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Climate Variability and Vulnerabilities among Transitional Farming Communities along Southern Coast of India

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Abstract

If the natural resources are protected and conserved, to ensure good ecosystem health, human health and better productivity, the production systems like aquaculture ,inland fishery etc. that depend on these resources will manage the resource for best utility. However, as is any other system, vulnerabilities posed by changes in natural resources is an inherent part of transformations in transitional societies. Effect of water quality changes induced by pollution and climatic variability on food production is a concern contributing to food and nutritional insecurity. Therefore, it is important to understand the vulnerability and risk caused by water quality variations in artisanal aquaculture. Some of the prominent hazards due to water quality changes in aquatic ecosystems are mortality, diseases, and retarded growth of aquatic organisms. This pose vulnerabilities among aquatic communities .Likewise, the economic risk of water quality changes is reflected in damage costs caused by the hazards in aqua culture. The objective of this study is to assess the vulnerability posed by water quality changes along different artisanal farming systems and practises along Vemband wetland, Kerala India. Secondly to understand the risk posed by water quality changes in artisanal aquaculture farming communities which leads to transformations in the systems. To understand water quality primary water samples were collected from the wetland ecosystems and wetland based aquaculture farms on various parameters like pH, salinity, temperature, Ammonia, nitrate, nitrite, BOD, DO. Hazards were assessed based on the farm based primary data collected from 222 farms along the wetland ecosystem. The study shows that water quality of wetland could be a source for vulnerability among small scale aquaculture farmers and deterioration of water quality has higher probability to cause risk in the farming system.

Keywords: Climate variability, Vulnerability, transitional farming communities, coast,South India.

INTRODUCTION

Water is an essential ingredient for the existence of life .Many ecosystems like forests, lakes or wetlands need water as a medium to recharge life. Along with same many production sectors like agriculture, manufacturing , energy need water .Water also holds some aesthetic and cultural uses .Water is fundamental for human food and nutritional security as sufficient quantity and quality is required for agricultural production and processing. Though water is very important this resource is under increasing stress .Population growth, conflicting needs arising out of changing life styles, consumption patter, increasing demand from various economic sectors has brought in competition for this degrading resource .Pollution from agriculture and industry has made water unfit for specific uses and many ecosystem functions and services got degraded. These core problems are intensified with climatic changes which disproportionately effecting the marginalized communities. With human population to grow at 9.6 billion people by 2050,percapita water availability to further decline with water pollution (Palaniappan, 2010) and variation in supply of water paused by climatic changes (Bates, 2008)all together humanity is in a dilemma on managing this limited natural resource which is crucial for food and nutritional security .

As the axiom goes “ Fish is a rich food for poor” as it is rich in nutrition and is depended by the poor and marginalized communities for primary source of animal protein .The study by (FAO., 2012) points out that fish contributes about 4.3 billion people with about 15 percent of their average per capita intake of animal protein globally. With capture fishery levelling off , fish production from marine and inland fishery is on a cross road .Aquaculture is long envisaged as a means for improving food & nutritional security ,livelihood security, trade and employment in developing and under developed countries. Its estimated that about 38.4 million people are involved in global aquaculture value chain (FAO 2010).

Fish has been pointed out as the solution for Indian malnutrition and for its southern state Kerala, 77% report to consume fish ,while low and middle income consume more fish than upper income class in Kerala (Kent, 1987).This shows importance of fish in food security of Kerala, India. Fish being an aquatic life, and water quality an important resource for aquaculture production, we are marching to a catastrophe from food and nutritional security perspective .This crisis thus evolved should be analyzed and managed scientifically with better policy directions to sustain resources and achieve economic efficiency. The objective of this study is to assess the vulnerability posed by water quality changes along different artisanal farming systems and practices along Vemband wetland, Kerala India Secondly to understand the risk posed by water quality changes in artisanal aquaculture farming communities which leads to transformations in the systems.

LITERATURE REVIEW

Wetland, the most productive ecosystem is fast degrading. World over wetlands are degrading and the threats to wetlands include siltation, eutrophication, reclamation, encroachment, pollution etc. (Barbier, 1997).Value of wetlands occur at three

levels of ecological hierarchy that is population, ecosystem and biosphere (Mitsch & Gosselink, 2000). The wetlands provide many provisional, regulating, existence values and with degradation these ecosystem services also got altered.
Most of the wetland threats could have caused as we have undervalued the ecosystem service of wetlands well. The ecosystem services of wetlands include flood mitigation, storm abatement, aquifer recharge, water quality improvement, aesthetics, and abstinence use. The degradation is attributed to climatic and human induced changes such as fragmentation of hydrological regimes, siltation from degraded catchments, pollution, spread of invasive, species and over-harvesting of resources (Ministry of Environment, 2015). With time we have understood that environmental degradation is a treat to the existence of life (UNDP, 2013).Air, water, soil the valuable resource on which most of our production relation depends are destabilized which has amplified the risk in terms of health, wealth and prosperity. Many debates on sustainable development, climatic change, pollution, markets etc. centers around this ideology. Dearth of information on the extend of degradation and its impact on production relations, risk, manageability of risk are vital in addressing policy concerns on environment vs. development, climate change negotiations, sustainability development etc.

