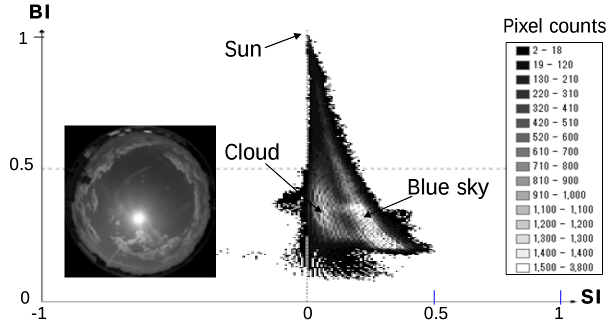


Fig. 2 Frequency of SI and BI combination's pixel on one whole sky image.

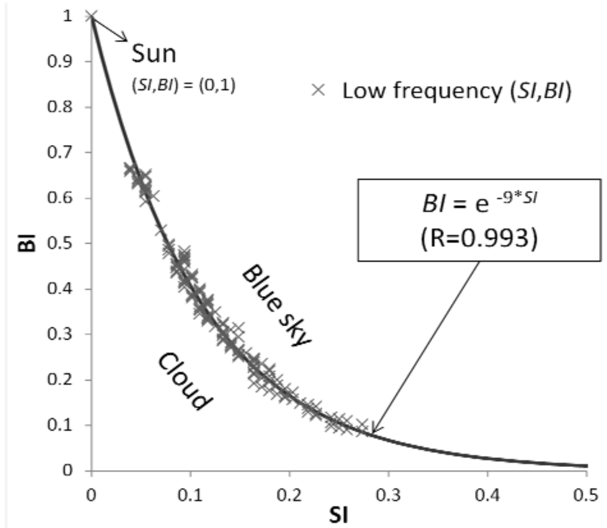


Fig. 3 *SI* & *BI* threshold to divide cloud and blue sky portions.

3.1 Projection of Fisheye Lens

Our used fisheye lens has equidistant projection. In case of setting the ADFC fixed to north direction and leveled horizontally, the center pixel of whole sky (hemisphere) image corresponds to the zenith.

According to equidistant projection, the distance from the image center is in proportion to zenith angle shown in Eq. (3).

$$\frac{d_{ed}}{R} = \frac{\theta}{90} \tag{3}$$

Where,

d_{ed}: distance from zenith (pixels);

R: Radius of whole sky image (pixels);

θ: Zenith angle (degrees).

Fig. 4 shows equidistance projection by fisheye lens and its projected whole sky image.

Consequently, the zenith (θ) and azimuth (ϕ) angles on whole sky image are able to calculate from the image coordinates (u, v). The *HD* (horizontal distance) from the ground-based observation point, that is central position of whole sky image, to the target cloud can be estimated by given the approximate cloud height supposed from each cloud type. And then, the cloud portions on whole sky image are projected to map coordinates (x, y) using θ, ϕ and *HD*.

In these calculation and conversion, any distortions of fisheye lens and the curvature of ground surface are left out of considerations.

3.2 Calculation of Zenith and Azimuth Angles

Calculation of zenith and azimuth angles at any hemisphere image coordinates can be shown in Eqs. (4) and (5).

$$\theta_i = \sqrt{(u_i - u_o)^2 + (v_i - v_o)^2} \times \frac{90}{\mathrm{R}} \quad (4)$$

when $0 \leq \theta < 180$,

$$\varphi_i = 180 - \cos^{-1}\left(\frac{v_i - v_o}{\mathrm{R}} \times \frac{90}{\theta_i}\right) \quad (5.1)$$

when $180 \leq \theta < 360$,

$$\varphi_i = 180 + \cos^{-1}\left(\frac{v_i - v_o}{\mathrm{R}} \times \frac{90}{\theta_i}\right) \quad (5.2)$$

where:

u_i, v_i: Image coordinates of column and row (pixels);

u_o, v_o: Image center coordinates (pixels);

θ_i: Zenith angle (degrees) at (u_i, v_i);

ϕ_i: Azimuth angle (degrees) at (u_i, v_i).

In this study, the image size of hemispherical area has 1,650 pixels and 1,650 lines. Therefore, the radius of circle (R) is 825 pixels and the image center coordinate (u_o, v_o) is (824, 824) in case of the image upper left coordinates as (0, 0) shown in Fig. 5.

3.3 Conversion onto Satellite Image

For each pixel classified as cloud portion on whole sky image, its pixel can overlay onto the satellite image as one of projected map coordinates using zenith (θ) and azimuth (ϕ) angles by given any cloud heights approximately. Generally, lower clouds such stratocumulus appears from near the ground to 2 km and in case of cumulus, it appears from 0.6 km to 6 km.

The conversion from the each pixel (u_i, v_i) of cloud portion on whole sky image to map coordinates (x_i, y_i)

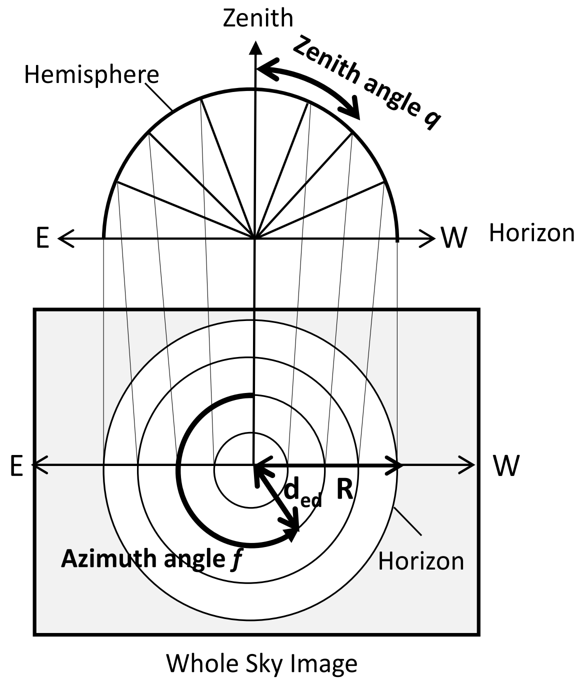


Fig. 4 Equidistant projection of used fish eye lens and whole sky image.

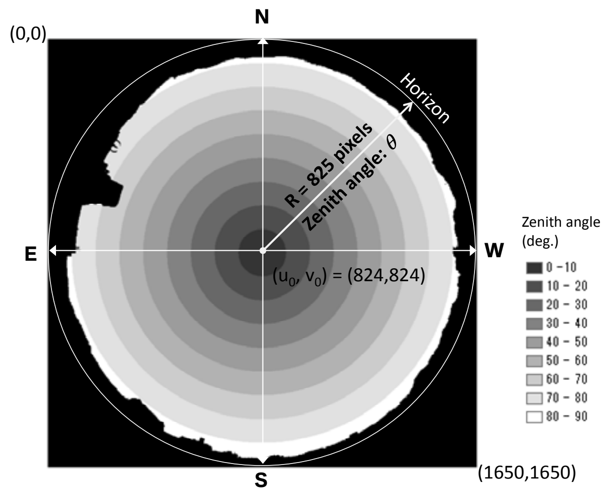


Fig. 5 Zenith angle on whole sky image by equidistant projection.

can be shown in Eqs. (6) and (7).

$$HD_i = \tan\theta_i \times CH_{apr} \quad (6)$$

$$x_i = \sin\varphi_i \times HD_i + \mathrm{x_o} \quad (7.1)$$

$$y_i = \cos\varphi_i \times HD_i + \mathrm{y_o} \quad (7.2)$$

where,

HD_i: the horizontal distance from ground-based cloud observation point (m);

CH_{apr}: approximate cloud height (m);

x_i, y_i: map coordinates of image coordinates u_i, v_i (m);

x_o, y_o: map coordinates of ground-based cloud observation point (m).

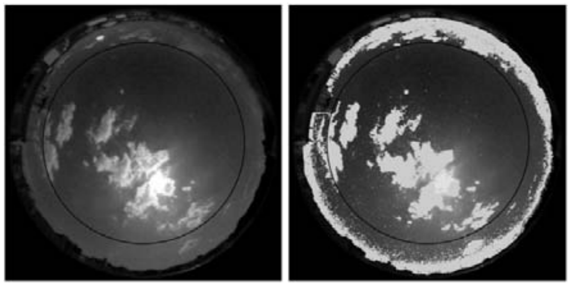
3.4 Experiments

As one of experiments, we examine to compare and overlay with whole sky images and those synchronous Terra & Aqua/MODIS images observed in central Kyoto, Japan. The grand-based cloud observation point is located at (35.018243°N, 135.768278°E). In this experiment, we use UTM (universal transverse mercator), (Zone53N, WGS84) as map projection.

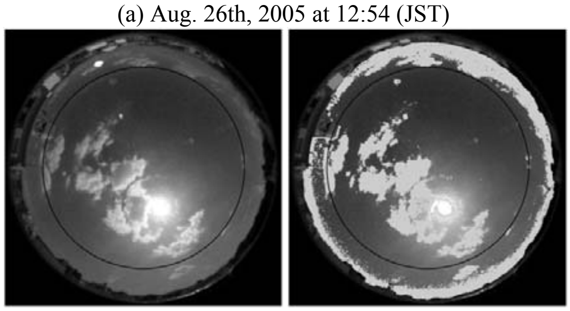
Fig. 6 shows the results of cloud discrimination from whole sky images taken at 12:54 and 12:56 on Aug. 26th, 2005. The black circle lines correspond to the area boundaries of zenith angle less than 65°.

Cloud type is recognized as cumulus of small size visually. Also cloud type such cumulus and stratocumulus have low *SI*, very close to *SI* = 0, and high *BI* values digitally. Outside of this circle seems to be out of cloud coverage range because of the long pass of atmospheric layer from the view at large zenith angle. Here, the target area is in less than 65° of zenith angle.

Fig. 7 shows Aqua/MODIS observed at 12:55 JST (Japan standard time) on Aug. 26th, 2005 as the sample satellite image in this experiment. There is not so much cloud coverage around the observation point as comparing with northern part of this MODIS image. However, it is certainly confirmed the clouds white circle lines in Fig. 7 indicate the overlaying area existence around the observation point visually. The



(a) Aug. 26th, 2005 at 12:54 (JST)



(b) Aug. 26th, 2005 at 12:56 (JST)

Fig. 6 Cloud detection results (right) from whole sky images (left) at 2 min time difference. Upper (a) and lower (b) were taken at 12:54 and 12:56 JST (Japan standard time) on Aug. 26th respectively. Cloud discrimination pixels are painted as bright gray on whole sky image. The black circle lines show the area boundaries of zenith angle less than 65 degrees.

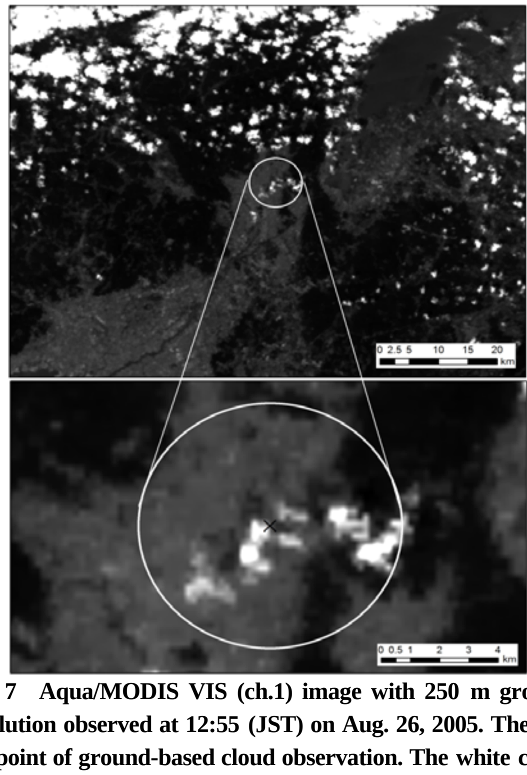


Fig. 7 Aqua/MODIS VIS (ch.1) image with 250 m ground resolution observed at 12:55 (JST) on Aug. 26, 2005. The x is the point of ground-based cloud observation. The white circle lines indicate the overlaying area boundaries with zenith angle less than 65° in case of *HD* calculation as CH_{apr} = 2,000 m.

boundaries of cloud portions on whole sky image with zenith angle less than 65 degrees in case of CH_{apr} = 2,000 m.

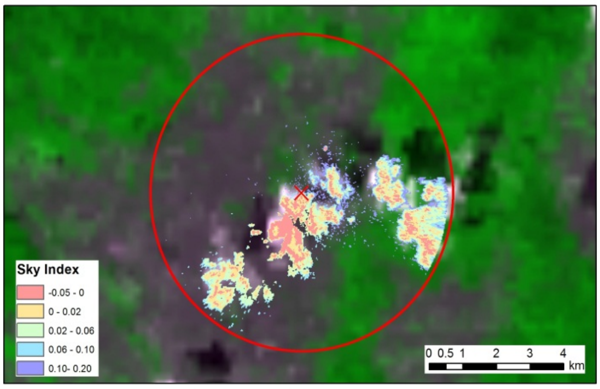
4. Results and Discussion

For overlaying cloud portions onto MODIS image, the horizontal distribution of cumulus clouds discriminated from whole sky image are calculated in four cases of *HD* calculation as CH_{apr} = 600, 1,000, 1,500 and 2,000 m by considering general cloud height of cumulus firstly. After calculations, it seems the best fit to both ground and satellite-based images in the case of *HD* calculation as CH_{apr} = 2,000 m.

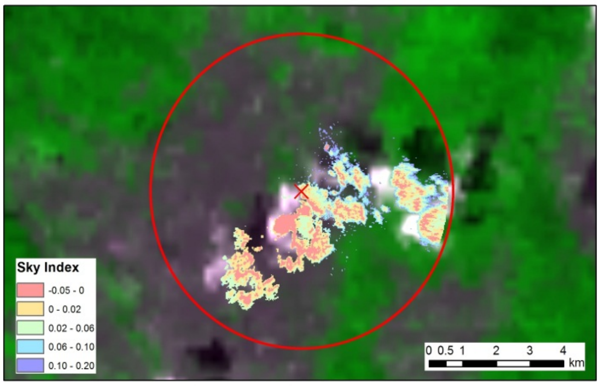
Fig. 8 shows the results of overlaying the cumulus clouds area discriminated from whole sky images taken at 12:54 and 12:56 (Fig. 6) to Aqua/MODIS observed at 12:55 on Aug. 26, 2005 (Fig. 7). Legend colors show *SI* value calculated from whole sky image. *SI* in almost clouds area shows very low.

