Conference Proceedings

2nd International Conference on Climate Change 2018

(ICCC 2018)

15 -16, February 2018

Colombo, Sri Lanka

Committee of the ICCC- 2018

The International Institute of Knowledge Management (TIIKM)

Tel: +94(0) 11 3132827

info@tiikm.com

Disclaimer

The responsibility for opinions expressed in articles, studies and other contributions in this publication rests solely with their authors, and this publication does not constitute an endorsement by the ICCC or TIIKM of the opinions so expressed in them.

Official website of the conference

www.climatechangeconferences.com

Conference Proceedings of 2nd International Conference on Climate Change 2018 (ICCC 2018)

ISSN 2513-258X online

Published by The International Institute of Knowledge Management (TIIKM), No: 531/18, Kotte Road, Pitakotte ,10100, Sri Lanka

Tel: +94(0) 11 3098521

Fax: +94(0) 11 2873371

Hosting Partner:

University of Colombo, Sri Lanka

Supporting Ministry:

Climate Change Secretariat, The Ministry of Mahaweli Development and Environment**,** Sri Lanka

Academic Partner:

Colorado State University, USA

Strategic Partner:

Colombo Plan

Organized By:

The International Institute of Knowledge Management (TIIKM), Sri Lanka

ICCC 2018 Committee

DR. ERANDATHIE LOKUPITIYA	(Conference Chair, ICCC 2018) *Senior Lecturer, Department of Zoology and Environment Sciences, University of Colombo, Sri Lanka*
PROF. KEITH PAUSTIAN	(Keynote Speaker, ICCC 2018) *Department of Soil and Crop Sciences, Senior Research Scientist, Natural Resource Ecology Laboratory, Colorado State University, USA*
DR. KEVIN SCHAEFER	(Keynote Speaker, ICCC 2018) *National Snow and Ice Data Center, University of Colorado, USA*
DR. SALUT MUHIDIN	(Session Chair, ICCC 2018) *Macquarie University, Austalia*
PROF. ASHFAQUE AHMED	(Session Chair, ICCC 2018) *University of Dhaka, Bangladesh*
DR. BIJOY NANDAN	(Session Chair, ICCC 2018) *Cochin University of Science and Technology, India*

DR. MERY BISWAS (Session Chair, ICCC 2018)
Presidency University, India

DR. CHATURANGI WICKRAMARATNE (Session Chair, ICCC 2018)
Environmental Foundation Limites , Sri Lanka

DR. SURANJANA BANERJI (Session Chair, ICCC 2018)
Presidency University, India

PROF. NEBIYE MUSAOGLU (Session Chair, ICCC 2018)
Istanbul Technical University, Turkey

DR. CARLO MONTES (Session Chair, ICCC 2018)
International Maize and Wheat Improvement Center, Bangladesh

PROF. JANENDRA DE COSTA (Session Chair, ICCC 2018)
University of Peradeniya, Sri Lanka

DR. MD. MIZANUR RAHMAN (Session Chair, ICCC 2018)
Bangabandhu Sheikh Mujibur Rahman Agricultural University, Bangladesh

DR. MD. MAIN UDDIN MIAH (Session Chair, ICCC 2018)
Bangabandhu Sheikh Mujibur Rahman Agricultural University, Bangladesh

DR. MONTHIRA YUTTITHAM (Session Chair, ICCC 2018)
Mahidol University, Thailand

MR. ISANKA. P. GAMAGE (Conference Convener, ICCC 2018)
The International Institute of Knowledge Management, Sri Lanka

MR. OSHADEE WITHANAWASAM (Conference Publication Chair, ICCC 2018)
The International Institute of Knowledge Management, Sri Lanka

MR. KEERTHI CHANDANA (Conference Secretariat, ICCC 2018)
The International Institute of Knowledge Management, Sri Lanka

MESSAGE FROM THE SUPPORTING MINISTRY ICCC 2018

It is an honor and a privilege to deliver this message on behalf of the Climate Change Secretariat of the Ministry of Mahaweli Development and Environment for this important event of the International Conference on Climate Change 2018 organized by the International Institute of Knowledge Management and hosted by the University of Colombo, Sri Lanka. As most of us aware, one of the major challenges faced by the world community today is the rise of global warming mainly due to human activities. With the world population increase, it seems more pollution will be taken place. Hence it is undebatable that immediate actions have to be taken to control further rise of global warming due to unsustainable consumption and production pattern and practices. During the last three decades, concerns have constantly been growing on climate change and its consequences.

At the 21st session of Conference of Parties (COP21) to the United Nations Framework Convention on Climate Change (UNFCCC) held in Paris in 2015, a decision was taken to act together as a global community to limit the rise of global warming below 2 degree Celsius by 2100. Additionally, the agreement aims to strengthen the ability of countries to deal with the adverse impacts of climate change. Climate change is now inevitable and it will affect all systems, sectors and communities. Some of them may be highly vulnerable and some may be less vulnerable.

In this respect, all the sectors and communities that are vulnerable to adverse effects of climate change are needed to be built resilience to overcome such impacts. Many researches and systematic observations are taken place in this aspect all over the world. Intergovernmental Panel on Climate Change (IPCC) is the main scientific body where the all findings are gathered and compiled for forecasting the vulnerability. Although many researches are going on climate change impacts in Sri Lanka, this information is scattered. In addition, qualitative and quantitative climate change impact assessments, reliable forecasting are still hard to find. Therefore, these gaps are yet to be filled.

At this juncture, I must appreciate the effort that has been taken by the University of Colombo and the International Institute of Knowledge Management to fill the gap encouraging researchers to conduct researches on climate change issues in Sri Lanka and compiling the findings for policy and ground level interventions.

Last but not least, I take this opportunity to congratulate the organizers and participants for the colossal success of this prestigious and timely event.

Dr. R.D.S. Jayathunga,
Director,
Climate Change Secretariat,
Ministry of Mahaweli Development and Environment,
Sri Lanka.

MESSAGE FROM THE HOSTING PARTNER ICCC 2018

I take the privilege of writing this on behalf of University of Colombo, the hosting partner of International Conference on Climate Change 2018 (ICCC 2018) for the second time. This year's theme on climate change and global sustainability is important to all the global nations, including those who have overexploited the earth's resources and those who are highly vulnerable to climate change impacts. Climate change has become the most important global environmental issue and it has significantly impacted the sustainable development. Similarly certain sustainable development plans across the world have not considered climate change impacts at the correct magnitude. Therefore it is high time to have more communication and information sharing in relation to the above involving all the stakeholders including scientists, policy makers, and private sector organizations. I hope ICCC 2018 will provide the ideal platform for the above purpose.

Sri Lanka has shown a great concern about the issue of climate change and a remarkable number of scientific studies have been conducted within the country. As an island nation, the country has been facing the impacts and challenges of climate change and it has been vulnerable to increased occurrence of extreme weather events and sea level rise, etc. The country needs to develop suitable sustainable development strategies with particular attention on adaptation- and mitigation measures and there is an unprecedented role to be played by academics and researchers, based on the newest developments in this field. I hope ICCC 2018 will help the scientists from Sri Lanka and other participants and resource person coming from the different parts of the world to share their experiences and benefit through developing collaborative links for better, regional and global scale research and networks.

As a university, the University of Colombo has already taken several green measures which include tree planting campaigns, minimization and management of waste, and moving towards greener energy, which will also contribute towards the efforts by the country in achieving its sustainable development goals and targets based on Paris Agreement of 2015. I hope this conference will be a landmark event which would provide a great opportunity for knowledge-sharing in relation to climate change and sustainable development. I wish to convey my best wishes to all the participants and resource persons coming from different continents of the world, for a fruitful meeting and a memorable time in Sri Lanka.

Prof. Lakshman Dissanayake,
Vice Chancellor,
University of Colombo,
Sri Lanka.

MESSAGE FROM THE CONFERENCE CHAIR ICCC 2018

Climate change has impacted the global economies and the nations worldwide have paid more attention towards sustainable development. However, due to the large magnitude of the impacts and costs associated with the adoption of remedial measures for reducing the impacts, the sustainability of the adopted measures might not always be viable. In dealing with climate change, sustainable remedial measures, international cooperation and knowledge sharing with regard to new developments in the field are essential, since no single nation alone can deal with the complicated impacts of climate change. The Paris Agreement adopted at the 21st Conference of the Parties of the UNFCCC (COP21) held in Paris in 2015 aims at limiting the global average temperature rise during the century to well below 2 ^{0}C above pre-industrial levels by taking necessary action. The 1st International Conference on Climate Change 2017 (ICCC-2017) was successfully held in Colombo, Sri Lanka in February 2017 with the theme *' Climate Change, Facing the challenge beyond COP21'*, as there is a big challenge ahead of us in facing the impacts of climate change.

The theme of the 2nd International Conference on Climate Change 2018 (ICCC-2018) is *'Climate change and global sustainability: Action for bridging the gap'*. One of the key goals of this conference is creating dialogue among those involved in research and development activities in Climate Change Mitigation, Vulnerability, and Adaptation, nationally and internationally, with an emphasis on the sustainable development. As the Chair of the conference I hope this event will create continued dialogue during and beyond the ICCC-2018, with the participation of local and international scientists. Through this event, it is envisaged to share and disseminate information relevant to research and development experiences encompassing important areas such as vulnerability and impacts of climate change on food security, biodiversity and natural resources, health and sanitation, developments in adaptation and mitigation research, remedial measures, and various other aspects such as greenhouse gas measurements, modeling and climate predictions, etc. Both ICCC 2017 and ICCC 2018 received a large number of abstracts from all around the world and it was not an easy task to select the abstracts tallying the conference program and the theme. I wish the presenters of those selected abstracts including the young scientists, representatives of the academia, research institutes, government and non-governmental institutions, etc., to have a pleasant and fruitful event and I hope ICCC-2018 will provide a great opportunity for you to share your valuable experiences.

Erandathie Lokupitiya, PhD
Senior Lecturer,
Department of Zoology and Environment Sciences,
Faculty of Science,
University of Colombo,
Sri Lanka.

Table of Contents Page No

Proceedings of the 2nd International Conference on Climate Change, Vol. 2, 2018, pp. 1-10

ISSN 2513-258X online
DOI: https://doi.org/10.17501/iccc.2018.2101

A STUDY OF THE EFFECT OF CLIMATE CHANGE ON RESILIENCE AND HUMAN HEALTH USING BIOCLIMATIC INDICATORS

Mohsen Hamidian Pour[1] and Siroos Ghanbari[1]

[1]*Faculty of Geography and Environmental Planning, University of Sistan and Baluchestan, Zahedan, Iran*

Abstract Nowadays, climate change has been accepted as a rapidly changing phenomenon. With the help of documents, these changes would implicitly or explicitly influence human health. The purpose of this study is to examine the effect of important climatic factors on bioclimatic indicators for the human livability in Chabahar port, Iran. In this regard, four climatic models and three scenarios are taken into account. In addition, the average uncertainty of minimum and maximum temperature and precipitation variations are calculated based on the weighted method. According to the hybrid model, taken from the model and scenario, Chabahar temperature is on the rise between 0.52 and 2.38. Accordingly, bioclimatic factors would experience alteration. Eventually, it would lead to reduced resilience. The results of comfort-thermal indicators (bioclimatic) showed that the conditions are optimal and natural from October to March for individuals residing in Chabahar, Iran. However, the conditions are changing due to the future temperature increase. Such changes would significantly reduce the number of inhabitants in Chabahar and villages nearby.

Keywords: Climate change, Resilience, Emission scenarios, Chabahar

Introduction

Human health is explicitly and implicitly influenced by the change in weather patterns due to the formation of abnormal temperatures, severe winds, events associated with precipitation and moisture (Boumans et al. 2014, Anderson and Bell, 2011, Reid et al. 2009). The role of climate on human disease and human health has long been the center of debate so that Hippocrates stated that " Everyone who wants to learn medicine is required to know the following topics: He must learn the effects of seasons and their differences and know cold and hot winds and joint winds among countries, and especial winds for a certain location, and finally he should not forget the effect of water on human health." Weather variability and consequently climate can lead to the emergence of epidemics. This simple fact indicates that, prior to the appearance of medical science, when Hippocrates was teaching; numerous specific human diseases were associated with changes in seasons and temperatures (Committee on Climate; Ecosystems; Infectious Diseases; and Human Health, 2001). The fourth IPCC assessment report shows evidence of climate change contributing to Diseases and early mortality (IPCC, 2007). Climate, in fact, can play a key role in spatial and time distribution of certain infectious diseases such as malaria, bone marrow fever, tick-borne diseases, etc. In addition, climate change can be effective in seasonal distribution of pollen intensity of allergic species. Climate change is believed to increase the diseases caused by heat and extreme weather events. Note that the greatest impact of climate change would be felt in low-income countries, the urban poor, elderly, and children (Giannakopoulos et al. 2016). Studies about Iran in this regard show an increase in thermal wave frequency (Esmaeilnegad et al, 2014) so that the increase is consistent with the studies by Darand (2014) in plain areas. It also experiences a positive trend (Darand, 2014). The continuity of heat waves leads to greater number of causalities. These conditions can be reported in Iran's wet and southern regions due to feeling greater temperature (Dargahian, 2014). Extreme weather conditions have led some problems for human health and may also worsen the health problems. Under the influence of these extreme events, people may even die so that almost 16,166 individuals visited the emergency wards in California in 2006 as a result of thermal waves and 1,182 were hospitalized (Knowlton et al. 2009). In June 2015, 2,500 and 2,000 individuals died in Pakistan and India, respectively. In Central America, over 20 thousand workers have died in cane fields as a result of unknown kidney disease.

