



UNIVERSITI PUTRA MALAYSIA

***CLIMATE CHANGE AND ITS IMPACT ON REFERENCE
EVAPOTRANSPIRATION AT RASHT CITY, IRAN***

HEERBOD JAHANBANI

FK 2011 44

**CLIMATE CHANGE AND ITS IMPACT ON REFERENCE
EVAPOTRANSPIRATION AT RASHT CITY, IRAN**

By

HEERBOD JAHANBANI

**Thesis Submitted to the School of Graduate Studies, University Putra Malaysia, in
Fulfilment of the Requirement for the Degree of Master of Science**

February 2011

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

**CLIMATE CHANGE AND ITS IMPACT ON REFERENCE
EVAPOTRANSPIRATION AT RASHT CITY, IRAN**

By

HEERBOD JAHANBANI

February 2011

Chairman: Professor Ir. Lee Teang Shui, PhD

Faculty: Engineering

There are various factors of uncertainty regarding the impact of climate change on reference evapotranspiration (ET_0). The accuracy of the results is strictly related to these factors and ignoring each of them reduces the precision of the results, thereby affecting their applications. In this study, the uncertainty related to two methods of calculating ET_0 , the Hargreaves-Samani (HGS) and Artificial Neural Network (ANN); the climate change models: Atmosphere-Ocean General Circulation Model (AOGCM); and downscaling method under the climate change scenario (A2) for the period 2010 to 2039 was evaluated. Meteorological data for the Rasht station located in the northern part of Iran collected for 1961-1990 was used to evaluate the climatic data and calculate ET_0 . Since there were no lysimeter installed in the area, the FAO Penman-Monteith (PM, 1998) method was adopted as the reference ET_0 method and the ET_0 of the period (1961-

1990) produced by HGS and ANN methods was evaluated using performance functions including mean absolute error (MAE) and regression coefficient (R^2). Next, the Hadley Centre Coupled Model, version 3 (HadCM3) climatic model and the Canadian Global Climate Model, version 3 (CGCM3) climatic model and the Statistical Downscaling Model (SDSM) were applied to generate maximum and minimum temperatures for use in simulating ET_o using the HGS and ANN methods for 2010 to 2039. Results obtained showed average temperature increases of $0.95\text{ }^\circ\text{C}$ with the HadCM3 model and average temperature increases of $1.13\text{ }^\circ\text{C}$ with the CGCM3 model, relative to observed temperatures for 2010 to 2039. Accordingly, the predictions showed average increases of ET_o ranging from 0.48 to 0.6 (mm/day) for the period of 2010 to 2039. The study also revealed that uncertainty with the AOGCMs is more than the ET_o models applied in this study.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

**PERUBAHAN IKLIM DAN HENTAMANNYA TERHADAP
PENYEJATPELUHAN RUJUKAN DI BANDAR RASHT, IRAN**

Oleh

HEERBOD JAHANBANI

February 2011

Pengerusi: Prof. Lee Teang Shui, PhD

Fakulti: Kejuruteraan

Terdapat berbagai faktor ketidakpastian mengenai hentaman perubahan iklim keatas penyejatpeluhan rujukan (ET_0). Kejituan keputusan amat berkait-hubung dengan faktor faktor dan sekiranya tidak ambilkira setiap faktor akan mengurangkan kepersisan keputusan, namun akan menjejaskan kegunaan. Dalam kajian ini, ketidakpastian berkaitan dengan dua kaedah untuk menghitung ET_0 , Hargreaves-Samani (HGS) dan Rangkaian Saraf Buatan (ANN); model model perubahan iklim: Model Pengeliling Umum Atmosfera-Lautan (AOGCM); dan kaedah kurangsaiz bersenario perubahan iklim (A2) bagi jangkamasa 2010 ke 2039 telah dinilai. Data meterologi untuk stesyen Rasht terletak di bahagian utara Iran dikumpulkan bagi 1961 – 1990 telah diguna demi menilaikan data iklim dan menghitung ET_0 . Memandangkan bahawa laisimeter tidak dipasang di situ, maka kaedah FAO Penman-Monteith (PM, 1998) telah digunakan

sebagai kaedah ET_o rujukan dan ET_o bagi jangkamasa (1961 – 1990) dihasilkan dengan kaedah kaedah HGS dan ANN dinilai dengan fungsi fungsi prestasi termasuk ralat mutlak purata (MAE) dan pekali regresi (R^2). Kemudian, Model iklim Coupled Hadley Centre Versi 3 (HAdCM3) dan model iklim global Canada versi 3 (CGCM3) dan model Statistik Kurangsaiz (SDSM) diguna untuk menjana suhu maksima dan minima untuk dipakai demi mensimulasikan ET_o dengan kaedah kaedah HGS dan ANN bagi 2010 ke 2039. Keputusan yang dihasilkan menunjuk bahawa tambahan suhu purata sebanyak 0.95 °C dengan model HadCM3 dan 1.13 °C dengan model CGCM3, bernisbi ke suhu ditinjaukan bagi 2010 ke 2039. Namun begitu ramalan menunjukkan tambahan ET_o purata sebanyak 0.48 ke 0.6 (mm/hari) daripada 2010 sehingga 2039. Kajian ini juga menunjukkan bahawa ketidakpastian berkaitan dengan model model AOGCM lebih bererti dibandingkan model model ET_o yang digunakan dalam kajian ini.