Comparing with two figures of 2 min difference, there is no big movement on the image. Measured approximate distance of movement for 2 min between two figures of Figs. 8a and 8b) are about 500 m (velocity: 4-5 m/s). As other extension of overlaying clouds portion onto satellite image, there is clouds motion analysis by calculating the moving distance for 2 min in this case. For more high accuracy of horizontal clouds distribution, cloud height data with high accuracy is needed. As for the measurement of cloud height with high accuracy, Seiz et al. [7] have developed the method to estimate cloud bottom height by digital photogrammetric technique using two more camera systems.

Also, it seems that there is another application for the cloud fraction analysis at different definitions of the cloud fraction. Satellite-based observation derives the cloud fraction which means the horizontal area fraction covered by clouds. On the other hand, ground-based cloud observation using whole sky camera derives the cloud fraction as hemispherical sky covered by clouds. It is the definition of ground meteorological studies, so-called cloud amount. As for



(a) Aug. 26th 2005 at 12:54



(b) Aug. 26th 2005 at 12:56

Fig. 8 Overlaying cloud portions discriminated from whole sky image onto Aqua/MODIS VIS (ch.1) and NIR (ch.2) composite image (RGB: ch.1,2,1). Red X is the point of ground-based cloud observation. Red circle lines indicate the overlaying area boundaries with zenith angle less than 65 degrees in case of *HD* calculation as CH_{apr} = 2,000 m.

the calculation of both defined cloud fractions,Kassianov et al. [8] have demonstrated using hemispherical ground-based observation.

Furthermore, there is the possibility of this study on the assumption that this ground-based clouds observation methodology is applied across a wide area. For the validation of satellite-based clouds and earth surface observation, it seems that this observation system is suitable to set up at many sites, and also useful to collaborate with the existing ground-based observation networks such Asia Flux, AERONET (Aerosol Robotic Network) and SKYNET etc.. The proposed observation methodology and its applications should be connected to satellite products with high quality by implementation of sky and clouds observation covering a wide area.

5. Conclusions

In order to contribute to the advancement of satellite-based cloud discrimination accuracy, we proposed the efficient ground-based cloud observation methodology how to discriminate cloud portion on whole sky image and how to apply the ground-based cloud observation to satellite-based cloud discrimination as one of the validations for satellite products.

Through this study, we confirmed that our developed ground-based cloud observation methodology is useful to discriminate cloud existence and area of cloud coverage, and to overlay with satellite-based cloud image. As the possibility, this ground-based cloud observation can be expanded into wide area and set many observation points by corroboration with existing ground-based observation networks for application to various satellite images including geostationary satellites with very high temporal resolution.

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Journal of Environmental Science and Engineering A 2 (2013) 494-505
Formerly part of Journal of Environmental Science and Engineering, ISSN 1934-8932

Elemental Analysis of Soil Phosphorus Neighborhoods Using SEM, Spectral Mapping and GIS

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Received: June 04, 2013 / Accepted: July 17, 2013 / Published: August 20, 2013.

Abstract: The utility of GIS (geographic information system) methods and spatial statistical analysis on spectral maps of sediment samples were examined. Detailed elemental maps are often constructed using energy dispersive X-ray techniques and SEM (scanning electron microscopy). The elemental neighborhood associations of a single element, P (phosphorus), were quantified at a magnification of 3,000 ×. For each of the 170,000 pixels on the images which displayed a strong P concentration, neighborhoods from 0.1μm^2 to 12 μm^2 were examined for associated elemental concentrations. PCA (principal component analysis) revealed two significant neighborhood types associated with P in samples of pH 4, and three neighborhood types at pH 8. These neighborhoods corresponded to Mg-P associations commonly found to be chemically prevalent in river sediments impacted by agricultural operations. Discriminant analysis showed that the greatest accuracy in predicting sample pH could be achieved by using a neighborhood size of 12 μm^2. Potassium at relatively large neighborhood sizes was the element most significant in predicting pH. While many of the chemical associations in close proximity to P could be predicted and explained through mineral solubility, spatial analysis provided some interesting insights into the structure of the samples. Results also indicted differences in the spatial scale associated with different processes.

Key words: SEM (scanning electron microscopy), geographic information systems, energy dispersive X-ray analysis, principal components analysis, spatial analysis, soil chemistry.

1. Introduction

Traditional limitations to the study of soil such as opacity, heterogeneity and the complexity of integrating above and below ground dynamics have been overcome by the technical advances of the last decade [1]. As a result, interest in soil science is increasing and new methods of analysis are being developed to understand the intricate relationships in the chemistry of sediments. Spatial analysis at the microscopic level can provide valuable insights into these relationships. SEM (scanning electron microscopy), especially when paired with EDX (energy dispersive X-ray) analysis, can be used to produce images of element densities and relationships on the surface of soil particles. Analysis of satellite and other imagery within a GIS (geographic information system) have become commonplace in deciphering the relationships between the hydrology and soil chemistry of P (phosphorus) [2-5], however, the use of detailed imagery at the microscopic level in GIS is much less common. In this study we coupled SEM techniques with GIS analysis to examine the elemental neighborhoods associated with P in river sediments influenced by non-point source nutrient loading from agriculture.

1.1 Phosphorus in Freshwater Sediments

Phosphorus enrichment in both fresh and coastal water impacts water quality and often leads to

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eutrophication. Several recent studies have described the increased accumulation of phosphorus in soil as a threat to water resources globally [6, 7]. In freshwater sediments, the complex dynamics of P are primarily controlled by biological activity, P concentration and form, O_2 status and pH. Phosphorus in river sediments is typically either sorbed onto particles or precipitated as secondary minerals in the inorganic form [8, 9]. While adsorption impacts P retention at low P concentrations, precipitation of P minerals impacts solubility at high concentrations. Phosphorus minerals may represent relatively immobile sinks for P in sediment systems because, while surface adsorption and solubility of P is controlled by P concentration, mineral precipitate solubility is not [10, 11]. Phosphorus in sediments is predominantly associated with Fe and Al oxides, especially under lower pH conditions, while Ca and Mg phosphates form more frequently under alkaline conditions [12]. In the organic form, P is associated with plant and animal material and detritus [8, 9]. Microbial activity in river sediments can assimilate P, thereby reducing its availability, or liberate P through decomposition [9]. Higher P flux usually occurs in anoxic conditions [6].

In agricultural regions, manure applications on fields and runoff from feedlots and other high intensity animal operations can result in elevated P levels in adjacent freshwater and runoff receiving rivers. In systems influenced specifically by dairy operations, high levels of magnesium can alter the calcium-phosphorus relationship in favor of Mg-phosphate formation [13]. Calcium-P associations can be inhibited by DOC (dissolved organic carbon), Mg and Si inputs from manure, especially at high pH levels [14]. Variation in pH has also been found to play a key role in P chemistry of sewage sludge [15].

1.2 SEM and EDX

The combination of SEM, EDX element mapping, and GIS techniques provides a method for the spatial assessment of sediment chemistry. Mineral classification and quantification techniques in geology typically involve point counting of thin sections or X-ray diffraction methods, which may be prohibitively time consuming or deficient in spatial information [16]. SEM allows for spatial processing of image samples, while being used to determine the morphology of mineral concretions on the soil fabric [17, 18], however, it has rarely been used to spatially examine patterns in soil chemistry. Similarly, EDX has long been used as a point-based technique for deriving sample means and transect values of element densities and relationships to further the understanding of pedogenic processes [19-21], but it has been used less often to describe spatial relationships. One of the few exceptions is the work of Flesche et al. [16] that described the creation of a semiautomatic mineral classification system for geologic samples by applying supervised classification and discriminant analysis techniques to SEM and EDX element maps.

Through the combination of SEM techniques and GIS analysis, we take a novel approach to the examination of phosphorus chemistry and dynamics in freshwater systems. GIS techniques were used to create spatial neighborhoods of various sizes to correspond with every incidence of phosphorus found in SEM images. The objectives of the study were to: (1) define the spatial neighborhood relationships between phosphorus and associated Al, Ca, C, Fe, Mg, Mn, O, K and Si at the microscopic level; (2) examine differences in relationships among these element in sediments held at acidic and alkaline conditions; and (3) compare the spatial neighborhood associations of P on the surface of soil particles with values found in the literature.

2. Materials and Methods

The sampling site is located near the Curlesneck Dairy Farm (37° 30′ N, 77° 24′ W) in Henrico County, VA, which has been in continuous agricultural use since early 1600s. Dairy operation was especially active on the site for over 50 years beginning in 1933 and ending in early 1980s. Consequently, these dairy and agricultural operations have been discharging runoff from the field and barn into James River. In the summer of 2005, a scuba diver obtained sediment grab samples from the river using 1 m × 6 cm PVC. At the time of sampling, pH of the river averaged 7.7, although it varied within the water profile. Sediment samples were transported on ice to the laboratory and held anaerobically for four weeks under a nitrogen atmosphere. In order to examine the stable phosphate species that predominated under varying conditions, samples were held at both acidic (pH 4.0) and alkaline (pH 8.0) conditions. To maintain pH, either 1 N HCl or 1 N NaOH were periodically added to sediment samples. Samples were then dried and held in a dehumidifying chamber until analysis.

Sediment samples were analyzed using SEM and EDX to create spectral maps of P for use in GIS. Sediment particles were firmly pressed onto a double sticky tape mounted on aluminum stubs and carbon coated using EMS 950 × Turbo Evaporator (Electron Microscopy Sciences). The carbon coat thickness typically measured 15-25 nm, and after coating, samples were kept dry and stored in a dehumidifying chamber. Three stubs were derived from each sample and pH level, which were viewed in a Hitachi FESEM (field emission scanning electron microscope) at 20 kV. Spectral mapping at several locations per stub was performed at 3,000 × magnification using EDAX Genesis EDS software (AMERITEK, Mahwah, NJ) to determine percent elemental abundance for selected elements.

Spatial patterns in the elemental makeup of neighborhoods associated with P were examined using GIS techniques in ArcGIS 9.0 (ESRI, Redlands, CA). Twenty images, selected for clarity and completeness, were used in the GIS analysis. Eleven images were taken from seven stubs of the three pH 4 samples and nine images were derived from five stubs of the three pH 8 samples. Image size was 256 × 200 pixels; pixels were 0.167 µm on a side (an artifact of the 3,000 × magnification). Of the pH 4 images, a total of 89,088 pixels were identified as having moderate to high P levels (spectral signature 153 or greater) and of the pH 8 images, 82,792 pixels. In GIS, spatial neighborhoods were created to correspond with every incidence of phosphorus, over 170,000, found in SEM images.

Elemental abundance, estimated by pixel brightness values, was averaged for neighborhoods ranging in size from 0.1 μm^2 to 12 μm^2, centered on each site of moderate to high P abundance. Comparisons of standard summary statistics were made between neighborhoods of various radius lengths from P, for purposes of identifying consistent trends across scales and determining suitable scales for further research in this area. Every pixel with a strong P brightness was used as a center point for a neighborhood, but center points often lay within the neighborhood of other center points. On the average, greater radius lengths are associated with greater distances from P, as neighborhoods often overlap. The assumption that results will be dependent upon averages makes a large sample size essential, thus justifying our use of 170,000 pixels associated with P incidence.

PCA (principal components analysis) and other types of factor analysis are common in natural sciences and have been used in the literature to classify soil series and soil maps from profile descriptions [22]. In this study, PCA that implemented Varimax rotation and Kaiser normalization (SPSS 12.0, SPPS Inc.) was used to identify the elements with high component loadings in neighborhoods of particular sizes near P. A component was retained as significant if its initial eigenvalue was greater than 1. Results from the aggregation of all pixels and all images were compared with those derived from individual images to judge the variability in results. To determine which elements and radius lengths were most significant in predicting pH, a stepwise discriminant analysis algorithm was used (SPSS 12.0, SPPS Inc.).

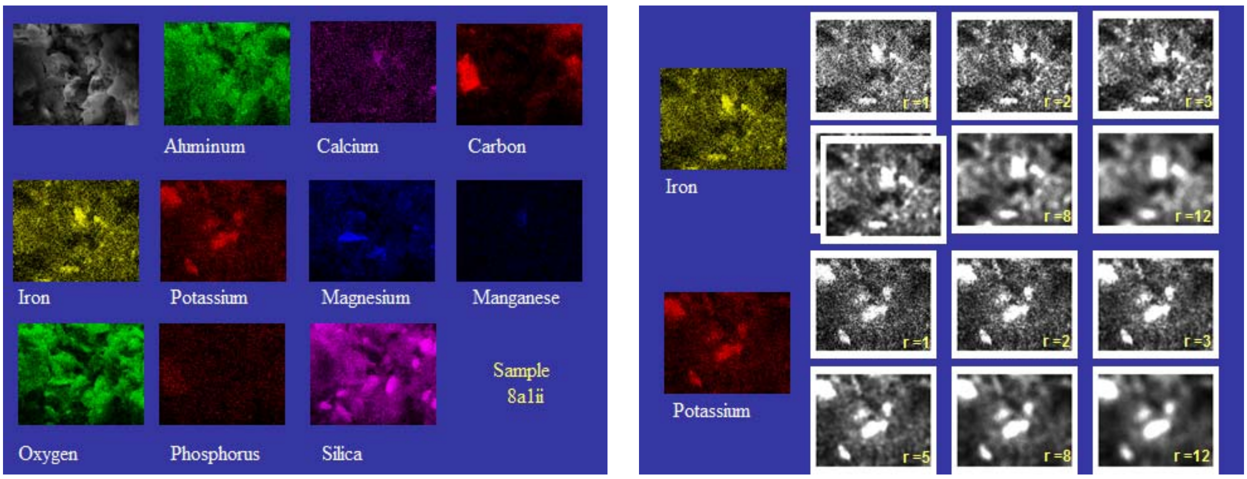
3. Results

3.1 Element Concentrations

Variation in spatial pattern among elements imaged for a particular location is shown in Figs. 1a and 1b shows results of a sample neighborhood analysis for Fe and Mg taken from the same location. Brightness values associated with the concentration of each element were averaged for varying neighborhood sizes; as neighborhood radius length increases, brightness values become more generalized or smoothed across the resulting visualization surfaces, and broader trends become more apparent.