Provision of water is a service which helps achieve basic livelihood needs as well as economic service for surplus generation. Water is a means of production whether in agriculture or in industry, whether in artisanal production or large scale industrial production. Water is more understood through two of its characteristics water quantity and quality. Requirements of accessibility and quality have typically been discussed less than the question of quantity of water or pricing (Bluemel, 2004). Water quality is relatively a new concept only extending over the past 150 years. Water quality degradation is one of the main global challenges having direct impacts on health, water resources availability and sustainability, food production, ecosystems, as well as economic growth *(*UN Water, 2012). *Ban Ki-moon (Secretary-General of the United Nations) opinioned that* how we use and manage water resources is central to setting the world on a more sustainable and equitable path .The newly-adopted Sustainable Development Goals (SDGs) of the 2030 Agenda calls for "improving water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally".
Aquaculture[1], being the fastest growing food production system in the world[2], is reliant on natural resources for its growth and sustainability. Aquaculture dependency on natural resources starts with land to site an aquaculture operation, water to support aquatic life, seed for stocking, feed for enhancement of production and materials like timber, steel etc for construction of the aquaculture system. In coastal culture fishery in tropical lands are predominantly extensive farming communities, dependent on these ecosystem services for species survival, growth and productivity. Any variation in this ecosystem service cause hazards like mortality, morbidity, and growth retardation and production loss. If aquaculture is to be sustainably developed for current and future food security and livelihood, its inter relationship with resource use, human activities and value systems need to be examined (Muir J. , 1995). The relationship between aquaculture and environment is well discussed in (Beveridge, Phillips, & Macintosh, 1997) (Funge-Smith & Briggs, 1998)
As a water dependent system aquaculture use many essential services from environment. Major components in this system are pond water and sediments, their interaction and in addition the external pond management. Every aquatic organism has a susceptible water quality criteria conducive for growth and survival. Water quality is defined scientifically as the physical, chemical and biological nature of water. Physical nature of water discusses those properties which we could see and feel like temperature, colour, hardness etc. Chemical nature of water means the chemical properties of water (those we can't see or feel directly) like DO, pH, NH_3 etc. and biological properties are known through the content like E.coliform,T. coliform etc.
This increased water management to handle the temperature fluctuations, flooding, bund breakages etc. Another issue which cause water quality to vary is pollution. Pollution can be classified as point source (emanating from an identifiable source) or non-point pollution (emanating from a diffuse source). The wastewater coming from point sources are easier to treat than that from non-point sources. The effects of diffuse pollutants are cumulative and can adversely affect wetlands and production systems like aquaculture even at some distance. The non-point pollution like agricultural runoff cause nitrate and phosphate addition which could cause eutrophication. Decline in wetland quality results in increased undesirable growth of weeds and algal blooms which are some times invasive species. When these algal blooms decompose, large amounts of oxygen are used up, depriving fish and other aquatic organisms of oxygen resulting in their death. Deterioration of water and soil quality is the major reason for reduction in wild seeds and feeds, increase disease out breaks, mortality and retarded growth in farming systems .The water quality as a resource /input in aquaculture has been discussed by natural scientist like hydrologist, biologist, aqua culturist etc as well as social scientists like economists, sociologists and fisheries management experts. Sustainability of aquaculture incorporates social, biological, technical, financial/economic and ecological concerns and depends on the interaction between the supply of and demand for environmental goods for aquaculture (Beveridge, Phillips, & Macintosh, 1997). We have differentiated review as science based studies and social science based studies on these lines.