Corresponding Author Email: [1]mhamidianpour@gep.usb.ac.ir, [2] sghanbari@gep.usb.ac.ir

The number of the victims is on the rise annually. It was first thought that the chemicals used in the fields caused the death. However, studies show that workers in coastal regions die and those working in higher and cooler areas do not develop such disease. In fact, dehydration rises with a sharp increase in temperature and their kidneys are exposed to extreme hyperactivity and ultimately they face the disease (Glaser et al. 2016). The review study by Lundgreen et al. on the effect of climate change on the working-class population shows that climate change and increased temperature lead to decrease in labor efficiency. It also results in decrease in the world's economic returns. Another result of the study is that climate change adversely affects the developed countries especially in tropical regions (Lundgren et al. 2013). Due to the effects of climate change on human health, a proper understanding of bioclimatic conditions of wet areas such as Chabahar in future periods seems necessary. Using general circulation models is a field of study in future periods. Therefore, these models can provide us with a future climate perspective. These models enable us to predict the future close to reality and anticipate the issue. World and Iranian studies have been conducted in terms of climate change in future periods and its effect on human health, outbreaks, and even death. Green et al. (2011) used climatic models. They concluded that the number of hot and cold nights and day will increase and the resulting deaths will increase, too. Namachulal et al. (2014) on the effect of climate change on the thermal comfort of the outer environment in the humid and hot areas of Douala, Cameroon showed that the results proved the definite effect in thermal comfort conditions. They stated that the effects are intolerable in very hot regions. Chabahar, coastal city, is located in almost tropical regions of Iran with moisture rarely less than 60%. In fact, the humidity in this coastal city is always high. Humidity, along with high temperatures and lack of wind, results in feeling a higher temperature than what a thermometer records. According to what was mentioned in introduction, the comments of scientists, the IPCC results (IPCC, 2013), and scattered studies in the world (Nian-Zhi et al. 2015) and Iran (Babaian, 2006, Massah-Bavani and Morid, 2006, Roshan et al. 2012), the temperature is on the rise especially in urban areas. This will deteriorate the conditions and have frequent consequences on human health (Smith et al. 2014) so that Jeremy et al. (2015), using regional climate change models, concluded that the evacuation of human habitations in the future is affected by climate change in South-West Asia. The purpose of this innovative study is take advantage of GCM outputs in order to calculate the climatic parameters such as maximum and minimum temperature and precipitation reception in Chabahar. Then bioclimatic indicators of Chabahar are calculated.

Data and Methodology

The purpose of this study is to calculate the bioclimatic conditions of Chabahar port, Iran in the future based on the global warming using GCMs outputs. Two categories of data are used in order to obtain the future climate profiles. The first category is the observed data of synoptic stations in over the period 1964-2010 and the second category is GCMs outputs. In this study, four GCM models (IPSLM4, CCSM3, HADCH3, and INM-CM3) were used together with three scenarios (A1B, A2, and B1). Due to the resolution of these data (more than 2.5 degrees), it is necessary to make the data small-scale in station using downscale techniques. To this end, Lars-WG5 is employed (Semenov and Barraw, 2002). Uncertainty reduction is an important topic in climate change studies (Wilby, 2010). Indeed uncertainty is the difference between simulated and measured values or observation data (Turley and Ford, 2009). So reducing the uncertainty leads in more reliable models. There are various methods for analyzing and calculating uncertainty. In this study, weighted mean was used. Weighted mean is used to calculate the weight of each of models in order to provide a hybrid model (Massah-Bavani and Morid, 2005), as follows.

$$W_{i,j} = \frac{\dfrac{1}{\Delta F_{i,j}}}{\sum_{i=1}^{n} (1/\Delta F_{i,j})} \quad (1)$$

Here, F is the meteorological variable, ΔF is the difference between the simulated variable under various scenarios and observation value at base period, W is the simulated weight of each general atmospheric circulation model under three scenarios in the month. The indices i and j are the month and the general atmospheric circulation model, respectively. Then the average climatic value of each parameter is calculated. After that, the future parameter value is calculated using the general atmospheric circulation model output and bioclimatic indicators including Equivalent Temperature Index, Approximate Thermal Pressure Index, W-Salt Sultry Degree Index, Humidix Humidity Index, and W-Strain Fatigue Degree Index (Blazejczyk, 2001).

Table 1 Tek - Equivalent temperature

below 18 °C	cold
from 18 to 24	cool
from 24 to 32	slightly cool
from 32 to 44	comfortable
from 44 to 56	slightly sultry
above 56	sultry

Table 2 W_Strain - Physiological strain weather subtype index

PhS or pPhS	W_Strain	Strain type
from 0.75 to 1.50	0 (T)	thermoneutral
above 1.5	1 (C)	cold strain
below 0.75	2 (H)	hot strain

Table 3 Humidex Index

Humidex (°C)	Danger category	Heat syndrome:
below 30	Caution	Little discomfort, Fatigue possible with prolonged exposure and activity
from 30 to 40	Extreme caution	Some discomfort, heat stroke, heat exhaustion and heat cramps possible with prolonged exposure and activity
from 40 to 55	Danger	Great discomfort, avoid exercise. Heat cramps or heat exhaustion likely. Heat stroke possible with prolonged exposure and activity.
above 55	Extreme danger	Heat stroke imminent with continued exposure

Table 4 W_Sult - Intensity of sultriness weather subtype index

HSI or pHSI	W_Sult	Intensity of thermal-and-hygric load
below 30	0	non-sultry
from 30 to 70	1	moderate sultry
above 70	2	strong sultry

Table 5 pHSI - Approximated heat stress index

below 0	Slight cool stress
from 0 to +10	Thermoneutral conditions
from more then 10 to 30	Slight and moderate heat stress
from more then 30 to 70	Intensive heat stress; health hazard for unacclimated persons
from more then 70 to 90	Very Intensive heat stress; water and minerals supply necessary
from more then 90 to 100	Maximal heat stress tolerated by young, acclimated persons
above 100	Hazard of an organism overheating; exposure time must be controlled.

Findings

Due to the geographical conditions of Chabahar (60.51° E and 25.30° N and 8 meters above the sea level) and Ambergeh and Demarton methods, it has a wet, hot climate. The mean temperature and relative humidity are almost 26 ˚C and 72% in long-term, respectively. Being near the coast is the main factor of high humidity. The relatively humidity rarely reaches less than 63%. Therefore, the city generally experiences a humid weather. Sultry intensity rises as relative humidity increases, and it is reduced as temperature decreases. On the other hand, the presence of humidity leads to increasing the felt temperature (Table 6).

Table 6 Monthly and Annual Climatic Parameter Changes of Chabahar in Long-term (I), average maximum temperature (˚C) (II), Average temperature (˚C), Average minimum temperature (˚C), Total Precipitation (mm) and Average Relative Humidity (%) (V).

Variable	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Annual
I	24.4	25	27.7	30.7	33.6	34.6	33.3	32	31.8	32.1	29.4	26.3	30.1
II	19.9	20.8	23.5	26.7	29.6	31.4	30.8	29.5	28.7	27.5	24.3	21.5	26.2
III	15.4	16.5	19.3	22.6	25.7	28.2	28.2	27	25.6	23	19.2	16.6	22.3
IV	30	26	16	4	0	0	6	2	1	4	6	19	114
V	63	68	71	73	75	78	79	79	78	75	68	63	72.5

Figure 1 and 2 show the long-term temperature and precipitation changes in Chabahar station. The changes are increasing and significant according to the Mann Kendall qualitative and quantitative method and Sen's slope at 95% level (Table 7). As it can be seen, average long-term temperature is almost 26.2 ˚C in this station. However, this figure has been on the rise in the two recent decades. According to Fig. 1, the temperature has experienced a rising pattern since the 1980s; the average temperature was 26.7˚ C at the turn of century, meaning that the temperature has raised almost 0.5 ˚C. The precipitation is a little complex so that a very slight increase is seen in terms of long-term precipitation. However, dramatic changes and fluctuations are seen due to the unruly behavior rainfall so that precipitation declined dramatically in the early 20th century. In other words, the stations recorded the precipitation of almost 0.7 mm in 20011. This has been the major factor of average precipitation in the last decade. As stated earlier, the general trend of the station is rising associated with the coastal location and the influence of marine conditions and regional convective rainfall.

[1] Note that the authors believed that there was a technical problem in recoding precipitation. However, the review of other stations showed that 6.3, 2.5, 7.5, and 18.3 mm precipitation were recorded in Iranshahr, Konarak, Saravan, and Zahedan, respectively. In fact, a severe drought occurred in Iran and especially in the region in 2004 and the subsequent year.

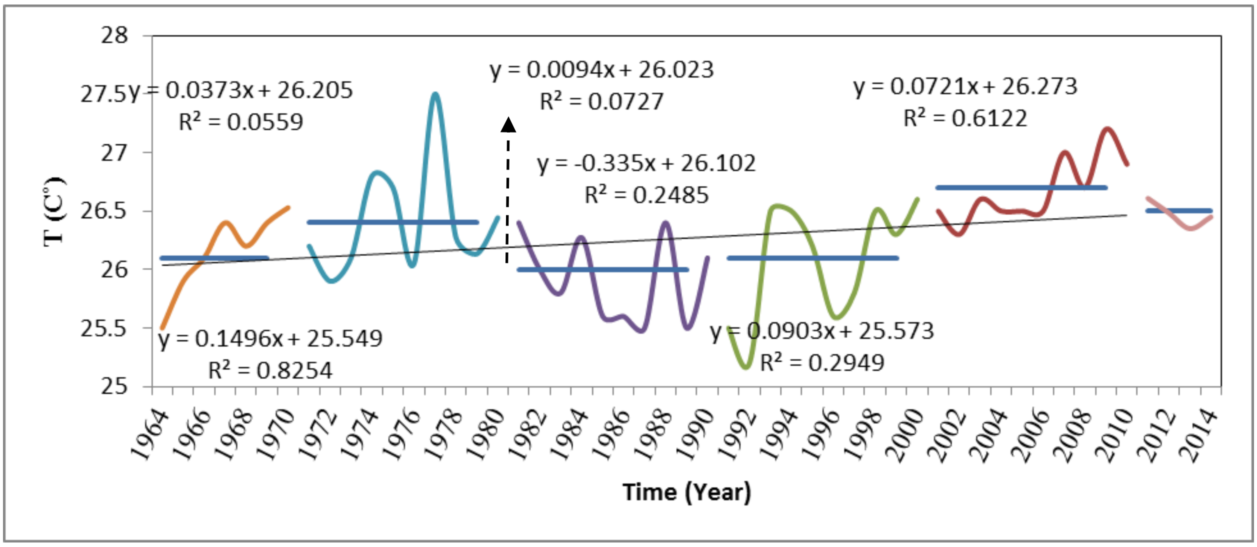


Figure 2 Long-term temperature in Chabahar Station (1964-2010).

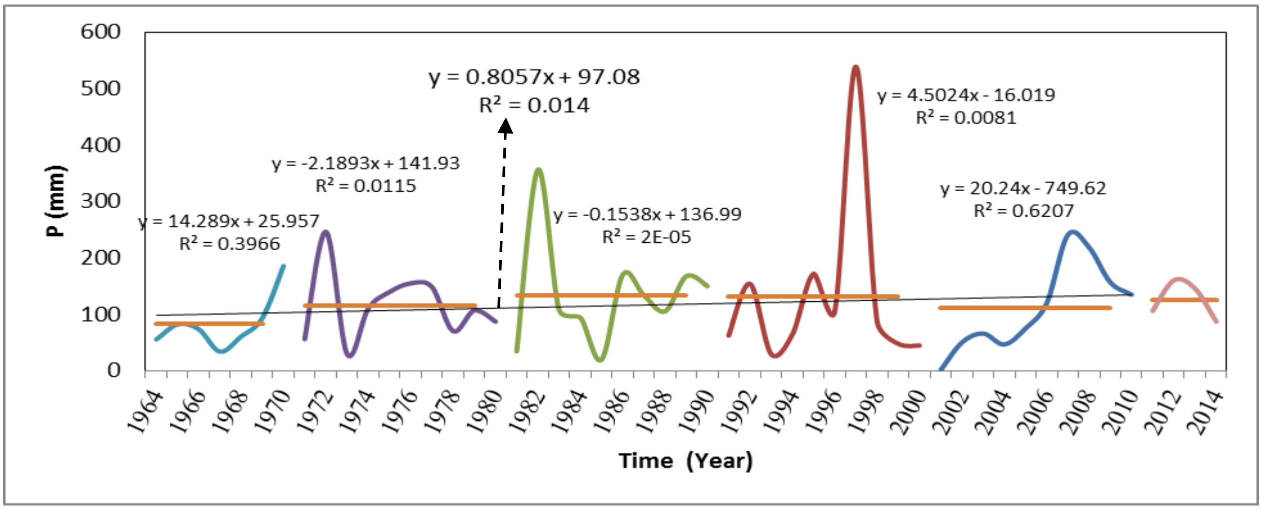


Figure 3 Long-term precipitations in Chabahar Station (1964-2010).

Table 7 Mann Kendall Coefficient and Sen's Slope Changes for Temperature and Precipitation in Chabahar (1964-2010).