Each of the nine elements examined in the neighborhood analysis occurred in greater abundance in neighborhoods near P than would be statistically expected from the overall average concentration of those elements in respective samples (Table 1). Concentrations of specific elements as measured by brightness varied between samples held at pH 4 and pH 8. In samples held at pH 4, Fe and K were present in significantly higher concentrations, than in the pH 8 samples. Less Ca occurred in the immediate neighborhood of P (1 pixel) than in larger neighborhoods. A higher average C concentration was present very close (1 pixel) and farther (12 pixels) than at intermediate intervals. Exceptionally high concentrations of Fe and low concentrations of Mg were found at a neighborhood radius of 2. K, Mg and O concentrations were highest at the neighborhood size of 12 pixels.

The concentrations of Al, Ca, C, O and Si in samples at pH 8 were higher than those at Ph = 4. While Mg concentrations were higher overall at pH = 8, concentrations were not significantly different at several neighborhood sizes. Concentration values of C, Mg and O decreased with distance from P, although there were no significant differences in K, Mn or Si concentration at different neighborhood sizes. Comparisons among element-specific values between pH classes showed that the largest neighborhood sizes, 12 μm^2 (radius of 12 pixels), were most often significantly different in concentration from other neighborhood sizes. Although the overall concentration of Mn in soils at pH 4 is slightly higher than found at pH 8, the neighborhood analysis shows that at moderate intervals (neighborhoods of size 3-8) soils at pH 4 had less Mn than those at pH 8.



(a) (b)

Fig. 1 (a) Examples of SEM image and associated spectral image maps of elements resulting from energy dispersive EDX (X-ray analysis). Images are from Sample A of Stub 1 of James River sediments held chemically at pH 8 for four weeks prior to drying and mounting. Each image is 200 × 256 pixels (42.66 × 33.33 μm^2); (b) Examples of energy dispersive X-ray images of iron and potassium from Sample A of Stub 1 of James River sediments held chemically at pH 8 for four weeks prior to drying and mounting. Associated moving average values of Fe brightness quantified using ArcGIS 9.0 Model Builder are shown by neighborhoods of radius length of 1, 2, 3, 5, 8, and 12 pixels. Each image is 200 × 256 pixels (42.66 × 33.33 μm^2).

Table 1 Average brightness for individual elements within neighborhoods of varying radius size centered on sites of moderate to high phosphorus levels. The sample size was 89,088 sites for pH 4 and 82,792 sites for pH 8. Sites were identified based on spectral signature.

		Al	Ca	C	Fe	K	Mg	Mn	O	Si
						pH = 4				
Radius (pixels)	1	92.47 a	35.11 c	59.65 b	66.37 c	67.38 b	44.64 b ^{x}	15.41 ab ^{x}	89.27 bc	92.11 a
	2	92.49 a	35.88 b	58.99 c	79.48 a	67.43 b	40.60 c	15.33 ab ^{x}	89.31 bc	92.06 a
	3	92.49 a	35.82 b	58.99 c	66.28 c	67.41 b	44.55 b ^{x}	15.28 ab	89.25 bc	92.03 a
	5	92.48 a	35.77 b	59.00 c	66.27 c	67.39 b	44.50 b ^{x}	15.23 b	89.20 bc	91.96 b
	8	92.44 a	35.77 b	58.95 c	66.29 c	67.39 b	44.50 b ^{x}	15.23 ab	89.11 c	91.86 c
	12	93.47 b	36.39 a	62.78 a	66.92 b	68.67 a	46.03 a	15.48 a ^{x}	91.37 a	92.18 a
	Overall	87.52	33.51	57.68	64.68	66.26	41.16	14.76	84.78	90.49
						pH = 8				
Radius (pixels)	1	95.55 b	40.08 b	61.30 a	65.52 c	56.04 a	44.56 ab ^{x}	15.54 a ^{x}	102.78 ab	99.36 a
	2	95.62 ab	40.08 ab	61.32 a	65.46 c	55.96 a	44.48 ab	15.47 a ^{x}	102.82 ab	99.31 a
	3	95.61 ab	40.02 b	61.28 a	65.52 ab	55.95 a	44.44 ab ^{x}	15.51 a	102.78 ab	99.28 a
	5	95.59 ab	39.94 ab	61.22 a	65.50 ab	55.91 a	44.43 ab ^{x}	15.50 a	102.67 b	99.29 ab
	8	95.49 b	39.92 ab	61.06 b	65.44 ac	55.90 a	44.33 b ^{x}	15.50 a	102.48 c	99.26 ab
	12	95.39 bc	39.87 b	60.85 c	65.33 c	55.89 a	44.22 c	15.49 a ^{x}	102.19 d	99.20 a
	Overall	92.29	37.21	57.92	61.88	52.90	42.18	14.56	99.03	96.86

a-d: letters indicate statistical similarity/difference in values between neighborhoods of the same pH and element.

^{x}: indicates not statistically different ($P = 0.05$) between neighborhoods of different pH but same element.

Manganese concentrations were not significantly different between pH 4 and pH 8 samples at 1, 2 and 12 pixel neighborhood sizes.

3.2 Principal Component Analysis

PCA was used to identify significant components in neighborhoods of particular sizes using an aggregated set of all P neighborhoods for each pH level. At all neighborhood sizes in the pH 4 samples, two components (A and B) were identified as significant through PCA with varimax rotation and Kaiser normalization (Table 2). Component A showed strong positive correlation with Al, C, Mg, O and Si at all neighborhood sizes in samples at pH 4. Component B is strongly correlated with Fe at all neighborhood sizes for samples at pH 4. Component B is also moderately correlated with Al, Ca, K and Mn. As neighborhood size increases from 1 to 12, the correlation between these four elements and Fe continue to increase. In neighborhood sizes 1 through 5 pixels, component A explains more variation in concentration than does component B, while in larger neighborhoods the trend is reversed.

At all neighborhood sizes in the pH 8 samples, three components were identified (Table 3). As in the pH 4 samples, Al, C, Mg, O and Si correlated strongly with component A, however, this component explains the most variation in data only at the radius lengths of 1 and 2 pixels. As neighborhood size increased, the correlation of Si, and to a lesser extent Al, decreased with respect to the other three elements in component A. Component B showed high correlation between Ca and Fe. At neighborhood sizes greater than 2, this component explained the most variation in data and Mn became strongly correlated with Ca and Fe. In component C, strong correlation was observed with K at pH 8, and as neighborhood sizes increased, so did the correlation with Al and Si.

The nature of SEM techniques makes aggregation measures suspicious because of the incredibly small sample image sizes. In recognition of this limitation, similar PCA analyses were performed on each image. Strong correlations that were evident with significant components are given in Table 4. The percentage of individual images that yielded high correlations between specific element pairs at both the smallest (1)

Table 2 PCA eigenvector scores identifying elemental characteristics of neighborhood associated with phosphorus on the surface of James River sediments (samples of pH = 4). Scores correlate the elemental brightness in neighborhoods of varying radius length from phosphorus with phosphorus presence as determined by SEM and energy dispersive X-ray analysis. Elements with the highest loadings (scores > 0.5) for each component are underlined.

		Neighborhood radius (in pixels)					
		1	2	3	5	8	12
		Component A					
Neighboring elements	Al	<u>0.636</u>	<u>0.677</u>	<u>0.656</u>	<u>0.651</u>	<u>0.652</u>	<u>0.648</u>
	Ca	0.232	0.271	0.253	0.271	0.281	0.261
	C	<u>0.579</u>	<u>0.592</u>	<u>0.655</u>	<u>0.668</u>	<u>0.680</u>	<u>0.698</u>
	Fe	-0.033	-0.121	-0.016	-0.024	-0.024	-0.018
	K	0.246	0.329	0.282	0.282	0.280	0.256
	Mg	<u>0.553</u>	<u>0.570</u>	<u>0.678</u>	<u>0.698</u>	<u>0.707</u>	<u>0.732</u>
	Mn	0.001	0.053	0.026	0.065	0.091	0.048
	O	<u>0.900</u>	<u>0.919</u>	<u>0.932</u>	<u>0.936</u>	<u>0.939</u>	<u>0.939</u>
	Si	<u>0.761</u>	<u>0.791</u>	<u>0.767</u>	<u>0.766</u>	<u>0.762</u>	<u>0.710</u>
%Variance^y:		32.658	37.279	43.131	47.427	17.313	18.249
		Component B					
Neighboring elements	Al	0.455	0.453	<u>0.524</u>	<u>0.543</u>	<u>0.547</u>	<u>0.577</u>
	Ca	0.486	<u>0.563</u>	<u>0.689</u>	<u>0.763</u>	<u>0.804</u>	<u>0.832</u>
	C	0.226	0.276	0.230	0.234	0.227	0.063
	Fe	<u>0.742</u>	<u>0.736</u>	<u>0.795</u>	<u>0.822</u>	<u>0.839</u>	<u>0.841</u>
	K	0.488	0.465	<u>0.577</u>	<u>0.604</u>	<u>0.623</u>	<u>0.644</u>
	Mg	0.353	0.492	0.493	<u>0.546</u>	<u>0.571</u>	<u>0.556</u>
	Mn	0.388	0.475	<u>0.592</u>	<u>0.703</u>	<u>0.770</u>	<u>0.815</u>
	O	0.090	0.111	0.151	0.176	0.186	0.192
	Si	-0.252	-0.250	-0.154	-0.133	-0.085	0.008
%Variance^y:		13.796	14.969	16.055	16.889	50.091	49.801

^{y}Percent variance gives the ranking of the component with regard to explanatory power as defined in PCA with Varimax rotation and Kaiser normalization.

and largest (12) neighborhood radius lengths is shown in Table 5. Strong correlations were obtained between elements with consistently higher concentrations in the imaged samples. At pH 4, within a radius of 1 from P locations, strong relationships were apparent among Al, C, and O and between O and Si. At a neighborhood of radius size 12 from P locations, the relationships between C and O; and O and Si remained consistent. The same associations were observed in pH 4 samples at radius of 12 among Al, Ca, and K; Al and Mg, C and Mg, Fe and Mn, and Mg and O. In two instances Si was negatively correlated with Ca, Fe and/or K. Each of these relationships among element groups corresponds directly to the components identified in the aggregated PCA for pH 4 samples.

Individual images were also examined for pH 8 samples and at radius size of 1, images of pH 8 samples exhibited consistently strong relationships in concentrations among Al, O, and Si; Al, C and Mg; Ca and Fe; Mg and Si. At radius 12, these relationships showed with slight modification whereby Mg became consistently correlated with Al, O and Si, while Mn became correlated with Ca and Fe; C was strongly correlated only with Mg. In several of the samples at both pH values, the concentration of Si was negatively correlated with Ca, Fe and Mn. When the correlations between elements in individual sample images were compared, many relationships were consistent across neighborhoods of various radii size, except for neighborhoods of radius 1 where some elements did not show patterns of correlation similar

Table 3 PCA eigenvector scores identifying elemental characteristics of neighborhood associated with phosphorus on the surface of James River sediments (samples of pH = 8). Scores correlate the elemental brightness in neighborhoods of varying radius length from phosphorus with phosphorus presence as determined by SEM and energy dispersive x-ray analysis. Elements with the highest loadings (scores > 0.5) for each component are underlined.

		Neighborhood radius (in pixels)					
		1	2	3	5	8	12
		Component A					
Neighboring elements	Al	<u>0.713</u>	<u>0.622</u>	<u>0.542</u>	<u>0.528</u>	<u>0.523</u>	<u>0.539</u>
	Ca	0.116	0.139	0.138	0.122	0.111	0.103
	C	<u>0.628</u>	<u>0.796</u>	<u>0.854</u>	<u>0.876</u>	<u>0.886</u>	<u>0.893</u>
	Fe	0.043	0.127	0.149	0.14	0.134	0.127
	K	0.226	0.050	-0.045	-0.064	-0.062	-0.051
	Mg	<u>0.611</u>	<u>0.648</u>	<u>0.624</u>	<u>0.621</u>	<u>0.62</u>	<u>0.624</u>
	Mn	-0.038	-0.088	-0.084	-0.053	-0.038	-0.025
	O	<u>0.779</u>	<u>0.726</u>	<u>0.662</u>	<u>0.641</u>	<u>0.63</u>	<u>0.628</u>
	Si	<u>0.532</u>	0.309	0.177	0.13	0.106	0.094
%Variance:		26.275	30.221	12.264	12.404	12.484	12.570
		Component B					
Neighboring elements	Al	0.018	0.056	0.070	0.073	0.072	0.077
	Ca	<u>0.673</u>	<u>0.743</u>	<u>0.785</u>	<u>0.825</u>	<u>0.847</u>	<u>0.864</u>
	C	0.165	0.051	0.041	0.040	0.034	0.026
	Fe	<u>0.786</u>	<u>0.794</u>	<u>0.818</u>	<u>0.845</u>	<u>0.859</u>	<u>0.869</u>
	K	0.158	0.301	0.337	0.361	0.386	0.418
	Mg	0.14	0.158	0.186	0.206	0.219	0.229
	Mn	0.451	0.615	<u>0.710</u>	<u>0.803</u>	<u>0.845</u>	<u>0.876</u>
	O	-0.02	-0.007	0.014	0.029	0.035	0.041
	Si	-0.375	-0.273	-0.235	-0.215	-0.199	-0.178
%Variance:		16.324	18.742	32.757	35.137	36.382	37.919
		Component C					
Neighboring elements	Al	0.247	0.498	<u>0.608</u>	<u>0.639</u>	<u>0.641</u>	<u>0.653</u>
	Ca	0.131	0.049	0.06	0.078	0.085	0.089
	C	-0.483	-0.281	-0.151	-0.117	-0.105	-0.102
	Fe	-0.092	-0.198	-0.191	-0.183	-0.181	-0.182
	K	<u>0.692</u>	<u>0.705</u>	<u>0.707</u>	<u>0.707</u>	<u>0.7</u>	<u>0.692</u>
	Mg	0.048	0.288	0.43	0.491	<u>0.561</u>	<u>0.529</u>
	Mn	0.392	0.252	0.21	0.211	0.216	0.228
	O	0.078	0.343	0.465	0.499	<u>0.51</u>	<u>0.508</u>
	Si	0.463	<u>0.707</u>	<u>0.773</u>	<u>0.799</u>	<u>0.818</u>	<u>0.837</u>
%Variance:		11.802	12.108	20.628	22.486	23.324	23.883

to those identified by PCA (Tables 4 and 5). The only relationship to be exhibited consistently at various radii lengths at both pH values was the relationship between Al and O (Table 5).