METHODOLOGY AND DATA

The study area is Vemband wetland (VW), Kerala, India. It's a Ramzar site of international importance .It is the longest lake in India and invariably considered as largest too. The total area of the wetland system is 1521.5 sq. km that is approximately

[1] is understood to mean the farming of aquatic organisms including fish, molluscs, crustaceans and aquatic plants. Farming implies some form of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators etc(FAO)
[2] average compounded rate of 8.1% per year since 1981(FAO,2008)

4% of the states geographic area and cover 50% of backwater area in the state. The width varies from 500m to 4km and depth from less than 1m to 12m. The wetland is fed by 10 rivers, originating in the Western Ghats, flowing westwards through the wetland system to join the Arabian Sea. The water body is freshwater from June till October and brackish from November to May .The Vemband lake is bordered by Alappuzha, Kottayam, Ernakulum and Thrissur districts in Kerala. The Pokkali fields along the Vemband Lake spread across Alappuzha, Ernakulam and Thrissur district which traditionally has rice-prawn rotational farming. Approximately about 24000Ha of the pokkali land holdings are there in this location with Taneermukkam bund in North and Enammakkal Bund in South as boarders.

Many studies has pointed out the impact of effluents and agricultural run off on the fish and crustacean community along water bodies in India (Jayakumar & Ramasamy, 1999) and Kerala with special reference to Vemband Lake (Soorya, et al., 2012), (Toms, 2010). Vembanad wetland is a receptive of large variety of industrial affluence and domestic waste from Cochin and and nearby small town areas.Cochin City alone generates 2550 million /litres /day of waste water that directly enters backwater un treated.Total dissolved solids in this zone is as high as 53750 mg/litre during summer and 160 mg/litre during mansoon.The pollution load from Cochin and Alappuzha town are 195547 kg/day and 64237 kg/day of BOD respectively. Annual fertilizer consumption in Kuttanad is 8409 tonnes of N,5044 tonnes of P and 6786 tonnes of K.Pesticides,fungicides,weedicides are applied to the tune of about 500tones/year.Vembanad Lake also have a high level of faecal coliform bacteria. Water quality is observed as very poor near Allapuzha where ammonium concentration is observed as high as 2mg/litre and nitrate values up to 30 mg/litre (James, 1998).

We have selected 6 study locations from 3 districts to study the aquaculture scenario in the lake area. All the three districts have openings to the sea and there is a mix of brackish water and fresh water which is amplified through tidel functions . Azikode bay at Kodungalore link the Thrissur district with the marine ecosystem while Cochin bar mouth link the Ernakulam district with the marine ecosystem. In case of Alappuzha , Andakaranazhi bay links the water body with marine ecosystem .All the study locations are within 6 kms radius from the respective opening to marine ecosystem .

The survey was conducted in 5 Panchayat and 1 municipality along north, central and southern zone of the Lake. Vellangalore panchayat and Kodungalore municipality in Thrissur district, Ezhikkara and Kottuvally panchayat's in Ernakulam district and Ezhupunna and Thuravoor Panchayat's in Alappuzha district are selected for the study.The survey villages were chosen based on water quality data and further discussed and confirmed with local government officials , experts, local community officials etc. The Panchaytah's selected from Ernakulam and Alappuzha were water logged wetland areas converted to paddy lands under princely rule. As paddy cultivation become less cost effective due to shortage of labour , high labor cost and retarded production farmers turned the land to fish farming fields as a livelihood strategy . Though fish/prawn filtration was done during off seasons it were a secondary activity .With Pink gold rush today fish/prawn farming has turned as a major activity along this fields . In case of Thrissur district, the selected panchayat's land cover were paddy fields. Today farmers have moved out of paddy cultivation and currently they are doing fish/prawn farming. From each districts 2 sample locations where selected. Its important to note that Ernakulam has the highest coverage of prawn filtration farms of 5188.85 Ha followed by Alappuzha at 1871.45 Ha and Thrissur at 1005.8 Ha. Distribution of samples in study location has been classified based on contract period, land size of farming and farming method. We have adopted a random sampling method for data collection. The sample frame used where the list of farms provided by MPEDA. 222 sample farms are studied across the study sites using structured questionnaire. Farms are defined as a water body which is used for farming shell fish /fish which has four sided dykes using clay /cemented with minimum 1 sluice gate wooden/cemented.