		Mann-Kendall trend			Sen's slope estimate									
Time series	n	Test S	Test Z	Sig.	Q	Qmin99	Qmax99	Qmin95	Qmax95	B	Bmin99	Bmax99	Bmin95	Bmax95
P	47		0.73		0.476	-1.466	2.679	-0.908	2.044	89.98	128.56	43.72	117.66	55.00
T	47		2.45	*	0.011	0.000	0.022	0.001	0.019	26.07	26.30	25.78	26.25	25.85

Chabahar bioclimatic indicators are calculated according to its synoptic station after examining temperature and precipitation in the base period and initially recognizing the parameter changes (Table 8). According to W-Strain Index, Chabahar is normal in five months (November, December, January, February, and March). The conditions are tiring in other seven months. According to Equivalent temperature Index (Tek), if they are greater than 56, the conditions are known as sultry (table 1). Accordingly, from April to November follows such pattern. According to Humidex Index, the figures above 30 display Extreme caution, Danger and Extreme danger conditions (table 1). The calculated Humidex index values in Chabahar Station are greater 41 from May to September, which indicates the hazardous conditions. W-Sultry index indicates that all months experience sultry condition; however, it is greater in warmer months. The last indicator, pHSI, shows the approximated heat stress index. If they range between 30 and 70, they show an alarming condition. For values higher than 70, a person is subject to severe thermal stress conditions. The months June and July follow such conditions (table 8).

Table 8 Biological indicators in Chabahar station (1964-2010).

		W_Strain	Tek	Humidex	W_Sult	pHSI
Indicator value in the past (Chabahar station)	Jan.	T	42.81	22.83	0	20.08
	Feb.	T	46.87	24.90	0	22.82
	Mar.	T	54.99	29.61	1	32.06
	Apr.	H	65.21	35.41	1	45.87
	May.	H	76.83	41.54	2	62.95
	Jun.	H	85.24	45.78	2	77.57
	Jul.	H	83.24	44.67	2	72.20
	Aug.	H	78.29	42.02	1	62.25
	Sep.	H	74.76	40.21	1	56.99
	Oct.	H	69.44	37.48	1	50.02
	Nov.	T	56.29	30.59	1	35.17
	Dec.	T	46.83	25.33	0	25.05

Discussion

As it is seen, Chabahar suffers from unpleasant climatic conditions. Biological resilience is affected by climatic conditions. However, climate is changing and the temperature is rising in the region. Accordingly, the regional climate is calculated based on ensemble conditions and calculation of uncertainty using four general atmospheric circulation models under three different scenarios. Table 9 shows the results of the previous indicators. As it can be seen, the mean temperature in Chabahar is on the rise according to the Chabahar Station and general atmospheric circulation models compared to the base period. Average temperature change is almost 0.52, 1.42, and 2.38 ˚C in 2011-2030, 2046-2065, and 2080-2099, respectfully. Obviously, such change would affect the bioclimatic indicators. Since bioclimatic comfort is affect by environmental factors such as temperature, it would cause to change bioclimatic conditions.

Table 9 Total precipitation and average monthly temperature in the base and future periods based on Ensemble

	Precipitation				Temperature			
	Base line	2011-30	2046-65	2080-99	Base line	2011-30	2046-65	2080-99
Jan	28.686	38.6	33.5	40.0	20.16	20.86	21.84	22.90
Feb	23.857	19.2	11.7	9.7	21.30	21.90	22.86	23.80
Mar	16.689	29.6	31.4	41.0	23.42	24.16	25.06	26.00
Apr	3.648	1.5	1.3	1.2	26.72	27.06	27.73	28.35
May	0.024	0.0	0.0	0.0	29.65	30.06	31.05	32.10
Jun	3.821	12.2	10.0	9.9	31.14	31.57	32.44	33.42
Jul	5.245	3.5	3.9	4.2	30.36	30.66	31.48	32.41
Aug	1.633	0.6	0.5	1.2	29.12	29.66	30.49	31.34
Sep	0.822	2.5	4.6	1.9	28.62	28.95	29.81	30.59
Oct	3.990	14.5	25.5	27.1	27.50	27.79	28.61	29.52
Nov	5.156	8.5	8.3	12.8	24.73	25.32	26.32	27.47
Dec	19.737	40.6	31.7	24.8	21.93	22.64	23.78	25.08
Annual	113.309	171.2	162.3	173.91	26.22	26.72	27.62	28.58

Table 10 shows the bioclimatic indicators according to the temperature and precipitation taken from four general atmospheric circulation models under three different scenarios considering uncertainty in future periods. As it can be seen, the indicators show a more critical and dangerous situation compared to the base period for Chabahar.

Table 10 Biological Indicators in Chabahar Station (2011-2030, 2040-60, and 2080-99)

Year	2011 -30					2040-60					2080-99				
Month	Tek	Humidex	pHSI	W_Strain	W_Sult	Tek	Humidex	pHSI	W_Strain	W_Sult	Tek	Humidex	pHSI	W_Strain	W_Sult
Jan	51.98	26.76	22.66	T	0	54.43	28.29	25.81	H	0	57.15	29.91	29.14	H	0
Feb	54.68	28.50	26.46	H	0	57.24	29.96	29.24	H	0	60.01	31.58	32.74	H	1
Mar	60.93	32.61	37.09	H	1	63.95	33.87	38.06	H	1	66.98	35.60	42.36	H	1
Apr	69.26	38.24	57.69	H	1	73.25	39.13	52.18	H	1	76.58	40.99	58.06	H	1
May	79.01	45.04	109.27	H	2	84.47	45.29	74.46	H	2	88.51	47.46	85.00	H	2
Jun	83.55	48.27	221.68	H	2	89.43	47.95	87.71	H	2	93.18	49.94	100.19	H	2
Jul	80.93	46.40	132.62	H	2	86.24	46.24	78.81	H	2	90.01	48.26	89.49	H	2
Aug	77.62	44.05	97.48	H	2	82.45	44.20	69.88	H	1	85.99	46.11	78.24	H	2
Sep	75.52	42.58	83.85	H	2	80.33	43.04	65.32	H	1	83.87	44.96	73.06	H	2
Oct	71.72	39.94	66.29	H	1	76.22	40.78	57.37	H	1	79.68	42.69	64.01	H	1
Nov	64.37	34.91	44.43	H	1	68.04	36.21	43.92	H	1	71.78	38.31	49.75	H	1
Dec	56.82	29.90	29.79	H	0	60.06	31.61	32.82	H	1	63.39	33.54	37.26	H	1

Table 11 summarizes the comfort-thermal indicator changes based on the scope of changes. In fact, this table states that, for example, based on the Equivalent temperature index (Tek) in the base period, 2 months have a few sultry conditions and 8 months of sultry conditions, while based on the ensemble output of the general circulation models (GCMs), the number of months in sultry is 9, 10 and 12 months in periods of 2011-2011, 2040-60, and 2080-99, respectively. In general, Chabahar port suffers from unpleasant resilience condition in terms of certain indicators and climate change during most of year.

Table 11 Predicted changes for the number of months in base period in future period according to the comfort-thermal indicators in Chabahar Station.

		Changes in the number of months			
Index	Stress Category	Baseline	2011-2030	2040-2060	2080-2100
Humidex	Extreme caution	2	4	4	4
	Danger	5	5	6	7
	Extreme danger	0	0	0	0
Tek	slightly sultry	2	3	2	0
	sultry	8	9	10	12
pHSI	Hazard of an organism	2	2	3	5
W_Strain	hot strain	5	12	12	12
W_Sult	strong sultry	3	2	3	5

Health studies have shown that numerous health problems appear due to changes in relative humidity and temperature, especially if people are busy with physical activity (Smith et al., 2014). At 27 ˚C and relative humidity of 40%, even healthy individuals might experience increased fatigue, sore muscles, irritability, and bad temper. A healthy individual busy with heavy physical activity such as construction workers or farmers might experience a 26 ˚C thermal stress. As the results show, assuming the constant humidity in Chabahar and the figure in the past (60%), Chabahar would be in alarming list for locals and tourists based on the temperature increase in Chabahar and other southern Iranian cities. The condition, therefore, requires public training and specific measures such as the localization of construction- that is, climate-based design- and establishment of warning thermal health systems, etc. Past studies have shown that Iranian southern regions are prone to some diseases such as Malaria (Tavousi et al. 2013). Increased temperature will increase the malaria incidence. Increased temperature in the region will contribute to dehydration and this, as previous studies in other regions have shown, results in increased Kidney stone. In fact, hot weather and exposure to situations that predispose an individual to Dehydration (sweating) can increase the Kidney stone risk. Climate change can worsen the situation in this regard in Chabahar.

Conclusion

According to the combined data of GSM outputs, temperature and precipitation are on the rise in Chabahar Station. The temperature is reported 26.2˚ C in the base observational period. According to the models, the temperatures are 26.72, 27.62, and 28.58˚ C in 2011-2030, 2040-2060, and 2080-2099. On the average, 0.52-2.38 increase is seen. In terms of precipitation, it experiences a rising pattern. Precipitation is reported 57 mm in the base period. Chabahar suffers from unpleasant conditions in all months using the bioclimatic indicators. In other words, it is constantly in warning list for human health and urban and rural ecosystem. This is a warning alarm for politicians and planners.

References

Anderson, G.B., and Bell, M.L., 2011, Heat waves in the United States: mortality risk during heat waves and effect modification by heat wave characteristics in 43 U.S. communities, Environmental Health Perspectives, 119(2),1552-9924.

Ashofteh, P.S., Massah-Bavani, A.R., 2012, Investigation of AOGCM Model Uncertainty and Emission Scenarios of Greenhouse Gases Impact on the Basin Runoff under Climate Change, Case study Gharanghu Basin, East Azerbaijan, Iran-Water resources research, 8 (2):36-47 .

Babaian, I., and Najafi Nik Z., 2006, Introducing and Evaluation of LARS-WG Model for Modeling Meteorological Parameters of Khorasan Province (1961-2003), Nivar Journal. 62(63):69-49 .

Boumans, R.J.M., Phillips, D.L., Victery, W., Fontaine, T.D., 2014, Developing a model for effects of climate change on human health and health–environment interactions: Heat stress in Austin, Texas. Urban Climate. 8:78-99.

Blazejczyk, M., 2001, Help of Biokima for window. Version 2.6.

Committee on Climate; Ecosystems; Infectious Diseases; and Human Health; Board on Atmospheric Sciences and Climate; Commission on Geosciences EaRDoEaLSN. 2001, The under weather: Climate, Ecosystems, and Infectious Disease. Washington, D.C.: National Academy Press.

Darand, M., 2014, Recognition and spatial-temporal analysis of heat waves in Iran. Geography and development Iranian Journal. 12(35),167-80 .

Dargahian, F., and Rezaie, Gh.H., 2014., Study of synoptic and bioclimatology conditions of heat index using geographic information system at coastal and see station, in south of country and its effects on human health. Geographical Data. 23(91),43-54.

Esmaeilnegad, M., khosravei, M., Aliganei, B., and masoodeian, S.A., 2014, Identifying Heat Waves of Iran. Geography and development Iranian Journal.11(33):39-54.

Greene, L., Kalkstein, L., Mills, D.J.S., 2011, An Examination of Climate Change on Extreme Heat Events and Climate–Mortality Relationships in Large U.S. Cities, American Meteorological Society, 3(4),281–92.

Giannakopoulos, C., Psiloglou, B., Lemesios, G., Xevgenos, D., Papadaskalopoulou, C., Karali, A., Varotsos, K.V., Zachariou-Dodou, M., Moustakas, K., Ioannou, K., Petrakis, M., and Loizidou, M.,2016, Climate change impacts, vulnerability and adaptive capacity of the electrical energy sectorin Cyprus. Regional Environmental Change, 16(7),1891–904.

Glaser, J., Lemery, J., Rajagopalan, B., Diaz, H.F., García-Trabanino, R., Taduri, G., Madero, M., Amarasinghe, M., Abraham, G., Anutrakulchai, S., Jha, V., Stenvinkel, P., Roncal-Jimenez, C., Lanaspa, M.A., Correa-Rotter, R., Sheikh-Hamad, D., Burdmann, E.A., Andres-Hernando, A., Milagres, T., Weiss, I., Kanbay, M., Wesseling, C., Sánchez-Lozada, L.G., and Johnson, R.J., 2016, Climate Change and the Emergent Epidemic of CKD from Heat Stress in Rural Communities: The Case for Heat Stress Nephropathy. Clinical Journal of the American Society of Nephrology, 11(8):1472-83.

Hamidian Pour, M., Baaghideh M, and Abbas Nia, M., 2016, Assessment of the Precipitation and Temperature Changes over South East Iran Using Downscaling Of General Circulation Models Outputs, Physical Geography Research Quarterly, 48(1),107-23 .

Jeremy, S. Pal and Elfatih, A.B. Eltahir, 2015, Future temperature in south west Asia projected to exceed a threshold for human adaptability, Nature Climate Change, 6, 197–200, DOI: 10.1038/NCLIMATE2833. www.nature.com/natureclimatechange.

IPCC, 2007, Climate change 2007-the physical science basis: Working group I contribution to the fourth assessment report of the IPCC. Cambridge, United Kingdom and New York, NY, USA.: Cambridge University Press.

IPCC, 2013, The Physical Science Basis. Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. First published 2013 ed. Cambridge, United Kingdom and New York, NY, USA,: Cambridge University Press.

Knowlton, K., Rotkin-Ellman, M., King, G., Margolis, H.G., Smith, D., Solomon, G., Trent, R., and English, P., 2009, The 2006 California heat wave: impacts on hospitalizations and emergency department visits. Environmental Health Perspect, 117(1): 61–67.