Potassium was the only element strongly correlated within a component occurring at both pH and all radii lengths. At neighborhood radius of 12, samples from both pH values showed consistent relationships between Al and Mg, C and Mg, Fe and Mn, Mg and O, and O and Si.

3.3 Discriminant Analysis

To determine the usefulness of this type of analysis for differentiating between sediment samples at pH 4 and pH 8, stepwise discriminant analysis was applied. As neighborhood size increased, the accuracy of

Table 4 Highly correlated ($r > 0.5$) PCA scores were identified during neighborhood analysis of phosphorus in 20 images of the surface of James River sediments. Letters in the following table indicate groups of highly correlated PCA scores for particular elements within each individual image. For example, elements designated "a" would be strongly correlated with other elements designated "a" in the same image row.

		Neighborhood radius = 1									Neighborhood radius = 12								
	Image	Al	Ca	C	Fe	K	Mg	Mn	O	Si	Al	Ca	C	Fe	K	Mg	Mn	O	Si
pH = 4	4a1	a	a		b	a	a	b	a	a	a	a	a	b	a	a	b	a	a
	4a12	a	c	a	b		a	d	a	c-	a	ac	a	b	c	a	b	a	c-
	4a2	ab			b				a	a	a	b	a	b	a	a	b	ac	c
	4a22	ac	c	a		c	a		ab	b	a	a	c	b-	a	c	a	bc	b
	4a32	a		a	b		a	b	a	a	a	a	a	b	a	a	b	a	a
	4b2	a	b	a	c	b		b	a	a	a	a	b-	a	a	ab	a	b	b
	4b3	a	c	b	a	a	b	c	b	a-b	a	a	b-	a	a	b	a	b	a-b
	4b32	a	b	a	b	a		b	a	a	a	ab	a	b	a	a	b	a	a
	4c12	a		a	b-	c	a		ab	ab	a	a	b	a	c	ab	a	b	b
	4c3	a	b	a	b	b	a		a	a	a	b	a	b	b	a		a	a
	4c32	a	c	ac-	c	c	a		a	b	a	b	c-	b	b	a	b	a	c
pH = 8	8a1	a	b	a	b	c	a		a	a	a	b	a	b	c	a	b	a	a
	8a12	a	c	b-	c	b	a	c	a	a	a	b	c-	b	c	a	b	a	a
	8a2	a	b	a	b	c	a			ab-	a	b	a	b	c	a	b	a	ab-
	8a22	c		b	b	c			a	a	bc	a	a	a	c	b	a	b	a-b
	8b3	a	c	a	c	a			ab	b	bc	a	c	a	b	c	a	b	b
	8b33	a		b	c			c	a	a	a	b	c	b		a	b	a	a
	8c1	b	a	b	a	c	b		b	a-	bc	a	b	a	c	b	a	b	a-
	8c12	b	c	a-	c	b	a	c	b	a	bc	c	a	c	b	a	c	b	a
	8c3	a	b	ab		b-	a	c	a	ab-	a	b	ab	c	b-	a	c	a	a

a-d: Indicates statistical difference in the principal component with which the element is strongly correlated in a particular image sample and neighborhood size;

-: Indicates statistical contrast or strong negative correlation with the principal component.

Table 5 Fraction of total images for which each pair of elements was strongly correlated to the same principal component. PCA was based on the average brightness for individual elements within neighborhoods of varying radius size from evidence of phosphorus on the surface of the sediments. Brightness values were derived with SEM and energy dispersive X-ray analysis from twenty images of samples from James River sediments. Elements which consistently had similar patterns of correlation with PCA components are shown in bold. Correlation of an element with itself reflects that the element was the sole element strongly correlated with a particular component.

		Neighborhood radius = 1									Neighborhood radius = 12								
		Al	Ca	C	Fe	K	Mg	Mn	O	Si	Al	Ca	C	Fe	K	Mg	Mn	O	Si
pH = 4	Al		0.2	**0.7**	0.2	0.4	**0.6**	0	**0.9**	**0.6**		**0.8**	0.5	0.4	**0.7**	**0.8**	0.5	**0.6**	0.4
	Ca			0	0.3	0.4	0.1	0.4	0.1	0.1			0.4	0.5	**0.7**	0.5	0.5	0.4	0.3
	C				0	0.1	0.5	0	**0.8**	0.5				0	0.4	**0.8**	0	**0.8**	0.5
	Fe				0.2	0.2	0	0.4	0	0					0.4	0.2	**0.8**	0	0
	K					0.1	0.1	0.1	0.2	0.2					0.1	0.5	0.4	0.4	0.3
	Mg							0	**0.6**	**0.4**							0.2	1	0.6
	Mn							0.1	0	0								0	0
	O									0.8									**0.8**
	Si									0.1									
pH = 8	Al		0	**0.7**	0	0.3	**0.6**	0	**0.7**	**0.6**		0	0.4	0	0.4	**0.8**	0	**1**	**0.8**
	Ca		0.1	0.1	**0.6**	0	0	0.2	0	0			0.1	**0.9**	0	0	**0.9**	0	0
	C			0.1	0.1	0.1	**0.6**	0	0.4	0.4			0.1	0	0	**0.7**	0	0.4	0.4
	Fe					0	0	0.3	0	0					0	0	1	0	0.1
	K					0.3	0	0	0.2	0.1					0.1	0	0	0.2	0.1
	Mg							0	0.3	**0.6**							0	**0.8**	**0.8**
	Mn							0.1	0	0								0	0.1
	O									**0.6**									**0.8**
	Si																		

prediction improved and all elements tested were significant in determining their association with a particular pH (Table 6). With knowledge of element concentrations at neighborhood size of 12 pixels away from P, choice of pH could be predicted with 71.1% accuracy. When the same method was applied, using only a specified element at all neighborhood sizes to predict pH, K was the most significant predictor at all neighborhood sizes except those at 2 pixel radius (Table 7). Given K concentration at neighborhoods of radius size 8 and 12, pH could be predicted with 63.5% accuracy. In a combined discriminant analysis including all elements and neighborhood sizes, 34 element/neighborhood combinations were significant, resulting in a prediction accuracy of 72.8%. These element/neighborhood combinations were nearly identical to those shown as significant in Table 7.

4. Discussion

The geochemistry of this system is complex, with pH differences influencing mineral and elemental stability and solubility as well as chemical weathering. Each of these in turn influences P dynamics. Since it is difficult to identify P minerals in sediments and soils [14], we have limited mineral identification. Standard XRD (X-ray diffraction) was applied to James River sediments for identification of specific minerals. However, it was impossible to distinguish among P minerals with XRD. Similar research has also found standard mineral classification and quantification techniques in geology to be prohibitively time consuming or lacking in spatial information [16].

Table 6 Elements in order of significance as determined by a stepwise discriminant analysis model used at each neighborhood radius size individually to discriminate between sediment samples held at pH 4 and pH 8. Values used in the discriminant analysis model for each element were the average sum of brightness for neighborhoods near phosphorus on the surface of the James River sediments. Brightness values were derived with SEM and energy dispersive X-ray analysis from twenty sample images.

Radius (pixels)	Significant elements in order of stepwise model								Model accuracy
1	K	O	Ca	Mg	C	Fe	Al	Si		59.0
2	Fe	O	K	Ca	Si	C	Mg	Al	Mn	62.8
3	K	O	Ca	Mg	Al	C	Fe	Mn	Si	64.0
5	K	O	Ca	Mg	Al	Fe	C	Mn	Si	66.4
8	K	O	Ca	Mg	Al	Fe	C	Mn	Si	68.3
12	K	Al	Ca	Mg	O	C	Fe	Mn		71.1

Table 7 Neighborhood size in order of significance as determined by a stepwise discriminant analysis model used for each element individually to discriminate between sediment samples held at pH 4 and pH 8. Values used in the discriminant analysis model for each element were the average sum of brightness for neighborhoods near phosphorus on the surface of the James River sediments. Brightness values were derived with SEM and energy dispersive x-ray analysis from twenty sample images.

element	Significant neighborhood radius lengths (pixels) in order of stepwise model					Model accuracy
Al	8	12	5	3		51.5
Ca	8	12	1	2	5	52.5
C	5	12	8	1	2	52.7
Fe	2	3	12	1	8	55.9
K	12	8				63.5
Mg	2	12	8	3	1	55.1
Mn	8	12	2			51.0
O	8	5	12			55.4
Si	8	5	3			54.6

The unique contribution of our GIS approach is the direct visualization of relationships present on the exterior of sediments due to surface sorption of elements. Phosphorus in river sediments is typically either sorbed onto particles or precipitated as secondary minerals in the inorganic form [8, 9]. This P, most likely resulting from recent deposits of P from dairying, poultry litter, or fertilizer use, is evidenced on the surface but is not an integral component of the sediment minerals, which takes several geologic times to form. The components identified in our spatial approach during PCA closely correspond to the results of Harris et al. [13] and Josan et al. [14] which identify Mg-P associations as critical in determining P availability in dairy-influenced systems, reducing the importance of Ca-P associations. The extent to which these elements are added to the animal feed could have influenced the availability of either element for binding P on the sediment surface. Nonetheless, spatial approaches that combine methods from GIS, standard statistical methods, and spectral signatures of elements seem to provide an alternative or complementary method of gaining additional information about soil geochemistry with respect to sediment surfaces.

Five spatial relationships were consistently identified across neighborhood scale during PCA on the aggregated sample set. The microscopic scale of this research raised the preliminary concern that spatial variability in the soil matrix may preclude the identification of consistent relationships. Therefore, it is the consistent relationships across scales and even across pH levels, rather than the differences, that support the usefulness of this method. Four relationships directly associated P with Mg and only two included associations between P and Ca. The strongest association at smallest neighborhood size for each pH level included Mg relative to the C, O, Si association, which is expected with manure components precluding the influence of Ca [13]. When individual sample images were compared, Mg relationships with Al, C, O and Si were consistent across pH levels. This indicated a situation described in the literature whereby P stabilization was preempted by Mg-P association [14]. The component seemed to influence samples at pH 8, as the concentration of C, O and Si were significantly higher; however, there was no significant difference observed with Mg. In addition, high P concentrations were found associated with organic debris, including shell fragments, and in association with O, C and Ca. Because samples were held at a consistent pH for a month before analysis, mineralization of organic matter would certainly have progressed to a greater extent in the more acidic environment. This is indicated by a decrease in organic matter (C and O) and a relationship between P and these elements in samples at pH 4. At this low pH, Ca would be released through dissolution of $CaCO_3$.

When neighborhood radius size increased beyond 2-3 pixels (300-450 μ), components correlating strongly with Fe and Ca and Mn became significant at both pH conditions. A major difference between the pH 4 and pH 8 samples was apparent with regard to K association with P. Under acidic conditions, clays and feldspar can release K while dissolution can release Fe, Ca and other cations [23]. In the pH 4 samples, K was associated with Fe-based components. In pH 8 samples K showed the strongest correlation with component C, with increasing association with Si, Al, Mg and O at larger neighborhood sizes. These results may indicate that at high pH levels K was held tightly by colloidal surfaces, while in acidic conditions, K was displaced by H and Al. The importance of K in pH 8 samples was reiterated by discriminant analysis identifying K as the most important element that differentiated between pH levels. Another interesting observation was the fact that there were significantly smaller concentrations of K at all neighborhood sizes in pH 8 samples compared to those at pH 4. This observation was confirmed by analyzing individual sample images. These results indicated the importance of K-P relationships for P stability in sediments, which warrants further research.

Other differences between pH levels can be explained by differences in mineral solubility. Phosphorus associations were common with Al and Fe at low pH and with clay (primarily aluminosilicates-Si, Al and O) at higher pH. Phosphorus precipitation in acid soils commonly occurs on metal (Al and Fe) oxides, while fixation by clays surface occurs over a wide range of conditions [24]. The solubility of Al and Fe increases in acidic conditions; with Al and Fe often precipitating as hydroxides [10]. Iron and Mn are both affected by redox; anaerobic and acidic conditions favor reduced states (Fe^{2+} and Mn^{2+}) and oxidation increases with increasing oxygen and pH levels. Under intensely reduced conditions Fe and Mn can be incorporated into aluminosilicate minerals, i.e., clays [25]. Geochemical modeling suggested that Al and Fe were associated with P at lower pH, possibly as amorphous precipitates while P was associated with Mg and to a lesser extent with Ca at higher pH values [26].

5. Conclusions

Phosphorus released from dairy and other confined animal operations impacts water quality through eutrophication of fresh water systems. Spectral mapping and GIS analysis are viable techniques for surveying such impacts and determining the scale of damage done to soil and water quality by overload of certain nutrient elements in manures. The complex elemental relationships evidenced by SEM and GIS on soil and sediment surfaces as impacted by non-point source of pollution from dairy farming mirror those discussed in the literature of chemical analysis. While it does not delve into the internal chemistry of sediments, associating GIS analyses with chemical interactions would certainly be an interesting tool that would provide additional information on the interaction of elements on sediment particle surfaces. Consistent relationships across neighborhood sizes seem to indicate that spatial variability is not so complex as to preclude the derivation of reliable element associations from the spatial examination of the sediment matrix. These general consistencies and their agreement with our knowledge of P geochemistry under varying pH conditions give credence to the significant difference in the role of K among these samples. Further analysis, chemically and geospatially, is needed to address the role of K and its influence on the association of Si with P in high pH environments.

This research indicates that SEM and GIS technologies are useful in conjunction with conventional methods to better characterize P distribution and differentiate the elemental and environmental factors associated with that distribution. These technologies can complement point chemical analysis when XRD is not able to identify mineral compositions with certainty. Spatial information can offer an approach to visualizing P fixation, its potential mobilization, and biological availability. However, if such a method is to be useful to soil scientists, further research is warranted to elucidate the spatial variability of the soil matrix at various microscopic scales.

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Journal of Environmental Science and Engineering A 2 (2013) 506-519
Formerly part of Journal of Environmental Science and Engineering, ISSN 1934-8932

Green Value Chain: A Case Study in Turkey about the Relationships among Antecedents, Initiatives and Results of Green Value Chain Implementations

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Received: May 08, 2013 / Accepted: June 13, 2013 / Published: August 20, 2013.