To assess the extent of water quality variation across wetland ecosystems, we use the secondary data on water quality variable for the period 2002-2012 based on water quality assessments by CPCB records[3]. These individual records consists of water quality assessments for 219 sampling locations across India pertaining to Lakes ,Ponds and Tanks. The study focus on environmental degradation in Vemband-Kole wetland, a ramser site, in Kerala along Southern India which is extended among 4 districts Kottayam,Alappuzha,Ernakulam and Thrissur. To explain the water quality of the Lake , the water quality of sampling points Kochin-Oil Tanker Jetty(near cochin bar mouth),Kodungalore Lake (near to Azhikode bay),Alappuzha Lake(near to Andakaranazhi Bay) for Ernakulam,Thrissur and Alappuzha districts respectively is considered for water quality assessments. The variables used for the analysis are temperature(^{0}C),Salinity(ppm),pH,DO(mg/l),FreeAmmonia(mg/l), Nitrite(mg/l) and BOD(mg/l).The data's were checked for accuracy and data's were standardization using prescribed methods before analysis. The CPCB data have conductivity as a variable to explain water quality. This data is converted to salinity values following the process prescribed in (UNESCO, 1983) as further analysis depends on salinity value rather than conductivity. Rest of the variables are used with out any change.

The data from Central pollution control board give us a glimpse on the water quality status of the lake which is a resource for many primary production activities like agriculture ,aquaculture ,fishery ,tourism etc .As the focus of the study is specific to aquaculture , the status of water quality condition of aquaculture farms along Vemband lake area need to be studied. To understand the water quality at farm level , we have used the unpublished secondary data provided by National Centre for Aquatic Animal Health, Cochin University of Science and Technology. The data was collected as part of the center's extension program where farmers were given free / subsidized water quality assessments in shrimp farms .The

[3] CPCB Record number :2002- 2012 are 10414,10414,10413,ON15,ON16,ON426,12106,ON280,ON426,ON426,ON654 respectively.

department used this information for creating probiotics etc. The water quality estimations for the period 2000-2012 is considered for the study. Out of 2018 water quality assessments made by the department, we have analyzed 448 data using the criteria, minimum 3 variables should be analyzed at least twice in a farming period. The variables studied are temperature(^{0}C), Salinity(ppm), pH, DO(mg/l), Free Ammonia(mg/l), Nitrite(mg/l) and Phosphate. These data give us the background of water quality variation in the wetland as well as the aquaculture farms in the study area. Further an arithmetic weighted index method is adopted to understand the overall water quality of the farm. The WQI is an index of water quality for a particular use. Mathematically, the index is an arithmetic weighting of normalized water quality measurements. The method uses indexing relative to a standard in the study. The weighted arithmetic index method (Brown, M. N. J., Deininger, & Connor, 1972) has been used for the calculation of WQI of the water for a macro picture in this study The water quality is analyzed using the formula,

$$WQI = \frac{\sum_{i=1}^{n} Qi * Wi}{\sum_{i=1}^{n} Wi}$$

where *n* represents the total number of parameters, *Qi* is the value assigned to parameter *i* after normalization, and *Wi* is the weight of the parameter (an indicator of its' relative importance for aquatic life/human water use). In the above equation, WQI is calculated as the weighted sum of the different sub index scores. Several alternative methods have been proposed to aggregate the individual parameter scores into a final index value. The water quality is indexed as Unsuitable ,Very poor, Poor, Good and Excellent. The vulnerability and risk are classified based on Holzmann and Jorgensen (2000) and analyzed using Mini-Max Indexing Method

$$I_{qc}^{t} = \frac{x_{qc}^{t} - min_c(x_q^t)}{max_c(x_q^t) - min_c(x_q^t)}$$

X= indicator value for independent farm ;
Min = Min value of the indicator in the region ;
Max = Max value of the indicator in the region.

The role of institutions for risk management is studied using Case study method .We select three cases from study area, where we analyse how formal and informal institutions involve in risk management .

RESULT AND DISCUSSION

Aquaculture is an environment dependent food production system. Fish being an aquatic organism, water is the most important resource they depend on. The study among three inland culture communities along six panchayat's in north, central and southern parts of the Vembanad Lake shows water quality variation is a major threat for inland culture communities as recurring hazards are intensified in magnitude and frequency year on year. The water quality indexing for a period of 2000-2012 shows following results.

Table: 1 Water quality indexing for North, Central and South zone – 2000-2012

	North Zone				Central				South			
Year	WQI Lake	Status	WQI_{farm}	Status	WQI Lake	Status	WQI farm	Status	WQILake	Status	WQI_{farm}	Status
2000	75	Good	64	Medium	67	Medium	64	Medium	74	Good	66	Medium
2001	76	Good	69	Medium	67	Medium	54	Medium	76	Good	49	Bad
2002	70	Medium	75	Good	76	Good	71	Good	74	Good	65	Medium
2003	69	Medium	60	Medium	57	Medium	72	Good	72	Good	76	Good
2004	68	Medium	69	Medium	75	Good	59	Medium	75	Good	63	Medium
2005	73	Good	59	Medium	74	Good	61	Medium	68	Medium	71	Good
2006	65	Medium	61	Medium	67	Medium	62	Medium	64	Medium	75	Good
2007	58	Medium	64	Medium	66	Medium	66	Medium	68	Medium	66	Medium
2008	58	Medium	69	Medium	57	Medium	64	Medium	56	Medium	75	Good
2009	65	Medium	69	Medium	64	Medium	65	Medium	65	Medium	56	Medium
2010	66	Medium	68	Medium	63	Medium	60	Medium	56	Medium	55	Medium
2011	71	Good	74	Good	66	Medium	72	Good	68	Medium	56	Medium
2012	69	Medium	78	Good	66	Medium	70	Good	62	Medium	57	Medium