Lundgren, K., Kuklane, K., Cao, C., and Holmér, I., 2013, Effects of heat stress on working populations when facing climate change .Industrial Health, 51(1):3-15.

Massah-Bavani, A.R., and Morid, S., 2006, Impact of Climate Change on the Water Resources of Zayandeh Rud Basin. Journal of Science and Technology of Agriculture and Natural Resources, 9(4),17-28.

Massah-Bavani, A.R., and Morid, S., 2005, Impact of climate change on water resources and agriculture, Iran-eater resources research, 1(1),40-47.

Nematchoua, M.K., Roshan Gh. R., and Tchinda, R., 2014, Impact of Climate Change on Outdoor Thermal Comfort and Health in Tropical Wet and Hot Zone (Douala), Cameroon. Iranian Journal of Health Sciences, 2(2),25-36.

Nian-Zhi, J., Da-Ke, C., Yong-Ming, L., Xiao-Ping, H., Rui, Z., Hai-Bo, Z., Zhi-Jian, J., and Fei, Z., 2015, Climate change and anthropogenic impacts on marine ecosystems and countermeasures in China. Advances in Climate Change Research, 6(2):118-125.

Reid, C.E., Neil, S.O.M., Gronlund, J.C., Brines, J.S., Brown, G.D., Diez-Roux, V.A. and Schwartz, J., 2009, Mapping community determinants of heat vulnerability, Environmental. Health Perspectives, 117(11):1730–36.

Roshan, Gh.R., Khoshakhlagh, F., and Azizi, Gh., 2012. Assessment of Suitable General Atmosphere Circulation Models for Forecasting Temperature and Precipitation Amounts in Iran Under Condition of Global Warming. Geography and development Iranian Journal, 10(27), 19-36 .

Semenov, M.A., and Barrow, E.M., 2002, Lars-WG a stochastic weather generator for use in climate impact studies. User's manual, Version3.0.

Smith KRA, Woodward D, Campbell-Lendrum DD, Chadee Y, Honda Q, Liu JM, et al. Human health: impacts, adaptation, and co-benefits. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, United Kingdom and New York, NY, USA.: Cambridge University Press; 2014.

Tavousi, T., Khosravi, M., and Hosseinabady, N., 2013, Monsoon Systems Impact in the Exacerbation of Malaria in Southern Sistan and Baluchestan Province with Emphasis on Chabahar city. GEOGRAPHY AND ENVIRONMENTAL HAZARDS, 7(2): 5-8.

Turleya, M.C., and Ford, D.E., (2009) Definition and calculation of uncertainty in ecological process models. Ecological Modelling. Volume 220, Issue 17, 10 September 2009, Pages 1968-1983.

Wilby, R.L., and Dessai, S., 2010, Robust adaptation to climate change, Journal *Weather*, 65(7), 180–18;65(7):180–18. DOI: 10.1002/wea.543.

Proceedings of the 2nd International Conference on Climate Change, Vol. 2, 2018, pp. 11-21

ISSN 2513-258X online
DOI: https://doi.org/10.17501/iccc.2018.2102

LONG-TERM MONITORING OF WETLANDS VIA REMOTE SENSING AND GIS: A CASE STUDY FROM TURKEY

Nebiye Musaoglu[1*], Aysegul Tanik[2], M. Umit Gumusay[3], Adalet Dervisoglu[1], B. Baha Bilgilioglu[1], Nur Yagmur[1], Tolga Bakirman[3], Duygu Baran[2] and M. Fatih Gokdag[3]

[1]Geomatics Engineering Department, Istanbul Technical University, Turkey
[2]Environmental Engineering Department, Istanbul Technical University, Turkey
[3]Geomatics Engineering Department, Yildiz Technical University, Turkey

Abstract: Remote sensing that is a low cost data source capable of making temporal observations has more advantages than the traditional methods to obtain land-use/cover change maps. In this study, temporal land-use/cover change of surface water bodies in Konya Closed Basin was evaluated via Landsat satellite images for the past 30 years. The basin, located in Central Anatolia Region of Turkey, faces water scarcity problems; however, wet agricultural activities are still favoured and practiced. Therefore, water resources are becoming more important than ever; public complains about long-lasting drought conditions and on lessening of surface water resources. There are 16 surface water bodies, and 3 of them are lakes; whereas the rest are wetlands of importance. Two of them are Ramsar sites. Results indicate that the surface area of the water bodies in Konya Closed Basin declined by approximately 23.5% within the inspection years. One of the important wetlands of the basin named as Akgol Wetland has almost lost its water surface by 96% at the same time interval, and is in danger of extinction. Thus, this vulnerable wetland has been focused on in the study. The decrease of water surface in the wetland is matched with the meteorological conditions.

Keywords: Wetland, Konya Closed Basin, Akgol Wetland, Turkey, Remote Sensing, Geographic Information System

Introduction

Wetlands are among the world's important natural resources and vulnerable ecosystems (Wdowinski et al., 2006; Wu, 2018). They are fertile ecosystems and form a suitable habitat for a wide variety of flora and fauna (Costanza et al., 2011). They have hydrological functions such as regulation of water regimes, storage of water, prevention of floods, coastal stabilization, control of erosion, acquisition of groundwater, deposition of sediments and pollutants, stabilization of local climatic conditions (Bergkamp & Orlando, 1999), and ecological functions like preserving biological diversity, providing ecological balance and critical habitat for many migrating birds (Coban, 2017). They also have a special precaution as part of the cultural heritage of mankind (Wu and Liu, 2015). Moreover, they also provide important economic benefits that include use as a water source, provision of fisheries, agriculture, timber and other building materials, provision of energy resources through peat and plants, use of wildlife resources, transportation and utilization of wetland products, recreation and tourism. Wetlands in the matter of their hydrological and energy transfer characteristics provide balance between natural phenomena especially precipitation and temperature (Korkanc, 2004). In addition, wetlands are among the most important ecosystems in terms of carbon emission (Meng, 2016) and an optimal natural environment for the long-term storage of atmospheric CO_2 (Frolking et al., 2011).

Despite the numerous and valuable functions of wetlands, natural and anthropogenic activities in the long-run spoil their well-being, making their management a crucial business. Over the last few decades importance of wetlands has even become more pronounced and their functions are better understood as areal reductions all over the world by more than 50% since 1900 is recognized (UNESCO-WWAP, 2003; Gallant et al., 2007).

*Corresponding Author Email: * musaoglune@itu.edu.tr*

The International Panel on Climate Change (IPCC) attracted the attention of society to global warming of over 2^0C and a CO_2 concentration in the atmosphere over 450 ppm. IPPC report suggested that CO_2 emissions should be reduced by 25-40% until 2020, and by 90% until 2050 to stay below these critical values (Algedik, 2012). In that sense, control and protection of wetland ecosystems may be appropriate for an overall climate change mitigation strategy (Bergkamp and Orlando, 1999). Need for information in supporting wetland management is multi-scalar from global to regional and national assessments as depicted by Rebelo et al. (2009). Remote Sensing (RS) and Geographic Information Systems (GIS) are modern tools of technology utilized for detecting, monitoring and management of natural resources and environment (Garg, 2015). Analysing and extracting reliable and consistent information via RS technology enables to form a base dataset to be further utilized for monitoring and mapping wetlands (Durduran, 2010) that has so far proven to be an efficient, helpful and frequent application tool in over large areas with low cost and time (De Roeck et al., 2008; Adam et al., 2010; Klemas, 2014). Optical and radar remote sensing obtained from many different satellite sensors such as Landsat MSS/TM /ETM + (Ji et al., 2009), SPOT (Dehouck et al., 2012) and AVHRR (Prigent et al., 2001) have been used for wetland identification and observation, prediction of biological parameters and classification of vegetation cover (Simard et al., 2006; Evans and Costa, 2013). After a thorough survey in RS science, it is seen that Landsat images are more suitable for extracting water bodies due to the SWIR band that have as used by Mcfeeters (1996), Xu (2006), Ji et. al. (2009) and by Sheng et al. (2016).

Turkey, based on its geographic location, contains many natural wetlands as it is under the effect of different climatic conditions, forming a bridge between Europe and Asia continents. An important characteristic of the country is that it is a point of attraction for some endangered and migratory birds, and the two main migration routes cross over the country. According to the Ramsar Convention, 135 wetlands of Turkey are of '*International Importance*'. Majority of these sensitive and vulnerable areas have international reserves regarding water birds and fish species. Konya Closed Basin (KCB) located in Central Anatolia is one of the 25 river basins of Turkey and houses 13 wetlands. Actually, it has 16 water bodies of which 3 are lakes. One of the internationally recognised wetlands of the basin is Akgol Wetland known to be an abundant one regarding its biodiversity in the past years. Ayranci, Ivriz and Godet Dams put into operation in 1958, 1984 and 1988, respectively, have started to cut the water flow to Akgol; thus, considerable decrease in the water area and in turn, in the volume has occurred. The surface area of Akgol had been around 21.500 ha till 1960's; since then, majority of it had been lost due to water drainage, water cuts and to withdrawals for agricultural irrigation. Moreover, semi-arid character of the region is another bottle-neck of the wetland as its only water feeding is by precipitation which tends to decrease through the climate change effects in the near future.

In this study, temporal changes of KCB in general and Akgol specifically were analysed using RS data in a period of about 30 years (1984-2017). Long-term meteorological data including precipitation, temperature and evaporation values were also considered in the evaluation of the findings derived from satellite images. Relationship between climate data and wetland water change is evaluated chronologically based on the images belonging to different years. All the results achieved were compiled and integrated in a GIS environment; a convenient system that will be able to make further queries.

Study Area

KCB located in Central Anatolia of Turkey has been declared as one of the 200 ecologically significant regions of the world by WWF International (Dursun et al., 2012). It covers 7% of Turkey's surface area and bears total annual usable water resources of 4,365 billion m^3. However, water consumption of 6,5 billion m^3 points out that there is an annual water deficit of approximately 2 billion m^3. Semi-arid climatic conditions prevail in the overall basin. The average annual rainfall in the basin was around 407 mm taking into account the average of all the available years from 1923 to 2013. However, this annual precipitation value is found lower in this study that considered only 1971-2015 period. It can be stated that the precipitation value in general is almost half of the country's value. Larger surface area with less flowing water bodies, lower precipitation with higher evaporation are the significant characteristics of the basin; however, an interesting water balance is observed (CCIWR, 2016). This basin consists of only 2% of the country's overall surface water resources and whereas 17% of the groundwater resources. This fact can be briefly summarized as '*KCB is a basin that bears the minimum surface water resources while owning the highest groundwater resources*' (DMP, 2015).

Agricultural areas cover almost 55.5% of the basin followed by forests and semi-natural areas by 37.4% (DGWM, 2016). The rest of land-use distribution is shared by urbanized areas and water surfaces. The region's agricultural production capacity has a strategic importance for Turkey's food supply, although; KCB has the least amount of rainfall in Central Anatolia (Celebi and Direk, 2017).

Akgol Wetland in KCB and its vicinity is an important biogeographic region with different habitats, rich biological diversity and microclimate as shown in Figure 1. Akgol was the largest wetland area in Turkey in 1950s with a surface area of 24.000 ha. Average elevation of the region is 998 m. The south of the wetland is covered by the extensions of the Taurus Mountains and the east, west and north sides are surrounded by flat steppe areas. There are also some volcanic elevations. This wetland has started losing its water within years due to human-induced activities and to natural climatic changes. As such, its natural boundaries have changed. The total surface area of Akgol till 1960's had been around 21.500 ha and almost 16.200 ha of this amount had been dried since then. The main reasons that led to a considerable decrease in the water level were primarily water cut to the wetland due to river diversions during the operation of the dams, and secondly, the drying of lakes was so common these days due to fight against malaria disease; thus, combating with malaria accelerated the drying practice.