Abstract: The present study was conducted to determine the green value chain implementations of large and medium size businesses and to investigate the relationships among antecedents, initiatives and results of green value chain implementations. The antecedents of green value chain implementations were considered from four dimensions namely regulations, public concerns, expected competitive advantage and top management commitment; green value chain initiatives were considered from three dimensions namely green primary activities, green internal support activities and green external support activities; the results of green value chain implementations were considered from two dimensions namely economic performance and socio-ecologic performance. A model was created according to the objectives of the study and hypotheses were formed. Multiple regression analyses were performed to investigate the relationships between the antecedents and initiatives of green value chain implementations. A relationship was not observed between green primary activities and economic and socio-ecologic performance. While a positive relationship was observed between green external support activities and economic performance, a positive relationship was observed between green internal support activities and both economic and socio-ecologic performance.

Key words: Green value chain, green primary activities, green internal support activities, green external support activities, economic performance, socio-ecologic performance.

1. Introduction

Environmental disasters and the problems experienced by individuals and societies have raised environmental awareness among them. Businesses are largely responsible for environmental pollution and they have been forced to act in a conscious fashion towards the environment with the implementation of legal regulations. Environmental awareness and environmental management activities along with this awareness include highly beneficial, but difficult to achieve, activities. These practices are also expressed as environmental management implementations and are implemented through a wide range of activities from raw material supply to the disposal of products (purchase, production, marketing, waste management etc.). Herein, businesses use techniques that can guide them in environmental protection issues like the green value chain. Green value chain implementations express the value added created to form a competitive advantage through various stages from the design of the products to after-sale services. Together with the strategic importance of value creation, entire activities herein focus on environmental impacts, prevention or minimization of environmental pollution, environmental protection and even proactive regulations.

It was reported in the literature that environmentally conscious activities had significant impacts on the performance of businesses [1-5]. Increased performances were observed with increasing environmental awareness

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levels. Performance can be evaluated under different headings such as economic, financial, ecologic, socio-ecologic, operational and social. Increases in quality, efficiency, productivity, sales and profit margins, cost savings, new market opportunities or increases in market shares are all considered under either economic or financial performance. A decrease in environmental complaints about products, decreases in waste and emissions, an increase in recycling activities, improved business image and social attachment are considered under socio-ecologic performance. In this context, a positive relationship may be assumed between green value chain implementations and the economic, socio-ecologic performance of businesses. Moving from this point forward, the objectives of the present study were set as to determine the green value chain implementations of businesses and to investigate the relationships among the antecedents, initiatives and results of green value chain implementations. Initially, the concept of the green value chain will be described, the antecedents of green value chain implementations and possible outcomes will briefly be explained and finally the results from the developed model will be presented.

2. Materials

2.1. Green Value Chain

The concept "Value Chain" was as the combined evaluation of nine general activities creating a value for the competitive advantage of businesses [6]. Beside this, Handfield et al. [7] defined the value chain as follows: combined evaluation of different factors along the life cycle of a product like design, supply, logistics, installation, production, marketing, sale and after sale service. The green value chain on the other hand, just adds a new dimension namely the "environment" to the traditional value chain [8]. The green value chain expresses the appraisal of the value creating activities of a business by also taking natural resources and the environment into consideration with in a holistic and sustainable perspective. It is also used as a tool to put the strong and weak points of business activities through ecological evaluations. Such a tool evaluates the business as a whole, does not limit itself only to popular issues like marketing and advertising but also takes environmental consciousness into consideration [9].

In the literature, green value chain implementations are evaluated from different perspectives. Among these perspectives, the most widely accepted approach is using the value chain analysis that primary and auxiliary activities [10, 11]. Solvang et al. [8] evaluated green value chain implementations within the framework of waste reduction approaches throughout the process from suppliers to consumers. Sitkin [12] evaluated green value chain functions under upstream (sourcing and production) and downstream (packaging and logistics) activities. Table 1 summarizes green value chain implementations as primary and supportive activities (internal and external support).

2.1.1 Primary Activities

The primary activities of green value chain implementations are considered under four dimensions, namely green logistic, green operations, green marketing-sales and green services. These dimensions are described separately below.

2.1.1.1 Green Logistics

Logistic activities are considered in two parts as inbound and outbound. Inbound logistics are responsible for receiving the materials from the suppliers and storing them until they are ready for use. Eco-efficiency can be achieved in all related activities like transportation, martial handling, storage and warehousing [11]. Outbound logistics are concerned with customer requirements and finished goods [11]. Logistic activities including the supply, transport, storage and distribution of finished goods are evaluated with regard to environmental impacts in the green value chain and an attempt is made to ensure that all the processes are realized by taking environmentally friendly goods and ecologic productivity into consideration.

Table 1 Green value chain [10, 11].

Internal support activities	Primary activities				External support activities	
	Green operations	Green logistics	Green mark and sales	Green services		
Green infrastructure development	Recyclable packaging	Transport impacts, transportation and storage modes	Raw materials, supply	Receipt and environmental disposal of used products		Economic conditions
Green technology	Pollution minimization and control, energy efficiency	Waste management, alternative energy sources	Packaging reduction	Restorations and improvements		Nongovernmental organizations
Green human resource management	Corporate environmental awareness, corporate culture, training programs	Contracts, supplier selection, staff selection	Internal and external communication, community liaison	Incentives, rewards for green ideas and practices		State
Green regulations, management systems	"Just-in-time" processes	Recyclability	Green product development, green product supply	Environmental standards		Goverment policies

2.1.1.2 Green Operations

Businesses take inputs, pass them through a conversion process and create a value. During these processes, businesses should be environmentally conscious and should take environmentally friendly actions in the purchase, design, technology, waste disposal and energy use of all business activities. Businesses tend to strategic environmental management while performing such environmental actions to spread environmental awareness throughout the business. Strategic environmental management includes planned-programmed regulations in the structure, systems and activities of the business to comply with the changes around the business or to improve the adaptation capacity of the business to such changes. In green value chain implementations, the aim is to achieve the concept of "from cradle to grave, kill off the pollution before it happens" [9].

2.1.1.3 Green Marketing and Sales

Green marketing practices, including environmentally friendly pricing, promotion and delivery of the products of a business, aim to create a value for all sharers of the business. At this point, environmentally conscious customers are able to know and prefer environment-friendly products and the marketing approach is shaped around the preferences of consumers. Beside environmentally conscious product development activities, businesses also have green packaging [13], ecologic labeling [14] like environmental activities.

2.1.1.4 Green Services

Green consumers select and use environmentally friendly products, require to be informed about the conscious disposal of the products and provide feedback after use of the products. All these issues force businesses to provide post-sale services. Such services include a "product stewardship" program indicating the monitoring of a product throughout its lifecycle [14], updating product labels, promoting environmentalist ideas and implementations, providing environmentally friendly disposal and the recycling of used products.

2.1.2 Support Activities

As can be seen in Table 1, support activities in green value chain implementations are considered under two headings as internal and external. These activities are briefly explained below.

2.1.2.1 Internal Support Activities

(1) Green Infrastructure

Development: Green infrastructure development includes the activities involved in developing a conducive operating environment suitable for GVA. The organizational structure, control mechanisms and organizational culture usually impact infrastructure environment of a firm [11]. Environmental standards guide businesses in infrastructure formation and the development of green activities.

(2) Green Human Resource Management

Businesses have to adapt their own human resources policies to changing conditions while developing and introducing green products, efficient waste management systems and establishing new relationships with environmentally conscious sharers [15]. Unless they convince and motivate their staff to environmental consciousness, the implementation of an environmentally friendly approach will never be possible. Therefore, the pre-condition for the success of environmentally related programs is to ensure the awareness and commitment of staff to such programs [16].

(3) Green Technology Adoption

The technologies protecting the environment, polluting less, using all resources in a sustainable fashion, recycling wastes at high rates and disposing of them efficiently are all defined as green technologies [17]. Such technologies form the focus of the technology and management practices of a business. The use and adoption of green technologies deeply affect all the production functions and activities of the business. Moreover, technologic compliance may provide significant benefits to reduce production costs and to gain a competitive advantage and also to minimize the environmental impacts of business activities and implementations. Such a case means both an economic and ecologic gain/value for the business.

(4) Green Procurement

Environmental standards and procedures play a significant role in the regulation and control of the environmentally related issues of businesses. Businesses should comply both with legal environmental regulations and the regulations issued by the environmental management system of the business, if there is one, in both current production activities and in new products and investments. Such a case may provide benefits in the determination of both current and possible future environmental impacts on the business. Green regulations play a key role in pollution prevention and the reduction of pollutant sources, recycling or re-use of used products.

2.1.2.2 External Support Activities

(1) Government Policy, Regulation

Most governments in the world are committed to environmental protection as a priority issue [11]. According to Henriques and Sadorsky [18], the primary factors' forcing businesses to environmental consciousness are the legal regulations shaped around government policies. The negative impacts of businesses on the environment are mostly controlled by issuing legal regulations. Within the concept of "polluter pays", high fines for environmental pollution, sometimes even higher than the cost of pollution prevention measures and technologies, force businesses to act in an environmentally conscious fashion.

(2) Public Support

The prominence of environmental problems and sustainability actions has not only businesses but also governments conscious about the environment. In particular all kinds of state-initiated environmentally related projects, works or research & development studies are supported under various headings. In addition, environmental investments are either financed by incentives or they are subjected to tax exemptions.

(3) Economic Condition

There is a positive relationship between proper economic conditions and environmental initiatives [19]. Green entrepreneurs initially evaluate the economic conditions of the country and business as the success factor of investments. A healthy economy makes significant contributions to the purchase and investment decisions of businesses.

(4) NGO (Non-governmental Organizations)

Since the 1970s, environmental activists have viewed businesses as the focus of environmental problems and put them under pressure to be the solution those problems [9]. Since the support of voluntary organizations may mean the support of several sharers, such support plays a great role in the environmentally conscious acts of businesses [11].

2.2 Antecedents of Green Value Chain Implementations

The ever-increasing significance of environmental management has forced businesses to set their positions in environmental issues and has forced managers to reevaluate their value chain activities and implementations [7]. The reasons why environmental practices motivate businesses, or the expected benefits from such practices, are considered under four headings in the literature [3, 18, 20, 21]: regulation, public concern (corporate image), expected competitive advantage and top management's commitment

2.2.1 Regulations and Laws

These two factors constitute the primary factors forcing businesses to adopt environmental consciousness. In this sense, with these regulations, policy makers tend to monitor entire processes from the design to packaging and delivery and even the disposal of an item [21].

2.2.2 Public Concerns

This is an external environmental factor which is effective in the environmentally conscious behaviors of businesses. Environmentalist actions, pressure exerted by consumers and green products, allow people to be conscious about the environment. Businesses should definitely pay heed to the voices raised from society.

2.2.3 Expected Competitive Advantages

To be superior over competitors or expect competitive advantage is among the primary factors forcing businesses to act in an environmentally conscious fashion. In general, businesses tend to cost reduction, differentiation and focusing like competitive strategies to gain a competitive advantage. However, in recent years, they have realized that environmentally oriented activities may also provide competitive advantages. Therefore, they have put more emphasis on environmentally related activities.

2.2.4 Top Management Commitment

It is very difficult to implement environmental activities in businesses without the commitment and support of top management [22]. The organization is motivated, guided, and the perception and sustainability of the actions are provided by top management with a green management perspective.

2.3 Results of Green Value Chain Implementations

Gandhi et al. [23] suggested that the greening of the value chain will finally lead to future sustainability with the formation of win-win collaboration with regulatory, measures the community and consumers. With these practices, the negative impacts on the environment are minimized, the demands of green consumers are met and eco-productive products come into prominence. Such outcomes provide a sustainable competitive advantage to businesses. With green value chain analysis, sustainable competitive advantage may either be evaluated under financial, social and ecologic performance [6] or under financial and non-financial performance [3] or economic and socio-ecologic performance [4, 5].

2.3.1 Economic Performance

Existing studies have shown that sustainable competitive advantage via green value chain initiatives can lead to superior marketplace performance which can be measured in conventional terms such as market share, customer satisfaction etc., and financial performance such as return in investment shareholder wealth creation, profitability etc. [26, 27].

2.3.2 Socio-environmental Performance

The socio-environmental performance, also known as non-financial performance, of a company is demonstrated by indicators such as acquired environmental standards, improved 7 customers loyalty, greater satisfaction of employees etc. and can only be achieved by implementing a systematic approach through setting environmental objectives and targets [3]. GVCI will also lead to cleaner, greener and much more efficient operations, better environmental performance by reducing damages to the latter, besides overall improvement of the company's image. It is believed that environmental benefits enjoyed there from will spill over to the general public and thus will improve social performance [4, 5]. In brief, green value chain implementations target more sustainable development through increasing business image, sales, market share and profit.

3. Results and Discussion

3.1 Theoretical Framework and Hypothesis

Following the conceptual framework defined above, a research model (Fig. 1) was developed in the present study to determine the relationships among the antecedents, initiatives and results of green value chain implementations.

3.1.1 Antecedents of Green Value Chain Implementations

While businesses used to envisage the natural environment as an externality in the past, today they see it as a strategic factor and take it into consideration in every aspect of business. Legal enforcements and regulations have put businesses under pressure in term of their environmental activities [8, 11, 18] and such activities are also affected by several factors such as environmentalist actions, public and image concerns, customer expectations, development of the green competitive concept, changes in social responsibility perceptions and the perception of environmental standards [3, 9, 18, 20, 21]. Within this framework, the following hypotheses were formed in the current study:

H1a: There is a positive significant relationship between legal regulations and green primary activities.

H1b: There is a positive significant relationship between legal regulations and green internal support activities.

H1c: There is a positive significant relationship between legal regulations and green external support activities.

H2a: There is a positive significant relationship between public concerns and green primary activities.

H2b: There is a positive significant relationship between public concerns and green internal support activities. H 2c: There is a positive significant relationship between public concerns and green external support activities.