The results shows that the water quality of the ecosystem is in general having medium water quality though fluctuations persists. The water quality index for north zone, water quality is medium at basin level while a farm level more management efforts are required to handle the water quality improvement efforts. In case of Central zone, water quality index at basin level and farm level especially minimum indexes shows bad water quality which invites management concerns on degradation of resources and usage of resources for productive purposes like aquaculture. .In case of South zone, water quality index at basin level and farm level especially minimum indexes shows a decreasing trend towards Bad and Medium water quality status which is of management concern at basin level as well as for aquaculture farmers.

The primary data of water quality collected from respective study locations using same methodology point out that locations differ in their water quality availability.

Table 2 Water quality Index for zones along Vembanad lake (2014-2015)

Zone	Sample Location	WQI	Status
North Zone	Lake	55	Medium
	Farm	64	Medium
Central Zone	Lake	49	Bad
	Farm	57	Medium
South Zone	Lake	46	Bad
	Farm	37	Bad

Hazard to aquaculture from water quality variation are mortality, morbidity and retarded growth among species cultured (Feeny,2001).Mortality could happen out of sudden shocks caused by climatic variation or excess pollution load .It could also be due to the impact of constant changes in water quality , which leads to morbidity and there by mortality. It is difficult to distinguish precisely the reasons for mortality in many cases. It is considered that about 12% of sea food trade is lost annually due to disease among cultured species (FAO, 2000).Hence hazard identification and characterization is important. The hazards posed by water quality variations in aquaculture could be categorized as

- Mortality in fish/Shrimp
- Morbidity in fish/shrimp
- Retarded growth in fish/shrimp

Table 3 Hazard distribution (in days) along study zones during study period 2014-2015

Zones	Mortality	Disease	Retarded Growth
North Zone	1.36	2.26	4.30
Central Zone	6.93	6.66	3.63
South Zone	11.29	6.05	4.96
Lake	**6.55**	**5.00**	**4.30**

Risk analysis has wide applicability to aquaculture. The use of risk analysis can provide insights and assist in making decisions that will help to avoid negative impacts, thus helping aquaculture development to proceed in a more socially and environmentally responsible manner. Risk analysis is less commonly used to achieve successful and sustainable aquaculture by assessing the risks to aquaculture posed by the physical, social and economic environment in which it takes place. There exists, therefore, considerable scope to develop and expand the use of risk analysis for the benefit of aquaculture and the social and physical environments in which it takes place.

Risk is many time envisaged as a combination of probability and consequences .It is computed as a product of hazard potential and hazard consequences for each zone.

$$R = P * C$$

Where, R is risk, P is the probability of a hazard and C denotes consequence of a hazard.

Table 4 Risk assessment along zones during study period 2014-2015

District	Exposure Assessment	Consequence Assessment	Risk Assessment
North Zone	1.19	0.69	0.82
Central Zone	1.39	0.47	0.66
South Zone	6.08	0.51	3.11
Average	2.91	0.56	1.53

Risk analysis is a process that provides a flexible framework within which the risks of adverse consequences resulting from a course of action can be evaluated in a systematic manner. It permits a defendable decision to be made on whether a particular risk is acceptable or not, and the means to evaluate possible ways to reduce a risk from an unacceptable level to one that is acceptable (Arthur, 2008) . Though dependency of the tidal fed aquaculture systems along South and South East Asian countries is not contested, the dependency of this system on environment and the inherent risk evolving in the ecological- economic interaction is peripherally studied. The study reveals the hazard levels in aquaculture caused by water quality variation in lake and pond.The study also give us indications on the exposure level of hazards and consequence of the hazard. The risk assessment point out that, along with the environmental quality, pond management measures carried out individually and collectively by farmers, play an important role in economic success of these primary production system.

CONCLUSION

The study shows that water quality of wetland could be a source for vulnerability among small scale aquaculture farmers and deterioration of water quality has higher probability to cause risk in the farming system.

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