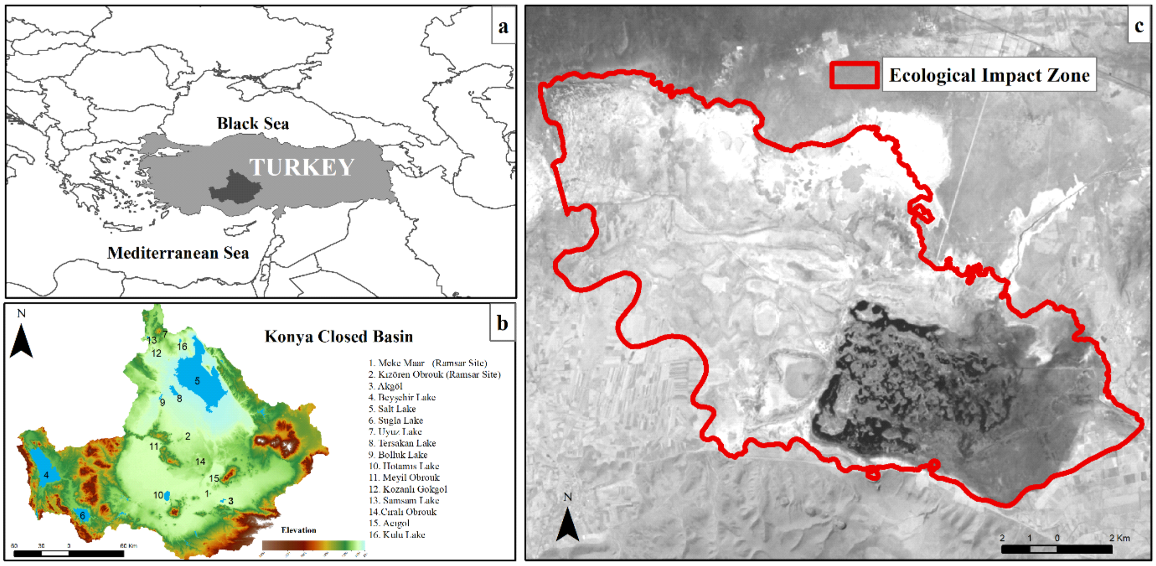


Figure 1 Geographical location of (a) Turkey, (b) Konya Closed Basin (KCB), (c) Akgol Wetland

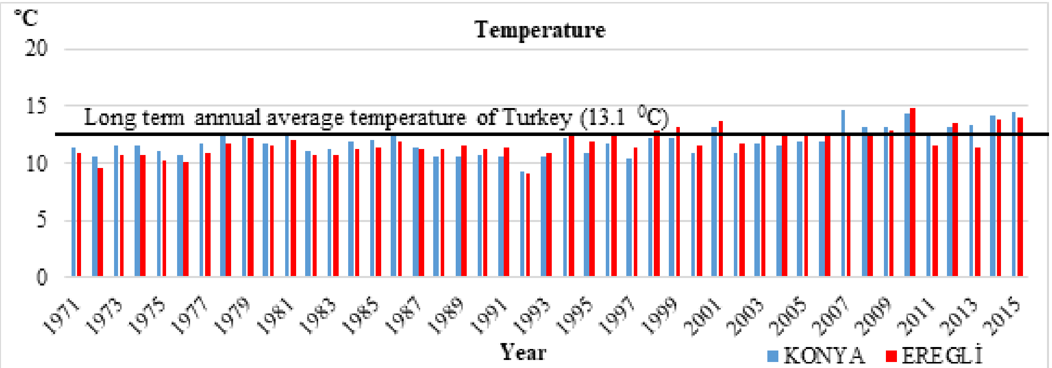
Materials and Methods

LANDSAT 5 TM, LANDSAT 7 ETM+ and LANDSAT 8 OLI data were used to determine the temporal changes of KCB and Akgol Wetland. General information about LANDSAT images that were downloaded from the USGS website is given in Table 1.

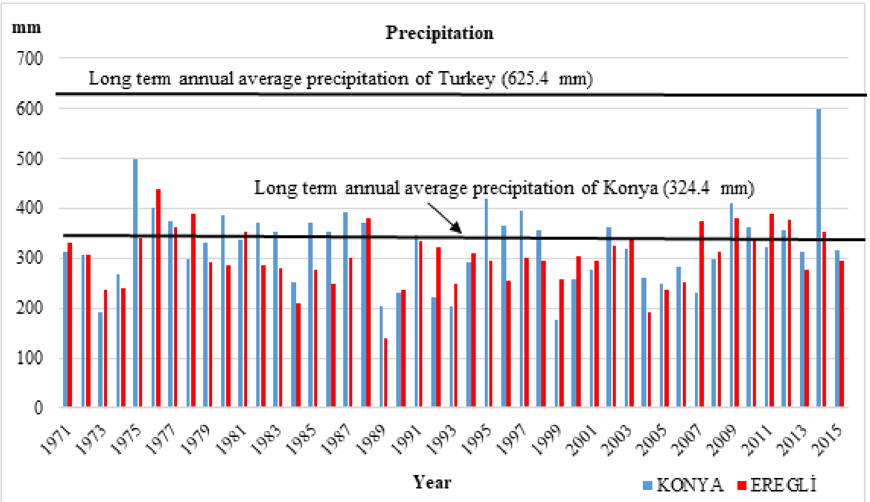
Table 1 Landsat data used in the study

Satellite (µm)	Spectral Resolution	Spatial Resolution(m)	Radiometric Resolution	Temporal Resolution
LANDSAT 5 TM (1987 and 1998)	7 Bands (0.45-2.35)	B1,B2,B3,B4 B5,B7:30 B6:120	8 bit	16 days
LANDSAT 7 ETM+ (2007)	8 Bands (0.45-2.35)	B1,B2,B3,B4 B5,B7:30 B6:60 B8:15	8 bit	16 days
LANDSAT 8 OLI (2017)	9 Bands(0.433-2.30)	B1,B2,B3,B4 B5,B7,B9:30 B6:60 B8:15	16 bit	16 days

Meteorological data was obtained from the State Meteorological Service (SMS) both for Konya Province that represents the entire basin and also for Eregli Meteorological Station representing the Akgol Wetland. These data that covered temperature and precipitation values between 1971- 2015 for both of the stations were considered together with the water covered areas classified from the processed satellite images at different times (Figure 2).



(a)



(b)

Figure 2 a) Mean temperature, b) mean precipitation values of Konya and Eregli meteorological stations

It is seen from the long-term temperature data that both of the stations illustrated almost similar degrees all throughout 45 years. The temperature of KBC is well below the Turkey's long-term average annual temperature; however, temperature presented a slightly increasing trend after 2000s. The average annual precipitation of Konya is observed as half of Turkey's rainfall underlying the fact that the basin is of semi-arid character. The precipitation seems to increase after 2007 and even pass the average annual value.

Satellite images after the mid of 1970's have started to be utilized for obtaining data that are further used in the modelling and management of water surfaces. Remote sensing (RS) has more advantages than the traditional methods of land-surface water mapping because it is a low-cost and reliable information source that is capable of making high-frequency and repeatable observations. For extracting information regarding surface water bodies, algorithms such as classification and indexes have been developed as they are the key points for transferring remotely sensed images into information for practical applications as Li et al. (2013) referred. Normalized Difference Water Index (NDWI) is commonly used to extract the water surface area. This index is designed to maximize the reflectance of a water body by using green wavelength, minimize the low reflectance in Near-IR, and take advantage of the high reflectance in Near-IR of vegetable and soil features (Li et al., 2013). Results vary between -1 and +1; where the water covered areas always take positive values. For image processing ERDAS 2016 software was used.

NDWI = (Green – Near Infrared) / (Green + Near Infrared)

Numerous studies have focused on land use/cover and change detection by using satellite data. Fu et al. (2013) applied classification algorithms to thirty-seven Landsat MSS/TM/ ETM+ satellite images from 1976 to 2010, the HJ-1A CCD image dated 2010 and the SPOT5 image dated 2005 to obtain spatial-temporal analysis of wetland landscape pattern characteristics for Yellow River Delta, China. Higgins and Caretta (2017) made comparisons between a Landsat satellite-derived history of lake surface area, local precipitation records, and corresponding anthropogenic activity in Tanzania and the results showed the impacts of agricultural and historical practices in the region. More recently, Hird et al. (2017) used Sentinel 2A images applied difference vegetation index (NDVI) and NDWI for wetland mapping in Alberta, Canada. Tangud et al. (2018) produced land cover maps for 1986, 1995, 2000, 2006 and 2004 years by using LANDSAT satellite image and Support Vector Machine Method. They found a strong negative correlation between grassland and barren land indicating that grassland degradation in this region is due to the regional modernization over the past 28 years. Finally, Arsanjani (2018) used GlobeLand30-2000 and GlobeLand30-2010 data to identify the rates and types of land change across different continents.

Given the large amount of environmental data that needs to be compiled for effective analysis, GIS was used as an efficient tool for organising, storing, analysing, displaying and reporting the spatial information. It allows the creation and modification of the analysis that makes the best use of available data. It is useful for wetland studies as remotely sensed data together with other available data are an opportunity to exploit the capability of GIS. This is because a fundamental cost of starting and operating a GIS system is data input. Five major steps of GIS spatial analysis for environmental and ecological studies include (but not limited to) (Dhanapal, 2012);

- Defining criteria for the analysis,
- Defining data needs and base map,
- Acquisition and preparation of the data as thematic maps,
- Creating GIS model/overlays,
- Evaluating results and refinement of the model.

Rawashdeh (2011) used GIS and change detection techniques to evaluate the efficiency of an automatic change detection method in mapping the changes that took place after the implementation of newly irrigated areas in dry zones. For this aim LANDSAT TM 1983 and LANDSAT ETM+ satellite images were used. Hadeel et. al.(2011) studied environmental degradation by using multi-temporal satellite data and GIS. Borfecchia et. al. (2014) used remote sensing data derived from digital surface model, LANDSAT, MODIS satellite data and GIS to support the photovoltaic potential assessment in urban areas. Agapiou et al. (2016) made water leakage detection using remote sensing, field spectroscopy and GIS in semiarid areas of Cyprus.

In this study, 1/25.000 scale topographic maps were used as basic maps. "Contour" and "elevation point" layers in the 1/25.000 scaled topographical maps and the digital elevation model (DEM) of the land were obtained as raster to make 3D analyses of the study area. To analyse urban pressure, borders of the settlements and demographic data were integrated to GIS media. For this aim, village locations around the Akgol Wetland were digitized from the topographical maps and transferred to GIS by using ARCGIS 10.1 Software. Then, population data of the villages around the wetland obtained from Turkish Statistical Institute were transferred into the system as a layer attribute. The location of the environmental infrastructure units of solid waste landfill that was established at the edge of the wetland's buffer zone, and the domestic wastewater treatment plant of Eregli district whose treated water is discharged to Akgol were digitized by using satellite images and the attributes such as width and volume of the stabilization ponds in the wastewater treatment plant were added to the system. Examples of created layers in GIS are illustrated in Figure 3. Land-use/cover classification processed from the satellite data were also added to the GIS environment. A web-based GIS has been implemented and published using the specified layers. The website is accessible from http://eregliakgol.itu.edu.tr

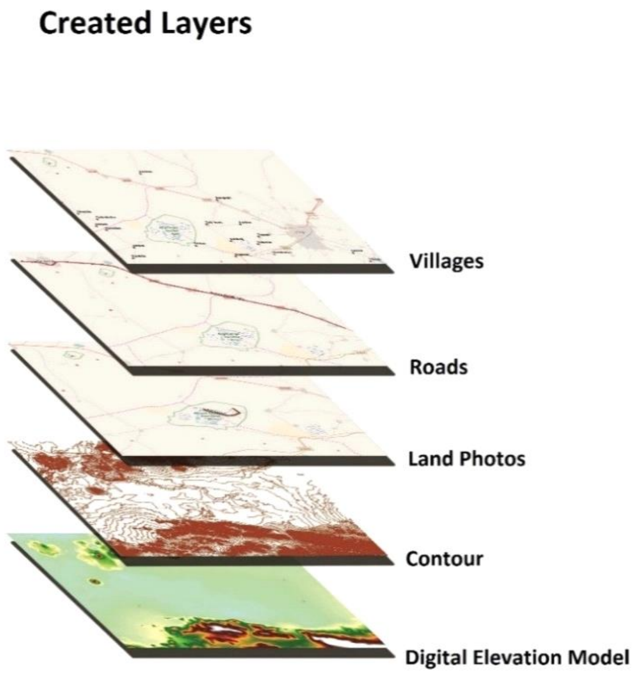


Figure 3 Examples of created layers in GIS

Results and Discussion

Temporal changes of water bodies in KCB and Akgol wetland were evaluated separately. All the index results are given in Figure 4 and Figure 5, respectively. The values of NDWI are shown in grey tone; however, the thresholds were determined and water covered areas are indicated in blue. Four satellite images belonging to 1987, 1998, 2007 and 2017 were selected as representative data indicating the reduction in water surfaces both in KCB and Akgol Wetland. According to these results, KCB has declined by approximately by 23.5% throughout the inspection period of 30 years. Akgol Wetland in Figure 4 that shows the entire KCB was just observable in 1987; but then onwards, in the large scale of KCB, it almost disappeared. Figure 5 specifically highlighted Akgol. While the water surface area of the wetland was 2958.4 ha in 1987, it decreased as 1153.9 ha in 1998, and it was only 12.7 ha in 2007. Suddenly, its surface water area has reached 117.2 ha in 2017 by the only feeding source that is precipitation.

Figure 6a demonstrates the total water surface area in KCB within the inspection time, whereas similar presentation is shown for Akgol Wetland at the same time lag. Akgol Wetland has almost decreased by 96% and is in danger of extinction. A long dike with a height 1.65 m was built by the Regional Directorate of State Hydraulic Works at part of the wetland from where high amounts of water escaped with the aim of regaining the wetland functions that have been lost with time, and of structurally strengthening the wetland to hold more water to overcome the negative effects of climate change. This technical construction was realized in July-September 2013 that targeted to end in a wetland with a water surface area of approximately 340 ha (Dervisoglu, et. al., 2017).