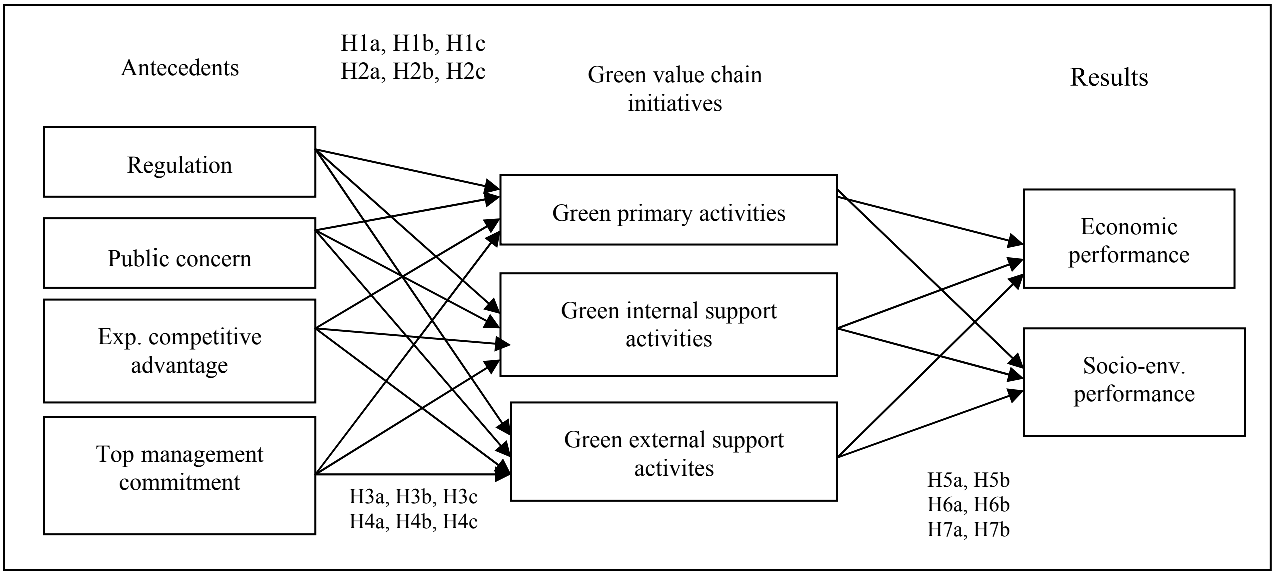

Fig. 1 Study model.

H3a: There is a positive significant relationship between expected competitive advantage and green primary activities.

H3b: There is a positive significant relationship between expected competitive advantage and green internal support activities.

H3c: There is a positive significant relationship between expected competitive advantage and green external support activities.

H4a: There is a positive significant relationship between top management commitment and green primary activities.

H4b: There is a positive significant relationship between top management commitment and green internal support activities.

H4c: There is a positive significant relationship between top management commitment and green external support activities.

3.1.2 Results of Green Value Chain Implementations

It was reported in the literature that green management practices yielded positive outcomes such as clean and green implementations, improvement and developments in processes, profitability, competitive advantage in products and services, increase in market share, development in company image and management systems [1, 3-6, 10, 11, 25, 28]. Moreover, the results of green value chain implementations are mostly evaluated within the frame of sustainable competitive advantage and social responsibilities of the businesses [1, 4-6, 28,]. While economic or financial performance constitutes the competitive advantage dimension of green value chain implementations, non-financial or socio-ecologic performance is evaluated under the social responsibilities of businesses. Within this framework, the following hypotheses were formed:

H5a: There is a positive significant relationship between green primary activities and economic performance.

H5b: There is a positive significant relationship between green primary activities and socio-ecologic performance.

H6a: There is a positive significant relationship between internal support activities and economic performance.

H6b: There is a positive significant relationship between internal support activities and socio-ecologic performance.

H7a: There is a positive significant relationship between external support activities and economic performance.

H7b: There is a positive significant relationship between external support activities and socio-ecologic performance.

3.2 Universe and Sample

Businesses operating in the Kayseri Organized Industrial Region constituted the universe of the study. Among the 822 businesses on the list of the Regional Directorate of Kayseri Organized Industry, 486 large and medium size ones (with more than 50 employees) constituted the universe. Research data were gathered through surveys conducted with the managers of quality departments or the managers responsible for the environmental practices of the businesses. Among the businesses, 182 responded to surveys and the respond rate was calculated as 41.73%.

3.3 Measures

The survey forms used to gather data were composed of three sections. There were 10 questions in the first section about the manager and the business to which the survey was applied, there were 41 statements in the second section about the factors forcing businesses to apply value chain implementation, and there were 17 statements in the last section about the results of green value chain implementations. The scales used in the study are presented below:

Antecedents of green value chains: These were measured by the 5-point Likert scale developed by

Cater et al. [3] with 18 statements indicating that the "environmental strategies of our business are primarily shaped around government regulations". Scale reliability, the Cronbach alpha value, was calculated as 0.902. Within the scale, 1 represents "certainly disagree" and 5 represents "certainly agree";

Initiatives of green value chain: These were measured by the 5-point Likert scale developed by Yang et al. [29] with 23 statements indicating that the "product designs and plans of our business are tried to be made with an environmental focus". Scale reliability, the Cronbach alpha value, was calculated as 0.934. Within the scale, 1 represents "certainly disagree" and 5 represents "certainly agree";

Results of green value chain implementations: These were measured by the 5-point Likert scale developed by Rao and Holt [24] with 17 statements indicating that the "productivity of our business has increased after green value chain implementations". Scale reliability, cronbach alpha value, was calculated as 0.941. Within the scale, 1 represents "certainly disagree" and 5 represents "certainly agree".

4. Research Results

4.1 Demographic Characteristics

Of the participants (Table 2), 29.1% were below the age 40, 42.3% were aged 31-40, 19.2% were aged 41-50 and 9.5% were over the age of 51. Male participants constituted 82.5% of total participants. With regard to the educational level of the 183 participants, 107 of them had graduate and higher level of education. With regard to business size, 75.3% of participant businesses have between 50-100 employees, 10.4% of them have between 101-200 employees and 14.3% have over 201 employees.

Demographic characteristics were used neither as dependent nor independent variables. Also, they were not used in hypothesis, relationship or difference analyses. They were just used to gather information about the study universe and to interpret the hypotheses.

4.2 Mean Values of Research Variables

In the present study, the dimensions of the antecedents of green value chain implementations (Table 3) (regulation, public concern, expected competitive advantages and top management support) had scores above the means (3.84, 3.55, 3.54 and 3.67, respectively). Green value chain initiatives also had similar means (3.67, 3.52 and 3.67). Among the results of green value chain implementations, socio-ecologic performance had a higher score (3.95) than economic performance (3.59).

Table 2 Demographic characteristics of participant managers and businesses.

Characteristics		Frequency	Percentage	Characteristics		Frequency	Percentage
Gender	Male	151	82.5	Education	Primary school	12	6.6
	Female	32	17.5				
	Total	183	100		High school	50	27.5
Age	20-30	53	29.1		Vocational college	12	6.6
	31-40	77	42.3		Undergraduate	107	58.2
	41-50	35	19.2		graduate	2	1.1
	51 +	17	9.5		Ph.D	-	-
	Total	183	100		Total	183	100
Business size	50-100 employees	137	75.3	Legal status	Incorporation	53	29.1
	101-200 Employees	19	10.4		Limited company	107	58.2
	200+ employees	27	14.3		Private company	24	12.6
	Total	183	100		Total	183	100

4.3. Correlation Table

The correlation matrix indicating the relationships among antecedents, initiatives and results of green value chain implementations are provided in Table 4.

As can be seen in Table 4, there was a positive significant relationship between the antecedents of green value chain implementations (regulations, public concerns, expected competitive advantage and top management support) and green primary activities. The level of relationships was medium and increasing green value chain implementations were observed with increasing factors motivating the businesses to green value chain implementations. Similarly, a positive significant relationship was observed between green primary activities and the results of green value chain implementations.

4.4 Hypothesis Testing

The research model and hypotheses of the model were tested through multiple regression analyses and results were interpreted accordingly.

As can be seen in Table 5, 67.9% of variation in green primary activities can be explained by antecedents orienting the businesses to green value chain implementations. A valid F value of 60.512 at 0.00 significance level indicates that the model is valid as a whole.

Table 6 presents the results of multiple regression analysis performed to see the effects of independent

Table 3 Mean and standard deviations of variables.

Variable		Mean	Standard deviation
Antecedents of green value chain implementations		3.67	0.62
	Regulation	3.84	0.72
	Public concern	3.55	0.72
	Expected competitive advantages	3.54	0.89
	Top management support	3.67	0.90
Initiatives of green value chain implementations		3.62	0.69
	Green primary activities	3.67	0.75
	Green internal support activities	3.52	0.88
	Green external support activities	3.67	0.73
Results of green value chain implementations		3.77	0.66
	Economic performance	3.59	0.72
	Socio-ecologic performance	3.95	0.71

Table 4 Correlation matrix.

	1	2	3	4	5	6	7	8	9
Regulation	1								
Public concern	0.454**	1							
Exp. comp. advantages	0.436**	0.645**	1						
Top man. support	0.425**	0.559**	0.630**	1					
Green primary act.	0.412**	0.629**	0.726**	0.747**	1				
Green int. support act.	0.382**	0.500**	0.546**	0.634**	0.694**	1			
Green ext. support act.	0.291**	0.495**	0.474**	0.576**	0.655**	0.686**	1		
Economic perf.	0.183*	0.175*	0.248**	0.219**	0.276**	0.467**	0.399**	1	
Socio-ecologic perf.	0.224**	0.161*	0.152*	0.214**	0.315**	0.411**	0.305**	0.703**	1

**$P > 0.01$, *$P > 0.05$

Table 5 Results of regression analysis performed to determine the effects of antecedents of green value chain implementations on green primary activities.

	R	R^2	Adjusted R^2	Standard error of estimation	F	Sig.
Green primary activities	0.824	0.679	0.671	0.417	60.512	0.00

$P < 0.05$; *Dependent variable: Green primary activities; Independent variable:* regulations, public concerns, expected competitive advantage, top management commitment.

Table 6 Coefficients of regression analysis performed to determine the effects of antecedents of green value chain implementations on green primary activities.

	Non-standardized coefficients		Standardized	*t*	Sig.
	Beta	Standard error	Beta		
Constant	0.692	0.202		3.432	0.01
Regulations	0.017	0.053	0.016	0.327	0.74
Public concerns	0.149	0.060	0.148	2.469	0.01
Exp. competitive advantage	0.313	0.051	0.371	6.090	0.00
Top management commitment	0.345	0.047	0.419	7.384	0.00

Table 7 Results of regression analysis performed to determine the effects of antecedents of green value chain implementations on green internal support activities.

	R	R^2	Adjusted R^2	Standard error of estimation	*F*	Sig.
Green Internal support act.	0.655	0.430	0.417	0.661	33.132	0.00

$P < 0.05$; Dependent variable: green internal support activities; Independent variable: regulations, public concerns, expected competitive advantage, top management commitment

Table 8 Coefficients of regression analysis performed to determine the effects of antecedents of green value chain implementations on green internal support activities.

	Non-standardized coefficients		Standardized	*t*	Sig.
	Beta	Standard error	Beta		
Constant	0.579	0.319		1.811	0.07
Regulations	0.077	0.084	0.060	0.922	0.38
Public concerns	0.164	0.096	0.137	1.712	0.08
Exp. competitive advantage	0.160	0.082	0.160	1.964	0.05
Top management commitment	0.409	0.074	0.417	5.521	0.00

Table 9 Results of regression analysis performed to determine the effects of antecedents of green value chain implementations on green external support activities.

	R	R^2	Adjusted R^2	Standard error of estimation	*F*	Sig.
Green external support act.	0.600	0.360	0.345	0.57	24.722	0.00

$P < 0.05$; Dependent Variable: green external support activities, independent variable: regulations, public concerns, expected competitive advantage, top management commitment.

variables composed of the antecedents of green value chain implementations (regulations, public concerns, expected competitive advantage and top management commitment) on dependent variable green primary activities. The results revealed the significant effects of public concerns (0.01), expected competitive advantage (0.00) and top management commitment (0.00) on green primary activities. The regulations did not have any significant effect on green primary activities. With these results, hypothesis H1a was rejected and hypotheses H2a, H3a and H4a were accepted.

As can be seen in Tables 7 and 8, the antecedents of green value chain implementations were able to explain 43% of the variations in green internal support activities. While expected competitive advantage (0.005) and top management commitment (0.00) had significant impacts on green internal support activities, regulations and public concerns did not have any significant effects on green internal support activities. Therefore, hypotheses H1b and H2b were rejected and hypotheses H3b and H4b were accepted.

As can be seen in Table 9, the *R* value indicating the relationship between the antecedents of green value chain implementations and green external support activities was found to be 0.600. There was a medium level positive significant relationship between the antecedents of green value chain implementations and green external support activities. The *F* value was calculated as 24.752. The model was valid as a whole at 0.00 significance level and the antecedents of green value chain implementations were able to explain 36% of the variations in green external support activities. Results of the *t*-test for the significance of regression coefficients revealed the significant effects of public concerns (0.00) and top management commitment (0.00) on green external support activities. Based on these results, hypotheses H1c and H3c were rejected and hypotheses H2c and H4c were accepted.

According to the results of multiple regression analysis performed to test the effects of initiatives of the green value chain implementations on economic performance (Tables 11 and 12), green value chain initiatives composed of green primary activities, green internal support activities and green external support activities were able to explain 24.2% of the variation in economic performance. The results of *t*-tests indicated the significant effects of green internal and external support activities on economic performance. Therefore, hypothesis H5a was rejected and hypotheses H6a and H7a were accepted.

As can be seen in Tables 13 and 14, the independent variables initiatives of green value chain implementations were able to explain 17.1% of the variation in dependent variable socio-ecologic performance. While the significant effects of green internal support activities (0.00) were observed on socio-ecologic performance, the effects of green primary activities and green external support activities were not found to be significant on socio-ecologic performance. Thus, hypothesis H6b was accepted and hypotheses H5b and H7b were rejected.

Table 10 Coefficients of regression analysis performed to determine the effects of antecedents of green value chain implementations on green external support activities

	Non-standardized coefficients		Standardized	*t*	Sig.
	Beta	Standard error	Beta		
Constant	1.641	0.277		5.916	0.00
Regulations	-0.052	0.073	-0.049	-0.716	0.47
Public concerns	0.251	0.083	0.256	3.021	0.00
Exp. competitive advantage	0.059	0.071	0.072	0.835	0.45
Top management commitment	0.309	0.064	0.384	4.796	0.00

Table 11 Results of regression analysis performed to determine the effects of initiatives of green value chain implementations on economic performance.

	R	R^2	Adjusted R^2	Standard error of estimation	*F*	Sig.
Economic performance	0.492	0.242	0.229	0.64	19.029	0.00

$P < 0.05$; Dependent variable: economic performance; Independent variable: green primary activities, green internal support activities, green external support activities.

Table 12 Coefficients of regression analysis performed to determine the effects of initiatives of green value chain implementations on economic performance.