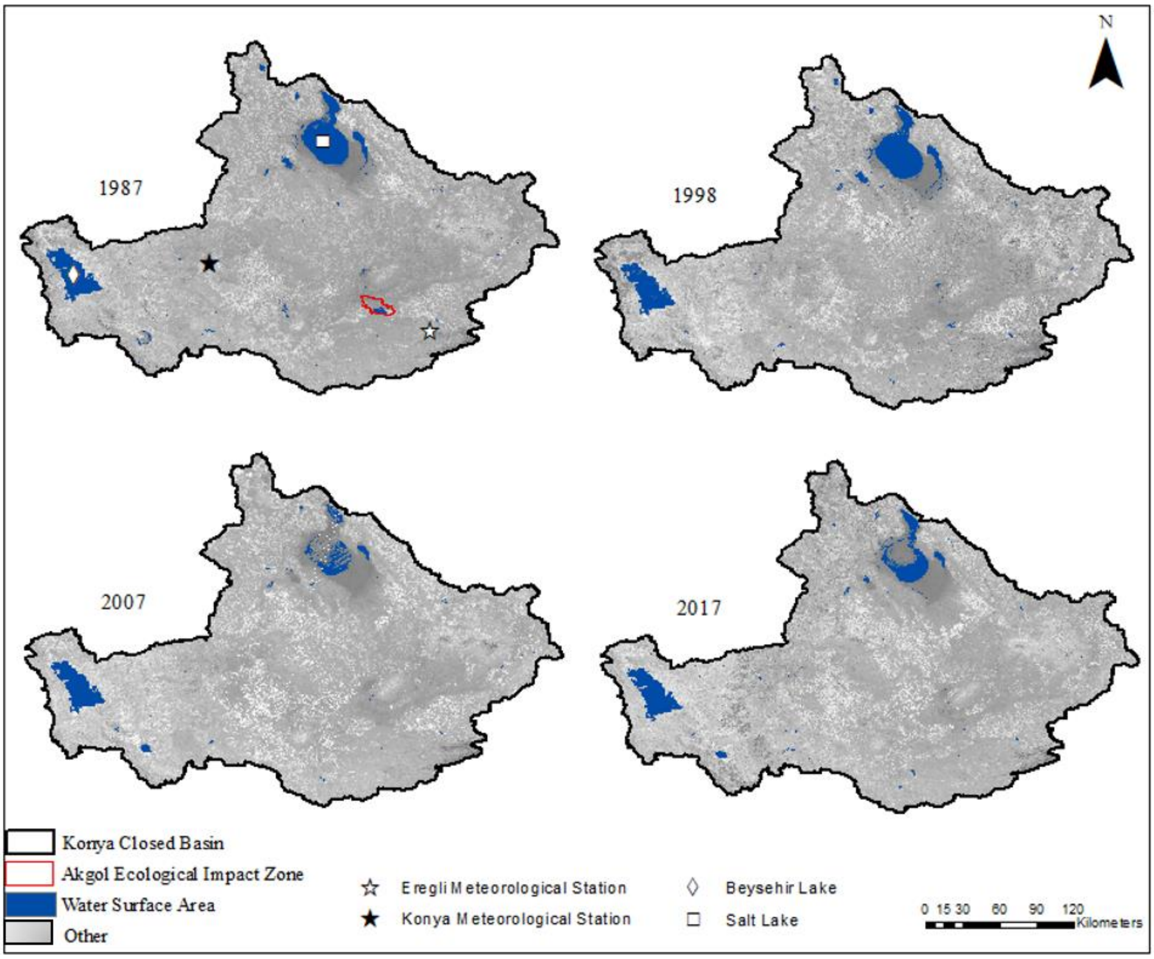


Figure 4 Temporal changes of water surface area in Konya Closed Basin

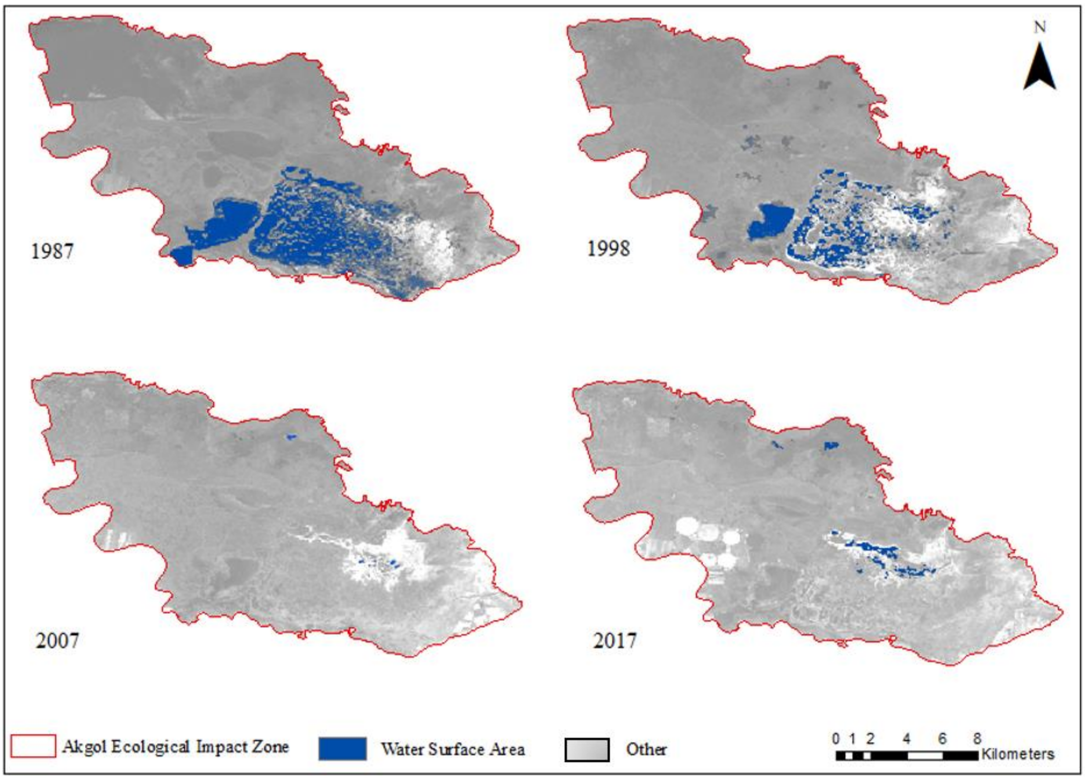
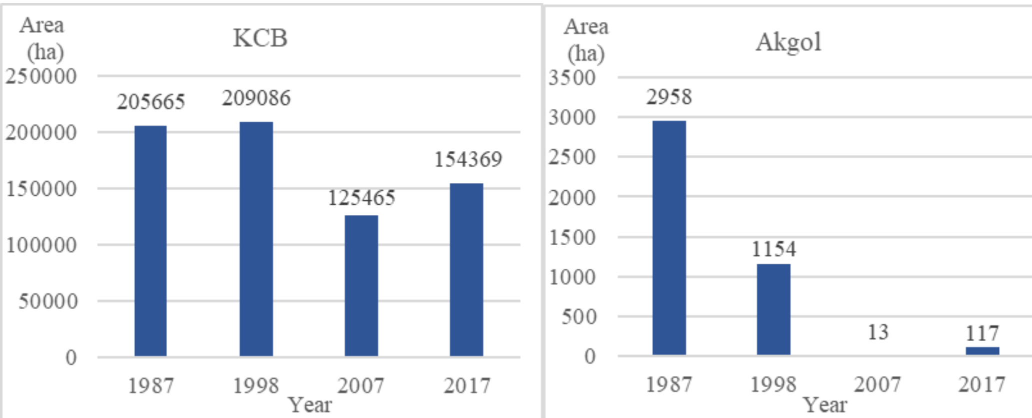


Figure 5 Temporal changes of water surface area in Akgol Wetland



(a) (b)

Figure 6 Water surface areas of (a) KCB, and (b) Akgol Wetland

Conclusions and Recommendations

Water potential of KCB is foreseen to be decreasing with time which may cause even more water deficit in future according to the outputs of climate change impacts on water resources project. Simply, the overall situation puts forth the losses in water holding capacity of these natural water bodies where majority of them are wetlands. Within this study, the changes in water volume are inspected in the past 30 years. The findings achieved designated the reality that surface water resources are declining with time. These alarming results actually urged the authors to focus more on a vulnerable watershed of the basin and inspect its physical situation. The results provided are for the decision-makers and related authorities in charge of the water related works in the basin. As such, multi-temporal change detection by using remotely sensed imagery has become a useful tool in gathering information on the status of the wetlands for the decision- makers and local authorities. By utilizing the remotely sensed data, one can generate wetland maps which may give rise to the estimation of its functions and services as well to further assessment of the gains and losses within years.

Acknowledgements

The authors would like to express their thanks to TUBITAK for their financial support to Project number 116Y142, and to Istanbul Technical University, Scientific Research Project Funding for their financial support to ITU BAP Project number MGA-2017-40803.

References

Adam, E., Mutanga, O. & Rugege, D., 2010, Multispectral and hyperspectral remote sensing for identification and mapping of wetland vegetation: a review. *Wetlands Ecology and Management*, 18 (3), 281-296.

Agapiou, A., Dimitrios, D. A., Kyriacos T. & Hadjimitsis, D. G., 2016, Water leakage detection using remote sensing, field spectroscopy and GIS in semiarid areas of Cyprus. *Urban Water Journal,* 13:3, 221-231.

Algedik, O., 2012, Assessment Report on climate change action plan, Heinrich Böll Stiftung Association-Turkey Representative (in Turkish).

Arsanjani, J. J., 2018, Characterizing and monitoring global landscapes using GlobeLand30 datasets: the first decade of the twenty-first century, *International Journal of Digital Earth*, (online).

Bergkamp, G. & Orlando, B.,1999, *Exploring Collaboration between the Convention on Wetlands (Ramsar, Iran 1971) and the UN Framework Convention on Climate Change*. Climate Initiative, IUCN, Washington, USA.

Borfecchia, F., Caiaffa,E., Pollino, M., Cecco, L. D., Martini, S., Porta, L. L. & Marucci, A., 2014, Remote Sensing and GIS in planning photovoltaic potential of urban areas. *European Journal of Remote Sensing*, 47 (1), 195-216.

Celebi, M., Direk, M., 2017, Farmer behaviours and sustainable water management in semiarid Konya Closed Basin in Turkey. *International Journal of Advanced Biological and Biomedical Research*, 6(1), 441-450.

Coban, A., 2017, The effect of climate change on wetlands and the situation of wetlands in Turkey, *The Turkish Journal of Occupational/Environmental Medicine and Safety*, 2.1 (3), 3-3.

Costanza, R., Kubiszewski, I., Ervin, D., Bluffstone, R., Boyd, J., Brown, D. and Shandas, V., 2011, Valuing ecological systems and services. F1000 Biology Reports, 3.

CCIWR, 2016, Climate Change Impact on Water Resources Project, Ministry of Forestry and Water Affairs, General Directorate of Water Management [Online]. Date of access: 21/04/2018 http://iklim.ormansu.gov.tr/Eng/

DGWM, 2016. Technical Assistance for The Conversion of River Basin Action Plans into River Basin Management Plans, Ministry of Forestry and Water Affairs, Directorate General for Water Management, TR2011/0327.21-05-01-001.

De Roeck, E. R., Verhoest, N. E. C., Miya, M. H., Lievens, O., Batelaan, A. T. and Brendonck, L., 2008, Remote sensing and wetland ecology: A South African case study. *Sensors*, 8 (5), 3542-3556.

Dehouck, A., Lafon, V., Baghdadi, N. and Marieu, V., 2012, Use of optical and radar data in synergy for mapping intertidal flats and coastal salt-marshes (Arcachon Lagoon, France). Proceedings of the Geoscience and Remote Sensing Symposium (IGARSS) 2012, pp. 2853-2856.

Dhanapal, G., 2012, GIS-based environmental and ecological planning for sustainable development, Geospatial World, [Online]. Date of access: 21/04/2018.

https://www.geospatialworld.net/article/gis-based-environmental-and-ecological-planning-for-sustainable-development/

Dervisoglu, A., Musaoglu, N., Tanik, A., Gumusay, U., Senol, A. and Bakirman, T., 2017, Monitoring the effect of an impoundment built for rehabilitation of Akgol Wetland- Turkey. Proceedings of the ICOCEE 2017 Cappadocia, Turkey, pp. 601-610.

DMP, 2015, Konya Closed Basin Drought Management Plan Project, Ministry of Forestry and Water Affairs, General Directorate of Water Management. Date of access: 21/04/2018. http://www.suyonetimi.gov.tr.

Durduran, S. S., 2010, Coastline change assessment on water reservoirs located in the Konya Basin Area, Turkey, using multitemporal Landsat imagery. *Environmental Monitoring and Assessment*, 164, 453–461.

Dursun, S., Onder, S., Acar, R., Direk, M. and Mucevher, O., 2012, Effect of environmental and socioeconomically change on agricultural production in Konya Region. Proceedings of International Conference on Applied Life Sciences (ICALS2012), Turkey, pp. 19- 36.

Evans, T.L. & Costa, M., 2013, Land cover classification of the Lower Nhecolandia Sub-region of the Brazilian Pantanal Wetlands using ALOS/PALSAR, RADARSAT-2 and ENVISAT/ASAR imagery. *Remote Sensing of the Environment*, 128, 118–137.

Frolking, S., Talbot, J., Jones, M. C., Treat, C. C., Kauffman, J. B., Tuittila, E. S. and Roulet, N., 2011, Peatlands in the Earth's 21st Century climate system. *Environmental Reviews*, 19, 371–96.

Fu, X., Gaohuan, L., Siyue, C., Chong, H., Fadong, L. 2013, Spatial temporal analysis of wetland landscape pattern under the influence of artificial dykes in the Yellow River Delta. *Chinese Journal of Population Resources and Environment*, 11 (2), 109-117.

Gallant, A. L., Klaver, R. W., Casper, G. S. and Lannoo, M. J., 2007, Global rates of habitat loss and implications for amphibian conservation. *Copeia*, 2007(4), 967-979.

Garg, J. K., 2015, Wetland assessment, monitoring and management in India using geospatial techniques. *Journal of Environmental Management*, 148, 112-123.

Hadeel, A., Jabbar, M., & Chen, X., 2011, Remote sensing and GIS application in the detection of environmental degradation indicators. *Geo-spatial Information Science*, 14, 1, 39-47.

Higgins, L., Caretta, M. A. 2018, Lake extent changes in Basotu, Tanzania: a mixed-methods approach to understanding the impacts of anthropogenic influence and climate variability. *Landscape Research*, DOI: 10.1080/01426397.2017.1416599

Hird, N. J. Delancey, E. R., McDermid, G. J., Kariyeva, J. 2017, Google earth engine, open-access satellite data, and machine learning in support of large-area probabilistic wetland mapping. *Remote Sensing*, 9 (12), 1315.

Ji, L., Zhang, Li. & Wylie, B.K., 2009, Analysis of dynamic thresholds for the normalized difference water index. *Photogrammetric Engineering & Remote Sensing*, 75(11), 1307-1317.

Klemas, V. V., 2014, Advances in Coastal Wetland Remote Sensing. Proceedings of the 2014 IEEE/OES Baltic International Symposium (Baltic), Talinn Estonia.: Date of access: 18/04/2018 http://ieeexplore.ieee.org/xpl/mostRecentIssue.jsp?punumber=6879365

Korkanc, S., 2004, Place of wetlands in watershed system. *ZKÜ Bartın Journal of the Faculty of Forestry*, 6(6), 117-126. (in Turkish)

Li, W., Du, Z., Ling, F., Zhou, D., Wang, H., Gui, Y., Sun, B. & Zhang, X., 2013, A comparison of land surface water mapping using the normalized difference water index from TM, ETM+ and ALI. *Remote Sensing*, 5, 5530–5549.

McFeeters, S. K., 1996, The use of the Normalized Difference Water Index (NDWI) in the delineation of open water features. *International Journal of Remote Sensing*, 17(7), 1425-1432.

Meng, L., Roulet, N., Zhuang, Q., Christensen, T. & Frolking, S., 2016, Focus on the impact of climate change on wetland ecosystems and carbon dynamics. *Environmental Research Letters*, 11, 100201.

Prigent, C., Matthews, E., Aires, F. & Rossow, W. B., 2001, Remote sensing of global wetland dynamics with multiple satellite data sets. *Geophysical Research Letters*, 28(24), 4631-4634.

Rawashdeh, S. B.A., 2011, Evaluation of the differencing pixel-by-pixel change detection method in mapping irrigated areas in dry zones. *International Journal of Remote Sensing*, 32 (8), 2173-2184.

Rebelo, L. M., Finlayson, C. M. and Nagabhatla, N., 2009, Remote sensing and GIS for wetland inventory, mapping and change analysis. *Journal of Environmental Management*, 90 (7), 2144-2153.

Sheng, Y., Song, C., Wang, J., Lyons, E.A., Knox, B.R., Cox, J.S. & Gao, F., 2016, Representative lake water extent mapping at continental scales using multi-temporal Landsat-8 imagery. *Remote Sensing of Environment*, 185, 129-141.

Simard, M., Zhang, K.Q., Rivera-Monroy, V.H., Ross, M.S., Ruiz, P.L., Castaneda-Moya, E., Twilley, R.R. and Rodriguez, E., 2006, Mapping height and biomass of mangrove forests in Everglades National Park with SRTM elevation data. *Photogrammetric Engineering and Remote Sensing*, 72, 299–311.

Tangud,T., Nasahara,K.,Borjigin, H. & Bagan, H, 2018, Land-cover change in the Wulagai grassland, Inner Mongolia of China between 1986 and 2014 analysed using multi-temporal Landsat images. *Geocarto International*, DOI: 10.1080/10106049.2018.1478457

UNESCO-WWAP, 2003. Water for people – water for life. The United Nations World Water Development Report, United Nations Educational, Scientific and Cultural Organization (UNESCO), United Nations World Water Assessment Programme (WWAP), UNESCO Publishing and Berghahn Books, Barcelona.

Xu, H., 2006, Modification of normalised difference water index (NDWI) to enhance open water features in remotely sensed imagery. *International Journal of Remote Sensing*, 27(14), 3025-3033.

Wdowinski, S., Kim, S., Amelung, F. and Dixon, T., 2006, Wetland InSAR: A new space-based hydrological monitoring tool of wetlands surface water level changes. Proceedings of the Glob Wetland Symposium, Frascati, Italy, pp. 6.

Wu, Q., 2018, GIS and remote sensing applications in wetland mapping and monitoring. *Comprehensive Geographic Information Systems*, (2), 140-157.

Wu, G., and Liu, Y., 2015, Capturing variations in inundation with satellite remote sensing in a morphologically complex large lake. *Journal of Hydrology*, 523, 14-23.

Proceedings of the 2nd International Conference on Climate Change, Vol. 2, 2018, pp. 22-29

ISSN 2513-258X online
DOI: https://doi.org/10.17501/iccc.2018.2103

POTENTIAL FOR CLIMATE CHANGE MITIGATION THROUGH LOW-CARBON RAIL TRANSPORT IN INDIA

Priyanka Pali

The University of Manchester, United Kingdom

Abstract: Climate change is possibly one of the most urgent and complex issue being faced by nations worldwide. Rising levels of greenhouse gas emissions is considered by scientists and academics to be the primary cause for increasing temperatures, which is known to result in global warming and cause climatic changes. Therefore, adopting measures and strategies to mitigate the adverse impacts being caused due to rising emissions is high on the agenda for policy makers and governments across the globe. Many sectors are responsible for feeding this rise in GHG emissions, including transport. In India, transport is the second largest greenhouse gas emitter from the energy sector. Despite the fact that a majority of GHG emissions in the Indian transport sector is from roadways, and rail transport is only responsible for 5% of the total transport emissions, the exponential increase in rail emissions over the past few years makes it imperative to focus on strategies and technologies to reduce the same. While current research is being undertaken to increase the share of railways due to their carbon friendly nature in comparison to road transport, it is submitted that a deeper engagement with developing and using actual low-carbon alternatives is required, which can in-reality help in achieving reduced emissions, and consequently bring down the GHG emissions from rail transport in India. Low-carbon alternatives, such as use of clean fuels and electrification of the rail network, are now being developed with the aim to move from using carbon intensive sources of energy to environment friendly ones. This paper discusses these GHG emissions reduction strategies being implemented by the Indian government within the rail network to determine whether these are in-reality assisting or have the potential to assist in bringing down the GHG emissions from railways in India. This will also determine the scope of climate change mitigation from these low-carbon alternatives being adopted by the government in the Indian rail transport sector.

Keywords: climate change mitigation, low-carbon transport, Indian railways, carbon emissions

Introduction

Growing awareness among policy makers, academics, scientists and beyond regarding the problems and challenges posed by climate change to our society, is leading to an increase in finding ways and means to reduce and stabilize the increasing levels of greenhouse gas (GHG) emissions into the atmosphere. This is critical within transport as it is one of the sectors worldwide where CO_2 Eq emissions are on the rise.

In India, the four main modes of transport, i.e. road, rail, navigation and airways, combined together are responsible for being the second largest source of GHG emissions within the energy sector, with a total of 142.04 million tons of CO_2 Eq emissions released in 2007 (Chakrabarty and Chakraborty, 2017). Amongst these four modes of transport, though the contribution of railways is only 6.84 million tons of CO_2 Eq which is 5% of the total emissions and is noticeably lower than road emissions which is responsible for 87% of total emissions from transport at 123.55 million tons of CO_2 Eq, it is crucial to also focus on controlling the

Corresponding Author Email: * priyanka.pali@gmail.com

release of CO2 Eq emissions from railways as rail emissions have seen a massive growth from 3.4 million tons of direct CO2 emissions in 2003-04 to 6.84 million tons of CO2 emissions in 2007 (Ministry of Environment and Forests, 2010).

One of the many ways to respond to this rise in CO2 Eq emissions from rail transport sector is through development of low-carbon means of rail transport across cities and countries. There are many direct and indirect potential benefits which can be realized from well-designed low-carbon alternatives, such as reduction in air pollution, enhanced mobility options and ease in traffic and congestion. These can be achieved by incorporating a low-carbon trajectory within rail transport, which can consequently provide a strong incentive for an aggressive, sustained and efficient move to a low-carbon economy.

Although environmental advantages of using low-carbon alternatives within the rail transport network are many, the key objective of this paper is to ascertain if there are any low-carbon alternatives being adopted by the Indian government to assist in reducing release of CO2 Eq emissions from railways, and whether these low-carbon alternatives *in fact* have the potential to positively impact the reduction of GHG emissions from the Indian rail network and support the Indian government's climate change mitigation targets. To respond to this, the paper will first start with a brief discussion on the current understanding on climate change mitigation, which will then be followed by elaborating on what India brings to the global platform to support climate change mitigation. This paper then proceeds on to discuss the ongoing low-carbon / green initiatives in railways being adopted by the Indian government, such as the use of renewable sources of energy and afforestation on railway land to increase carbon sinks, with an aim to determine whether these measures/initiatives *in fact* have the potential to enable or assist in controlling/reducing the increasing emissions from railways in India.

Current understanding of climate change mitigation

Climate change is possibly the most complex and urgent issue being addressed by countries worldwide. Though a global issue, the impacts of climate change are mostly felt at the local level. Most of the countries have collectively agreed to limit the global average temperature rise well below 2 degrees Celsius above preindustrial levels by signing and ratifying numerous international and multilateral agreements. This is also reflected in the Pairs Agreement on Climate Change 2015 (hereinafter the Paris Agreement), which was entered into force on 4 November 2016, and is a key international document adopting reduction in global temperature rise as its overarching climate goal.

To elaborate a little further on the different ways to tackle climate change, any response to climate change must revolve around one of the two possible approaches – mitigation (i.e. actions/measures which address climate change by reducing/stabilizing the rising levels of GHGs in the atmosphere) and adaptation (i.e. actions/measures which revolve around adapting to the already present effects and impacts of climate change).

This paper revolves around studying climate change mitigation, and a detailed study of academic literature and various environmental assessment reports indicate that any action to be categorized as climate change mitigation must fall into one of the following three categories –

- An action that reduces and curbs greenhouse gas (GHG) emissions;
- An action that increases sinks of GHGs; and
- An action that attends to the causes of climate change.

The main objective of this paper is to further the research in the area of climate change mitigation by gathering and studying the low-carbon actions and measures being undertaken by the Indian government at the domestic level to reduce the rising carbon emissions from rail transportation with an aim to determine if these measures are in-fact assisting the government in reducing CO2 Eq emissions from rail transport in India. To achieve this objective, the next section will briefly set the stage by elaborating on the efforts being undertaken by the Indian government to address climate change at the domestic level, which will be followed by a section on the specific actions being undertaken by the government to reduce CO2 Eq emissions from the Indian rail network.

What does India bring to the global platform to support climate change mitigation?

Countries have come together to set up intergovernmental organizations and signed treaties to address the problem of climate change. Some of the key ones adopted by them with an aim to stabilize the GHG concentration in the atmosphere and address climate change mitigation include the United National Framework Convention on Climate Change (UNFCCC), the Kyoto Protocol and the Paris Agreement. The Indian government has signed and ratified these three international documents, and consequently, has also pledged to undertake measures to reduce its GHG emissions intensity by setting up domestic emissions reduction targets.

In addition to signing and ratifying various international and multilateral agreements towards mitigating the harmful impacts of climate change[1], it is important to undertake initiatives which can support the reduction in release of harmful GHGs at national, city and municipality levels. These initiatives are reflected in the Intended Nationally Determined Contributions (INDC), which are plans that clearly outline the national GHG emissions reduction targets and goals towards climate action, and were submitted by countries before the preparation and release of the Paris Agreement.

Despite the fact that because of being a non-Annex 1 country under the Kyoto Protocol India does not have legally binding emissions reduction targets (Thaker and Leiserowitz, 2014), it nevertheless plays an active role in achieving global climate goals by putting forward mitigation strategies and setting up domestic targets to achieve them. Aligning with global climate objectives set up under the Paris Agreement, the INDC released by the Indian government in 2015 in response to their commitment under the Paris Agreement clearly points out India's attempts and commitments to work towards a carbon friendly path. To this effect, the INDC includes climate measures such as voluntary goal of reduction of GDP's emissions intensity by 33-35% below 2005 levels by 2030, increasing the share of electricity being generated from non-fossil fuels to 40%, enhancing energy generation from renewable sources of energy to 175GW by 2022, and enhancing its forest cover with an aim to absorb 2.5-3 billion tons of CO2 by 2030 (UNFCCC, 2015). A detailed discussion on the current status of these measures is a subject matter of another research, but this paper will now focus on the measures being adopted by the Indian government to respond to control the rising GHG emissions from railways in India.

Ongoing green initiatives in railways being adopted by the Indian government

As India aims to transition to a low-carbon economy, there are a number of green initiatives being planned by the Indian government to assist in reducing emissions intensity from the rail transport sector. They are at various stages of execution and a majority of them have stemmed up in response to the emissions reduction target set up by the Indian railways, which is a 33% reduction in GHG emissions intensity below 2005 levels by 2030. These are also being supported by the carbon friendly objectives set up for the transport in the INDC which pledges to develop a safe, smart and sustainable transport network focusing on emissions reduction and mitigation strategies from all modes of transport including railways. For instance, the INDC presents strategies and actions to meet its emissions reduction targets and achieve lower emissions intensity which includes plans to enhance the share of railways in land based transport from 36% to 45% and increase their

[1] See for example the Paris Agreement on Climate Change 2015.

focus on development of mass rapid transit system such as Metrorail across different cities in India. An elaborate study of these strategies is beyond the scope of this paper, but the section below will now elaborate on the various ongoing green initiatives being undertaken by the government to improve the carbon efficiency and green quotient of the rail network in India. Whether these are actually assisting the Indian railways in reducing their emissions intensity and supporting the move towards establishing a low-carbon rail network will be discussed in the subsequent section.