	Non-standardized coefficients		Standardized	*t*	Sig.
	Beta	Standard error	Beta		
Constant	2.145	0.263		8.162	0.00
Green primary activities	-0.158	0.093	-0.163	-1.696	0.09
Green Int. support activities	0.363	0.083	0.440	4.400	0.00
Green ext. support activities	0.203	0.095	0.205	2.150	0.03

Table 13 Results of regression analysis performed to determine the effects of initiatives of green value chain implementations on socio-ecologic performance.

	R	R^2	Adjusted R^2	Standard error of estimation	*F*	Sig.
Socio-ecologic performance	0.413	0.171	0.157	0.65	12.286	0.00

$P < 0.05$; Dependent variable: socio-ecologic performance; Independent variable: green primary activities, green internal support activities, Green external support activities.

Table 14 Coefficients of regression analysis performed to determine the effects of initiatives of green value chain implementations on socio-ecologic performance.

	Non-standardized coefficients		Standardized	*t*	Sig.
	Beta	Standard error	Beta		
Constant	2.661	0.270		9.861	0.00
Green primary activities	0.047	0.096	0.049	0.486	0.62
Green int. support activities	0.290	0.085	0.357	3.421	0.00
Green ext. support activities	0.028	0.097	0.028	0.283	0.77

5. Conclusions

The implementations able to serve a sustainable competitive advantage in global markets have strategic significance in today's world. Ever-changing and developing dynamic conditions, on the one hand, and the legal enforcements of state and governments and customer expectations on the other generate pressure on businesses and force them to look for new management approaches. Protection of the natural environment came into prominence especially at the end of the 1980s with the huge environmental problems and accidents at the time. The negative impacts of such problems also exerted pressure on the businesses since they were envisaged as the primary responsible sources of such problems. Therefore, since then, businesses have aimed to apply environmental implementations both to meet legal regulations, the expectations of the public and their customers and to gain a competitive advantage. Within this framework, the concept of "green value chain", considered among new management practices, was evaluated and the relationships among antecedents, initiatives and results of green value chain implementations were investigated in the present study. A model was created and hypotheses were formed to test such relationships.

Initially, the relationships between the antecedents of green value chain implementation (regulations, public concerns, expected competitive advantage and top management commitment) and initiatives of green value chain implementations (green primary activities, green internal support activities and green external support activities) were investigated and a relationship was not observed between the regulations and initiatives of green value chain implementations. While such findings do not support the findings of Refs. [7, 10, 11, 25], they support the findings of Ref. [4]. On the other hand, significant relationships were observed between public concerns and green primary and external support activities. Such findings partially support the findings of Refs. [7, 10, 11], but do not support the findings of Ref. [25]. Significant relationships were also observed between expected competitive advantage and green primary and external support activities. These findings comply with the findings of Refs. [7, 10, 11]. Finally, positive significant relationships were observed between top management commitment and initiatives of green value chain implementations (green primary activities, green internal support activities and green external support activities). Such findings support the findings of Refs. [10, 25].

Subsequent analyses were performed to test the relationships between initiatives of green value chain implementations (green primary activities, green internal support activities and green external support activities) and economic and socio-ecologic performance. While no relationship was observed between green primary activities and economic, socio-ecologic performance, a positive relationship was observed between green external support activities and economic performance and between green external support activities and both economic and socio-ecologic performance. Previous studies reported positive relationships between environmental implementations and operational performance criteria such as a decrease in environmental accidents, an increase in research & development works, a decrease in process costs and an increase in quality [1, 2]. There are also studies reporting the relationships of environmental implementations with only economic performance [3] and with both economic and social or socio-economic performance [2, 4, 5]. At this point, current findings comply with the findings of Refs. [2, 4].

To conclude, regulations, public concerns, expected competitive advantage and top management commitment, which were indicated as antecedents of green value chain implementations and forced businesses to environmental consciousness, were found to be related to green value chain initiatives. In addition, green value chain initiatives covering green internal support activities such as human resources training and development, creation of a green business culture, giving priority to environmentally friendly technologies and internalization of environment standard certificates had various impacts on both the economic and socio-ecologic performance of businesses. In this sense, it can be stated that green primary activities do not affect business performance provided that they are realized within the scope of legal regulations and public concerns but green external support activities including incentives of the state and government, foreign cooperation and economic conditions have significant effects on economic performance.

There are some limitations to the current study. Initially, since business performance was evaluated with regard to the perceptions of managers, it may not be subjective. Also, a regional study may not be generalized over the entire country. In any case, participating businesses are aiming towards green management, green value chain implementations and environmentally friendly activities. In future studies, value creation within the scope of green value chain implementations, possible cooperation, sustainable competitive advantage creation considering internal and external customers may be focused on. Such studies may even cover various regions or nations.

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Journal of Environmental Science and Engineering A 2 (2013) 520-522
Formerly part of Journal of Environmental Science and Engineering, ISSN 1934-8932

Morphometric Comparison of White Tambaqui (*Piaractus brachypomus*) in Lentic and Lotic Environments

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Received: May 07, 2013 / Accepted: July 12, 2013 / Published: August 20, 2013.

Abstract: The purpose of this paper is looking for associations between environmental factors and morphological parameters in tambaqui (*Piaractus brachypomus*) individuals to differentiate this species in lentic environments (lake) and lotic (river). In this, regard studied 30 specimens, 15 from lentic environment (lake) and 15 from lotic (river). Also, on right profile of these 25 morphometric variables were measured. On data matrix a PCA (principal components analysis) based on morphometric correlations matrix, which was defined in the new morphologic space of these specimens (3 principal components) which explain 73.23% of variability. Fish projection in first two principal components showed a morphological differentiation between two environments (lentic and lotic), with variables as， horizontal eye diameter, length maxilla, suggesting greater response of these fish in lotic environment by their adaptation to light conditions, predators threat and food distribution. Finally, in lotic environment these fish have thinner caudal peduncle, indicating greater plasticity, namely stylized fish.

Key words: Morphometric, comparison, tambaqui, environments and principal components.

1. Introduction

In fish, there is a clear relationship between form and function, allowing the morphology reflect adaptation to habitat and feeding niche [2]. In this regard, morphometric, measurement and shape analysis has been provided through computer programs, the tools for the analysis of multiple characters [1]. Thus, the PCA (principal component analysis) has been widely used as an exploratory technique to examine relationships between variables, and assumes no a priori division and focuses on the relationship between variables and between individuals within a single sample, reducing the dimensionality of the original data to a new set of variables with axes or orthogonal components. These components are simply linear combinations of the original variables. Additionally, it is a tool for low-cost, high value information we can know the relationship between environmental factors. The aim of this paper is to find associations between environmental factors and some external morphological parameters for differentiating individuals the white tambaqui (*Piaractus brachypomus*) in lentic and lotic environments using morphometric analysis.

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2. Methods and Data

This study was involved 30 *Piaractus brachypomus* youths approximately 400-500 g, 15 specimens from artificial ponds Papelón Fish Culture Station, and 15 from lotic environment (Portuguesa River). Twenty-five (25) morphometric variables were taken. Measurements were performed with digital vernier caliper (0.001 mm), except for body length which is measured with conventional punctuate. These variables were: (1) body length; (2) maximum height; (3) head length; (4) snout; (5) horizontal eye diameter; (6) maxillary length; (7) predorsal distance; (8) dorsal fin base; (9) interdorsal distance; (10) dorsal-flow distance; (11) caudal peduncle minor height; (12) caudal peduncle length; (13) anal fin base length; (14) anal-caudal fin distance; (15) pelvic fin-anal distance; (16) pelvic fin-caudal distance; (17) pelvic fin-fat distance; (18) pelvic fin-dorsal distance; (19) pectoral fin-pelvis distance; (20) pectoral fin-anal distance; (21) pectoral fin base length; (22) pectoral fin-caudal distance; (23) pectoral fin-fat distance; (24) pectoral fin-dorsal distance; (25) prepectoral distance and (26) pectoral distance. For statistical analysis univariate and principal components (R method) techniques were applied.

3. Results and Discussion

In Table 1 eigenvalues of morphometric principal component analysis correlation matrix are showed, which shows that in the first three (3) components the eigenvalues are greater than one (1), also the cumulative percentage of variance is of 73.23% which suggests a high correlation ($P < 0.05$) between most variables and defines the new morphological space (size is 3) where are specimens from lentic and lotic environment.

In Table 2 principal component analysis is showed for tambaqui (*Piaractus brachypomus*) (rotated solution), where observes that the PC1 (first component) is associated to variables: eye diameter, maxillary length, dorsal fin base, interdorsal distance, dorsal-caudal distance. On the other hand, the PC2 (second component) is associated to caudal peduncle length variable and finally the PC3 (third component) is associated to variables anal fin distance and pelvic-pectoral-anal fin distance.

In Table 3, there are marked differences in terms of variables associated with the head area such as eye horizontal diameter and maxillary length, suggesting a greater response of this species in the lotic environment, since it is better adapted to light conditions, developing sight sense for food finding, predator threat and counter-current, compared with lentic environment where there is increased turbidity in the water and a better food distribution. PC2 shows significant differences in the caudal peduncle variable, because in lotic environments this species has more slender caudal peduncle compared to lentic environment, suggesting greater plasticity to develop skills hydrodynamic, i.e., more stylized fish.

Table 1 Eigenvalues and variance proportion in data from morphometric correlation matrix.

Principal component	Eigenvalue	Variance proportion (%)	Cumulative variance (%)
1	13.40	53.62	53.62
2	3.04	12.19	65.82
3	1.85	7.41	73.23

Table 2 Principal component analysis of tambaqui (*Piaractus brachypomus*) (rotated solution).

Principal component	Variable	Factor
1	Eye horizontal diameter	0.78
	Maxillary length	0.83
	Dorsal fin base	0.72
	Interdorsal distance	0.77
	Dorsal-flow distance	0.79
2	Caudal peduncle length	0.91
3	Pelvic fin-anal distance	0.81
	Pectoral fin-anal distance	0.71

Table 3 Principal components analysis for tambaqui (*Piaractus brachypomus*) from lotic and lentic environments.

Principal component	Variable	Lotic	Lentic
1	Eye horizontal diameter	0.68	-0.04
	Maxillary length	0.92	0.08
	Dorsal fin base	0.65	0.85
	Interdorsal distance	0.66	0.90
	Dorsal-flow distance	0.78	0.93
2	Caudal peduncle length	-0.04	0.94
3	Pelvic fin-anal distance	0.13	-0.19
	Pectoral fin-anal distance	0.37	0.25

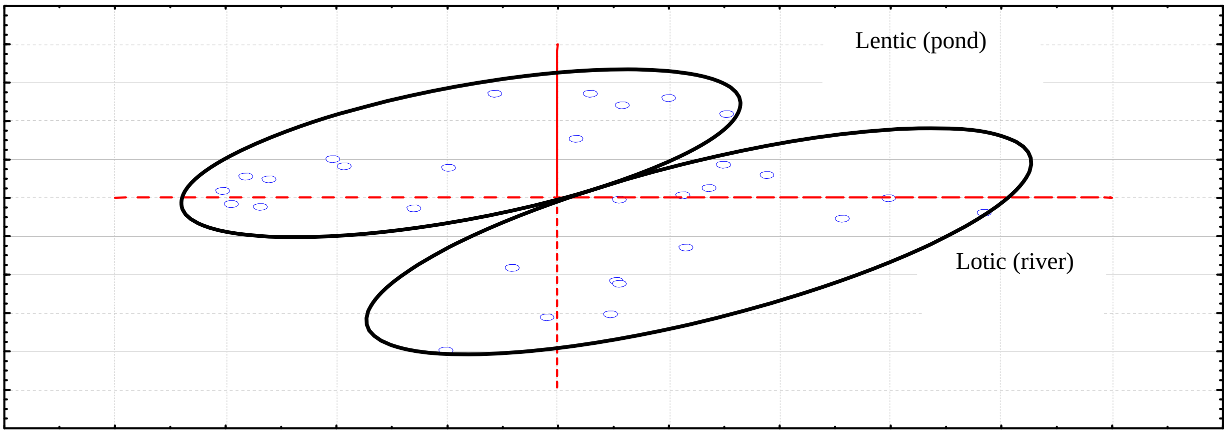

Fig. 1 Tambaqui specimens (*Piaractus brachypomus*) from lentic and lotic environments projected in two principal components.

5. Conclusions

In PCA is showed a morphological differentiation between two settings, with variables such as, eye horizontal diameter and maxillary length suggesting a greater response of these fish in lotic environment by adapting light conditions, threat of predators and food distribution. Finally, in lotic environment these fish showed thinner caudal peduncle, indicating greater plasticity, hydrodynamics skills, namely, more stylized fish. Results this paper shows a habitat and supply niche potential effect on these fish morphology.

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Journal of Environmental Science and Engineering A 2 (2013) 523-529
Formerly part of Journal of Environmental Science and Engineering, ISSN 1934-8932

DAVID PUBLISHING

Measuring Visitors' Preferences for Establishing Sustainable Tourism Products: An Empirical Research

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Received: March 28, 2013 / Accepted: June 22, 2013 / Published: August 20, 2013.

Abstract: The management of coastal zones in terms of tourism exploitation remains a crucial issue in achieving sustainable development and customer satisfaction. The interrelation between the coastal zone and the preference structure of visitors form a desired tourism setting and a hospitable destination in which environmentally friendly practices dominate the tourism aspects. Conjoint analysis was used with a purpose of eliciting respondents' preferences and answering questions concerning the features that compose a sustainable tourism product. In the survey, 16 proposed combinations of tourism characteristics were rated by 1,433 respondents. The three most preferred factors of the proposed tourism product were the accommodation factor, the sea activities factor and the fishery tourism factor with averaged importance scores 27,351,22,900 and 21,131, respectively.

Key words: Preferences, conjoint analysis, sustainable development.

1. Introduction

Tourism is directly associated with environmental issues since its impacts and pressures are related to the good ecological status of natural resources, coastal management policies, biodiversity conservation and the well being of humans [1-3]. Tourists depict a disposition to try out different experiences, and greater volatility in preferences rejecting conventional mass tourism [4]. It would be beneficial to reveal the features that affect visitors' preference and decode the respective patterns into applicable practices that match and allow for tourism accomplishments to coastal settings.

Supportively, the competitive advantage of the destination place is highly supported by tourism development based on quality, sustainability and diversity [5].

The purpose of this study is to define destination attributes based on consumer preferences as a function of conjoint analysis and advance sustainable coastal tourism products. Conjoint analysis detects the mode on which consumers build their preference structure and make decisions about products [6, 7]. To this effort, the aim of the analysis lies in determining the suitable features of the tourism product and eliciting the preferences of consumers that highlight its potential and broaden its applicability in coastal zones. Coastal development is deemed fundamental issue for Hellenic tourism policy. Policy makers seek for alternatives, tools and techniques that can equip them with a broad repertoire of options for developing coastal areas at a considerable level resulting in increased tourism demand and visitation rates.

In tourism planning the underlying factors that shape the destination choice and the understanding of the patterns of tourist behavior [8] largely determine tourism demand and forecast tourism perspective in the long term [9]. Traveler behavior can be decoded by using its preferences when visiting a destination [10]. Conjoint analysis as a stated preference method is a complementary tool for elaborating on travel

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preferences and the destination attribute evaluation aspects [11]. It would be practical to mention that the deference between stated and revealed preference methods is that in the revealed preference methods such as the travel cost approach, the researcher observes the actual behaviour of visitors. Such methodologies document and analyze the actual responses of visitors. In the stated preference methodologies respondents "state" or "express" preferences based on hypothetical questions. More specifically, stated preference methods measure how a respondent states that he or she will react in a certain situation [12].

2. The Study Area

The Maliakos Gulf and North Evboean Gulf in Sterea Ellada Region, in Greece (Fig. 1) was chosen as a subject to our research [13]. The Maliakos Gulf is a gulf of the Aegean Sea in the region of Pfthiotida in eastern Central Greece. It stretches east to west to a distance of 15 km to 22 km, depending on the definition. Its maximum depth is 27 m. The Maliakos Gulf is considered the most important within the mainland concerning environmental issiues such as biodiversity aspects and economic value. It is listed in the national list of habitats included in the European ecological network Natura 2000. The north Evboean Gulf is about 50 miles (80 km) long and up to 15 miles (24 km) wide. It separates the northern part of the island Evia from the mainland of Central Greece. Moreover, along the coast of Fthiotida are many popular summer resorts such as Kamena Vourla and Agios Konstantinos which are popular tourist destinations in Greece. In Kamena Vourla only more than 70 accommodation facilities operate while in the whole area of the prefecture of Fthiotida there are 152 accommodation facilities with a capacity of 6,735 rooms and 5 camping areas with an accommodation capacity of 2,148 people.

The Maliakos Gulf is a rich fishing resource with great production. The fishing activity is conducted by 322 registered fishing boats and 700 fishermen earn their living from such activity using a wide range of fishing boats and tools. Marine biodiversity strongly supports a large variety of goods and services for sustaining the social and economic structure of the study area. The marine environment of the area supports the welfare of the local population and keeps the various natural functions balanced climate reasons and natural causes contributed to a great extent to choose this area for implementing our research. Additionally, lack of innovative coastal tourism projects as well as the existence of conservative and traditional marketing process stimulated our interest to search for effective alternatives based on customer driven tourism products avoiding mass tourism approaches. Moreover, the wise allocation of human and technical resources will prove to be beneficial and

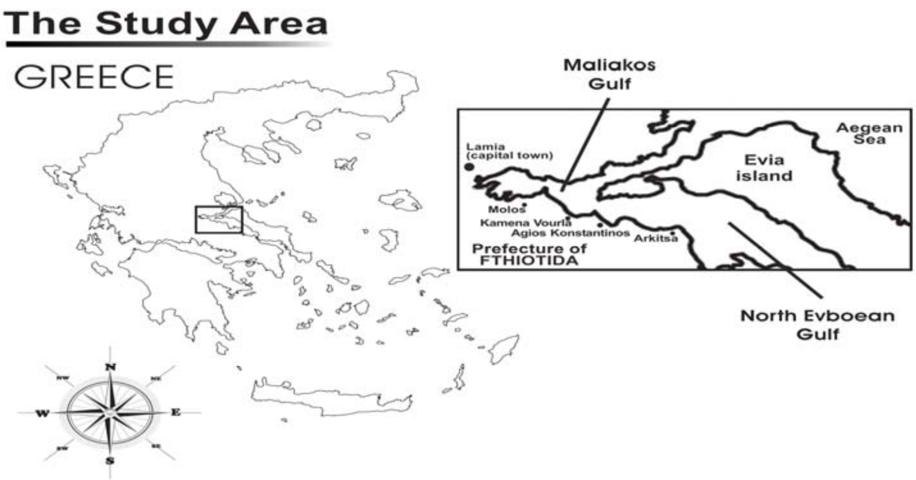

Fig. 1 The study area.

create high rates of return for investments if sustainable tourism plans will be put into practice.

3. Materials and Methods

Conjoint analysis can be applied in creating and developing new products [14] based on individual judgemnets coming from multi attribute stimuli [15] and studying how product attributes influence their responses [16]. It incorporates the preferences depicted by the targeted users of a product in a direct way. Policy makers use the method in measuring the value that consumers assign to features or attributes of the product [17] and decompose the holistic information about respondents' reactions (e.g., statements or choices) to a set of stimuli into the relative importance of each level of each factor (or attribute) according to a pre-specified utility model [18]. The utility that a consumer assigns to a good can be decomposed into part worth utilities or values regarding the benefits or attributes that this good offers [19]. The conjoint action of two or more qualitative features represents the independent variables and the preferences of individuals take the place of the dependent variables [20]. The assigned rank orders are translated into part-worth utilities disclosing the combinations that are most preferred by the respondents [21]. A conjoint analysis survey requires that individuals participating in the process start ranking product attributes or commodity descriptions (presented in a card list by the researcher) from the most preferred to the least preferred [22]. In essence, respondents should state their preference and decide which commodity description or combination of attributes is more attractive, interesting and preferred.

The first step in applying the method was to determine the characteristics (factors) of the proposed tourism product and the respective levels (Table 1) that will take part in the analysis and be valued by the respondents [23]. Defining the factors is a crucial task since it identifies the content and the potential of the product [24] while it should be policy and demand relevant [25]. The potential of the product and the competing alternatives offered will affect the demand for the usage of recreation facilities [26]. Predictive Analysis SoftWare (PASW ver18) was used to run the analysis and create the orthogonal design (orthogonal main-effect plan) in which the levels of the factors are uncorrelated and the estimate of one factor is unaffected by the estimates of the others [27]. A fractional factorial design can be produced using the main effects [17, 28].

The number of attributes to be valued remains a crucial issue. Too many combinations may lead to confusion, refusal, low rates of participation and no answer replies [29]. Five or six attributes may be

Table 1 Factors and levels for applying conjoint analysis.

Factors*	Levels
Choice of payment	Pay for beach use and sea activities Pay only for sea activities and free use of beach area
Time of visit	May, June-middle of July Middle of July-middle of August Middle of August-September
Sea based activities	Organized diving activities Touring with sea boats-Cruises Swimming-sunbathing
Fishery tourism	Fishing from the beach Watching "small scale" fishing processing—Tasting fish products Fishing from boats in the gulf
Accommodation	Large and famous hotel facilities Rooms to let-Camping Family owned hotels Traditional guest houses

*Factors and their levels are defined by the researcher in advance.

considered an adequate and manageable number with dependable results [30]. The most preferred combination took the value 1 and the least preferred took the value 16. Utility estimates allow the researcher to determine the preference of the respondents, interpret the findings in terms of sustainable tourism products and sound management efforts, reach the goals set and achieve results.

4. Results

The software created 16 combinations based on the factors input. The model had a good fit based on the correlation coefficients and *P* value (0.000). The statistics Pearson's *R* (0.956) and Kendall's tau (0.783) that depict the correlation concerning the observed and estimated preferences are deemed statistically significant [26, 31]. The utility scores or part worth utilities for each level of each factor are presented in Table 2.

The contribution of each factor to overall preference is reflected by the respective importance values [10]. Fig. 2 shows in a graph form the importance summary regarding the factors that compose the tourism product.

Negative values do not mean denial or rejection [22]. The higher the utility values the higher the preference but higher negative values lead to lower utility. The total utility of the most preferred combination can be derived by adding the most preferred levels of each factor of Table 3. The constant value is also included in the calculations. As a result, the most preferred combination of the tourism product makes a total utility of 10,381. The combination of characteristics that maximizes the preference of the respondents is: payment only for sea activities and free access to the beach, visit the study area between middle of July and middle of August, experience organized diving activities, enjoy fishing from sea boats and be accommodated in traditional guest houses (Table 2). Similarly, any possible and desired combination containing the factors and levels of Table 3 can be derived.

The range of the importance values is presented in Table 3. Factors with greater utility contribute to a greater extent compared to those with lower utility. The results showed that accommodation facilities play a significant role and mostly influence the respondents. Sea based and fishery activities featured largely in the preference structure of respondents. Time of visit is the fourth factor in the range of the importance utilities and is at a distance from the last factor. Choice of payment is the factor with the least important contribution to the overall preference. The above characteristics involve the users in a wide range of activities, offer a sense of excitement and help ecosystems remain productive.

Table 2 Utility estimates for each level.

Factors	Levels	Utility estimates
Choice of payment	Pay for beach use and sea activities	-0.216
	Pay only for sea activities (free use of beach)	0.216
Time of visit	May, June-Middle of July	0.007
	Middle of June-middle of August	0.031
	Middle of August-September	0.024
Sea based activities	Diving activities	0.499
	Cruises-touring with sea boats	0.303
	Swimming-sunbathing	0.196
Fishery tourism	Fishing from the beach	0.055
	Tasting fish products	0.291
	Fishing from boats in the sea	0.347
Accommodation facilities	Large-famous hotel facilities	0.440
	Rooms to rent—camping	0.205
	Family owned hotels	0.252
	Traditional guest houses	0.897
Constant		8.391

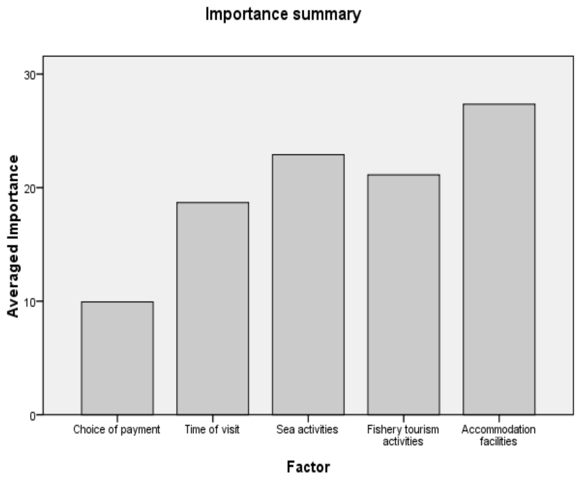

Fig. 2 The averaged importance values for each factor.

Table 3 The importance values of each factor.

Factors	Values
Choice of payment	9.940
Time of visit	18.678
Sea activities	22.900
Fishery tourism	21.131
Accommodation	27.351

5. Discussion

Defining the tourism product is a complicated issue since it incorporates the wise use of natural resources, the cultural and social characteristics of the local community, the needs and wants of the potential consumers, the market segmentation and the policy followed which ought to be financially viable and cost effective. A tourism product can be defined as a bundle of benefits, activities and services that constitute the entire tourism experience [32] or a satisfying activity at a destination place [33]. The multifaceted character of environmental goods in accordance with the innovative nature of tourism [34] makes conjoint analysis a beneficial tool to measure the relative values of attributes that have been considered jointly by the respondents [12]. The advantage that the analysis offers is based on identifying consumer segments judging from their individual preferences [35]. All characteristics and activities involved in the analysis are in harmony with the specific natural setting and can be supported by the water ecosystem. The translation of customer preferences into requirements demands key measures that put strategy into language that everyone can understand [36] and helps to remain competitive by creating new products which are the lifeblood of any business [37]. Trends in the tourism market will find the stakeholders aligned, flexible and determined to perform at high levels. Related issues such as value for money will largely assist the efforts to fulfill visitor' expectations and gain customer satisfaction. Getting the full benefit of the tourism product with a feeling of not losing time and money in conventional and "boring" tourism destinations is essential for effective costal tourism management. Viable plans, well defined preference structures and lessons learned from previous efforts support the avoidance of dysfunctions and adopt a win-win approach when conflicts of interests and competing beach uses occur. Stated preference data advance the efforts of researchers to shed light on travelers' behavior and make valuations regarding natural areas [38, 39]. The research was designed to further understand the coastal tourism market in the study area. Diversifications in the range of tourism products, quality services and innovative tourism practices can be deemed as stimulating factors and motives to visit the area. Continuous improvement processes as the never ending pursuit for excellence and benchmarking as a method for measuring your organization against those of recognized leaders or best of class [40] results in acquiring a target that should be reached and become more competitive. The concept lies in identifying system discrepancies, making solid decisions and developing plans that make tourism stakeholders and respective organizations capable of addressing problems and questions in response to sudden or gradual customers' changing preferences and patterns of diversity. Keeping tourism products customer oriented the local society should expect reduced unemployment, extended tourism seasons as well as income and revenue generation. Host community should assign social value to the tourism endeavours and enable its contribution to the anticipated market expansion and sustainable growth.

The route causes should be identified and effectively modelled providing evidence in a logical manner at a broader level. In this perspective, a joint effort of coastal resource development makes a good sense in adopting gainful and coherent tourism policies and establishing a starting point for further implementation in relevant natural settings. Sustainability remains a desirable objective of tourism policy and practice [41]. Sustainable tourism is defined as the tourism that meets the needs of tourists and hosts region, while at the same time it protects and improves opportunities for the future. It focuses on the management of all the resources in a way that all economic, social, and aesthetic needs are met while cultural integrity, key ecological processes, biodiversity, and life support systems are respected [42].

6. Conclusions

The aim of this research was to employ conjoint analysis and advance effective coastal tourism development. Such methodology can be applied in relevant coastal zones in Greece as part of its national coastal tourism policy. Considering that customer satisfaction which is a cumulative measure of total purchase and consumption experience [43] is of primary importance, managing change in existing tourism settings demands policies aligned with regional characteristics and balanced with knowledge and experience. Overall preference of respondents seemed to be a sustainable source of putting into practice fishery and diving tourism projects which act supportively in gaining environmental rewards and enhancing the performance status of the system. Increased visitation rates, expansion of the tourism period and improvement of the host community will be achieved through realistic goals and investment motives. The estimated "value system" of individuals using conjoint analysis [43] and the decomposition of its preference leads to avoidance of outdated management practices, effective confrontation of the volatile and unstable market conditions and last but far from least leads to experiencing a prosperous and promising sustainable future. By understanding the suitable for the destination tourism features, that could and would maximize the preference rates of visitors, viable and well defined tourism products will become a reality for the long term.

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