Emissions intensity reduction target

As a part of its low-carbon strategy, the Indian railways has envisaged a target of 33% reduction in its emissions intensity below 2005 levels by 2030. This is in response to the national GHG emissions intensity reduction targets put forth by the Indian government, i.e. 33-35% by 2030 from levels in 2005. Efforts are underway by the Indian railways to achieve this target by focusing on measures such as improvement in rail traction energy and increased use of clean fuel, which will be deliberated upon in the subsequent paragraphs.

Energy efficiency and conservation

The railways in India are known to be one of the highest consumers of electricity (Konda *et al.*, 2017). To meet this growing demand for energy required by the rail sector, the government has identified and implemented several strategies which revolve around the use of carbon friendly sources of energy, some of which have been discussed in the present paper, with an aim to improve the energy efficiency of rail transport. This use has resulted in a decrease, though very negligible, in its energy consumption from 18.25 billion kwh in 2014-15 to 18.22 billion kwh in 2015-16. This is notwithstanding the various measures being undertaken to enable massive growth of the rail network in India, in addition to efforts being initiated to increase the share of railways in Indian freight traffic from 36% in 2016-17 to 45% by 2030 (Ministry of Railways, 2017).

Further, the Indian railways is also undertaking measures to cut down the use of energy by replacing the existing lights and fans in non-traction areas with energy efficient LED lights and ceiling fans. This is resulting in a decrease in 2-3% of electricity consumption on yearly basis (Ministry of Railways, 2017). Another key technology being introduced in the Indian railways is the use of regenerative braking in rail systems, which is known to potentially reduce energy consumption (A. González-Gil *et al.*, 2013), and in the present context it has the potential to reduce up to 500 tons of CO2 on an annual basis (Ministry of Railways, 2016).

Use of alternative fuel

Use of alternative fuel such as biodiesel, bioethanol, liquefied natural gas (LNG) and compressed natural gas (CNG) play a crucial role in reducing the harmful environmental impacts being caused due to the growing use of fossil fuels as they have a lower carbon footprint compared to traditional fossil fuels which are being used for traction purposes (M.A. Hazrat *et al*, 2015). In response to the targets released by the Ministry of Railways towards the use of 5% biodiesel as a fuel for locomotives in India in its 2016-17 railway budget, which also supports the government's intentions presented in the INDC to promote biofuels (UNFCCC, 2015), the Indian railways has already introduced measures aiming at 5% of biodiesel blending with high-speed diesel across various parts of the country (Ministry of Railways, 2018). There is also a plan in the pipeline by the Indian railways to develop LNG locomotives by 2020 which will result in a substitution of 80% high speed diesel with LNG being used for locomotives in India. The use of CNG in locomotives as a dual fuel with diesel is also being promoted within the Indian rail network and the government has already started its use by converting the existing locomotives into dual fuel mode to run passenger trains across the country.

Renewable sources of energy

The Indian railways have released a target of meeting 10% of its energy requirement from renewable sources of energy by 2020 (Ministry of Railways, 2009). Consequently, the government through relevant authorities, are setting up solar rooftop panels on railway buildings and constructing solar power plants which will provide up to 1000 MW of energy which will be used for both traction and non-traction purposes (Ministry of Railways, 2018). Further, the 2015-16 Annual Report released by the Indian Railways lists installation of rooftop solar panels in 200 railways stations as a key target to be achieved by the government within the rail transport sector. In addition to solar power, the Indian railways is also planning to utilize wind energy by setting up windmill power plants which will provide up to 200 MW of energy to meet the growing energy needs of the Indian railways (Ministry of Railways, 2018).

Setting up of the Environment Management Directorate

In a bid to protect the environment and keep a tab on the energy consumption by railways in India, the Ministry of Railways set up an exclusive Directorate for Environment Management in January 2015 which became operational in April 2015. This is a first of its kind effort being initiated at the ministerial level in India. The directorate is responsible for monitoring and ensuring effective consumption and conservation of water and energy resources, along with monitoring pollution control and use of alternative sources of energy within the Indian railways. It is also working on finding ways and means to reduce the use of diesel and other carbon intensive sources of energy, which is one of the primary causes of global warming and climate change. However, according to the information available from the Ministry of Railways, as of October 2017, the work being done by the directorate has mostly been in the field of cleanliness of stations and tree plantation,[2] and concrete efforts towards pollution control and monitoring the use of carbon intensive sources of energy remains to be seen.

Afforestation efforts to increase carbon sink

Afforestation, which in the present context means increase in forest cover and planting of trees on vacant land owned by the Indian railways, is considered by academics and scientists as one of the significant ways to increase carbon sequestration and carbon storage (Whitehead, 2011). Presently, the Indian railways is undertaking initiatives to meet its intended target to plant 50 million saplings/trees by 2019-2020 through massive plantation drives on vacant railway land and alongside railway tracks (Ministry of Railways, 2018). These measures also support the Indian government's climate objectives under the INDC which aim at enhancing carbon sequestration by 100 million tons of CO2 Eq on an annual basis (UNFCCC, 2015).

Other energy conservation initiatives

Studies are being conducted worldwide to recognize the effect of electrification of railways on carbon emissions, which conclude that rail electrification has a positive impact on reducing direct GHG emissions from rail transportation (Jicheng He et al., 2011). In India, to reduce the dependence on high speed diesel which is being used to run rail locomotives, the government is incorporating strategies and undertaking numerous measures to electrify the Indian rail network by 2020, which will assist in reducing GHG emissions at the point of use. But there have also been studies which discuss the overall reduction of carbon emissions due to electrification and state that this electricity which is being used for traction purposes is typically being generated in coal based thermal power plants, which are highly carbon intensive (R. Ramanathan and J.K.

[2] Further details available online at http://www.indianrailways.gov.in/railwayboard/view_section.jsp?lang=0&id=0,1,304,366,1539. Date of access: 25/2/2018

Parikh, 1999). In the Indian context, more than two-thirds of the electricity being used for electric traction is being generated using coal (R. Ramanathan and J.K. Parikh, 1999), which will be discussed further in the section below. This will also throw light on whether or not the measures which have been discussed in this section are *in-fact* assisting the government in reducing harmful CO2 Eq emissions from rail transport in India.

Are low-carbon alternatives *in-fact* reducing GHG emissions from rail transport in India?

There are several green initiatives discussed above which are being undertaken by the Indian government to assist the railways in smoothly moving towards a low-carbon path. But their implementation and monitoring can become a challenge given the magnitude and volume of operations of the Indian railways. To answer the question put forward in this paper, i.e. whether the low-carbon alternatives and initiatives being adopted by the Indian railways are indeed helping the rail transport sector in reducing GHG emissions and thereby assisting in achieving the objectives set up towards mitigating climate change, it is submitted that a study of the current literature revealed a number of issues and barriers which arise and adversely affect rail sector's potential to assist the Indian government in achieving their climate change mitigation objectives. Based on the various available reports and academic articles (for example Rai *et al.*, 2013), these issues are highlighted below:

No law surrounding the use of renewable sources of energy in Indian railways

Though the Indian government has set targets towards the use of renewable sources of energy, absence of laws regulating their consumption and other related aspects is a huge barrier which dampens the effective and efficient utilization of these carbon friendly sources of energy. Having a structured legal setup to stimulate and motivate their usage is much needed, which can also assist the government in achieving their climate change mitigation targets from the Indian rail network.

Track electrification through electricity sourced from carbon intensive sources

To reduce its carbon intensity, the Indian railways is gradually electrifying its rail route network, which is being attributed by the government as an environment friendly initiative resulting in reduced visible pollution levels (Konda *et al.*, 2016). But a majority of electrification of the Indian rail network is being done using electricity from coal based thermal power plants which are highly carbon intensive due to the high ash content in coal (Rai *et al.*, 2013). Therefore, it is important to understand the sources of procuring electricity for electrification of rail network in India, and it is submitted that there needs to be much more rigorous mechanisms and policies to ensure that the electricity for electric traction is being sourced from carbon friendly sources.

Lack of standards for emission control for diesel locomotives

Absence of emission standards for rail locomotives, whose primary fuel is diesel, which is high in emissions and low on energy efficiency (Ramachandra and Shwetmala, 2009), escalates the problem of rising carbon emissions from rail transport in India. In its *Vision and Roadmap 2012*, the Indian Railways Organisation for Alternate Fuels, which is a part of the Ministry of Railways, has clearly confirmed the lack of emission standards from diesel locomotives, which requires immediate attention to set-up and implement mechanisms to regulate and monitor them.

Conclusion

India's rail transport sector is a growing contributor to the country's carbon emissions. Realizing emissions reduction from this sector must therefore be a part of the response from Indian government to reduce harmful CO2 Eq emissions. Setting up and implementation of green initiatives, such as the use of renewables to meet up to 10% of rail energy and use of clean and alternative sources of energy to meet energy demands for traction and non-traction activities, are a central part of India's response to climate change mitigation from rail transport. However, as mentioned in the preceding section, this paper submits that these measures are in fact not really supplementing the government's efforts to reduce GHG emissions from railways in India. This clearly exhibits an urgent need to intensify focus of relevant governmental authorities towards implementing prominent and substantial measures to control/reduce the release of harmful carbon emissions from rail transport in India, which presently has very limited attention of policy makers mainly due to the constant focus on regulating emissions from motorized means of road travel in India. The lack of focus on rail transport is validated by absence of GHG emissions standards from locomotives and dearth of stringent laws regulating the release of GHG emissions from rail infrastructure, which is accompanied by lack of awareness amongst policymakers to reduce GHG emissions and implement carbon reduction measures across rail network in India. These also suppress the potential for climate change mitigation from the Indian rail transport sector. But undertaking certain actions can address this problem, and some of these which are relevant to present paper are:

- Setting up fixed-step timely targets towards the use of energy from renewable sources in Indian railways.
- Drafting an act/statute which can direct the use of alternative fuels in the Indian rail transport sector.
- Aggressively restraining the use of coal for power generation, which is currently being used to fuel electrification of railways in India.
- Setting-up standards for emission control for diesel locomotives which are at present being used in large numbers to run the Indian rail network.

Implementing these measures is not easy and will not come cheap. They will also require regular and efficient monitoring, along with levy of penalties/sanctions for any act of non-compliance by the relevant authority/party. But the benefits associated with them are many, which can assist in lowering down the costs currently being incurred by the government to source fossil fuels for running the Indian rail network, along with reducing the levels of air pollution and improving the livability for future generations.

References

Chakrabarty, R. and Chakraborty, S. (2017) 'COP21 and India' Intended Nationally Determined Contribution Mitigation Strategy' in Hossain, M., Hales, R. and Sarker, T. (eds.) *Pathways to a Sustainable Economy: Bridging the Gap between Paris Climate Change Commitments and Net Zero Emissions*. Springer, pp. 149-166.

González-Gil, A., Palacin, R., and Batty, P. (2013) 'Sustainable urban rail systems: Strategies and technologies for optimal management of regenerative braking energy', *Energy Conservation and Management*, 75, pp. 374-388.

Hazrat, M.A., Rasul, M.G., and Khan, M.M.K. (2015) 'Biofuel: An Australian perspective in abating the fossil fuel vulnerability', *Procedia Engineering*, 105, pp. 628-637.

He, J. and Xu, Y. (2011) 'Energy Saving and Emission Reduction Estimations of Electrified Railways in China', *Advances in Climate Change Research*, 2(4), pp. 211-217.

India's Intended Nationally Determined Contribution. Available from: http://www4.unfccc.int/ndcregistry/PublishedDocuments/India%20First/INDIA%20INDC%20TO%20UNFCCC.pdf [Accessed 7th March 2018].

India, Ministry of Environment and Forests (2010) India: Greenhouse Gas Emissions 2007.

India, Ministry of Railways (2012) Vision and Roadmap 2012.

India, Ministry of Railways (2017) Environmental Sustainability-Role of Indian Railways: Annual Report 2015-16.

India, Ministry of Railways (2018) Towards a low carbon mass transportation system, Environmental Sustainability: Annual Report 2016-17.

Konda, C., Trivedi, S., and Shrimali, G. (March 2017) 'Decarbonization of Indian Railways', The New Climate Economy Working Paper.

Rai, V.K., Raman, N.S. and Choudhary, S.K. (2013) 'Thermal power plants: Policy framework for CO2 emissions reduction', *International Journal of Engineering Research and Science & Technology*, 2(2), pp. 82-88.

Ramachandra, T.V. and Shwetmala (2009) 'Emissions from India's transport sector: Statewise synthesis', *Atmospheric Environment*, 43(34), pp. 5510-5517.

Ramanathan, R. and J.K. Parikh (1999) 'Transport sector in India: an analysis in the context of sustainable development', *Transport Policy*, 6(1), pp. 35-45.

Thaker, J. and Leiserowitz, A. (2014) 'Shifting discourses of climate change in India', *Climate Change*, 123 (2), pp. 107-119.

Whitehead, D. (2011) 'Forests as carbon sinks – benefits and consequences', *Tree Physiology*, 31(9), pp. 893-902.