ACKNOWLEDGEMENTS

First and foremost, I would like to express my gratitude to the GOD for helping me to complete this thesis.

It has been an honour and pleasure to have Professor Lee Teang Shui as main supervisor. I am grateful to him for the time given to me to make this requirement, for his valued suggestions and encourages.

I would like to express my deepest thanks and admiration to my other committee members Professor Abdul Halim Ghazali and Dr. Alireza Massha Bavani for their valued helps, discussion and comments on this work.

My wife was so patient with my late nights, and I want to thank her for her faithful support in writing this research.

I would like to thank my father, mother and brother for supporting me to complete this research.

I certify that a Thesis Examination Committee has met on (February 2011) to conduct the final examination of Heerbod Jahanbani on his thesis entitled “Climate Change and its impact on Reference Evapotranspiration at Rasht City, Iran” in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

Members of the Thesis Examination Committee were as follows:

Ir. Salihudin b. Hassim, PhD

Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Ir. Wan Nor Azmin Sulaiman, PhD

Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Thamer Ahmed Mohamed, PhD

Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Salim bin Said, PhD

Professor
Faculty of Engineering
Universiti Malaysia Serawak
(External Examiner)

BUJANG KIM HUAT, PhD

Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 24 March 2011

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

Lee Teang Shui, PhD

Professor
Engineering
University Putra Malaysia
(Chairman)

Abdul Halim Ghazali, PhD

Associate Professor
Engineering
University Putra Malaysia
(Member)

Alireza Massha Bavani, PhD

Associate Professor
Engineering
University of Tehran
(Member)

Huang Yuk Feng, PhD

Lecturer
Engineering
University Putra Malaysia
(Member)

HASANAH MOHD GHAZALI, PhD

Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institutions.



HEERBOD JAHANBANI

Date: 7 February 2011

TABLE OF CONTENTS

	Page
ABSTRACT	ii
ABSTRAK	iv
ACKNOWLEDGEMENTS	vi
APPROVAL	vii
DECLARATION	ix
LIST OF TABLES	xiii
LIST OF FIGURES	xiv
LIST OF ABBREVIATIONS	xvi
CHAPTER	
1 INTRODUCTION	1
1.1 General	1
1.2 Global climate change considerations	5
1.3 An example of impact of climate changes	5
1.4 Problem statement	6
1.5 Objective	7
1.6 Scope of work	7
2 LITERATURE REVIEW	8
2.1 Introduction	8
2.2 Definition of climate change	8
2.3 Climatic and Non-climatic Scenarios	10
2.3.1 Non-climatic Scenarios	10
2.3.2 Climatic scenarios	13
2.3.2.1 AOGCM models	14
2.3.2.2 Simulating climatic parameters using AOGCM	15
2.3.2.3 Climate change models in use world wide	16
2.4 Downscaling	17
2.4.1 Using main cell data	18
2.4.2 Interpolating adjacent cells	19
2.4.3 Proportional downscaling method	20

2.4.4	Statistical Downscaling (SD) Methods	21
2.4.4.1	Regression methods	21
2.4.4.2	Weather Typing Schemes	22
2.4.4.3	Stochastic weather generator	23
2.4.5	Dynamic downscaling methods	23
2.5	Crop water requirements	24
2.6	Determining crop water requirement	27
2.6.1	Energy balance and microclimatological methods	27
2.6.2	Soil water balance	28
2.6.3	Lysimeter	29
2.6.4	ET computed from meteorological data (Indirect method)	31
2.6.5	ET estimated from pan evaporation	31
2.7	Overview of the MATLAB environment	32
2.8	Review of the world's climate change studies	33
2.8.1	Impact of climate change on the temperature and precipitation	33
2.8.2	Impact of climate change on irrigation requirement	39
2.8.3	Impact of climate change on evapotranspiration	43
2.9	Impact of climate change on Iran	45
2.9.1	Impact of climate change on meteorological parameters of Iran	45
2.9.2	Impact of climate change on water requirement of Iran	49
2.10	Summary of literature review	50
3	RESEARCH METHODOLOGY	52
3.1	Introduction	52
3.2	Study area	54
3.3	Research materials	58
3.4	AOGCM models	59
3.5	Downscaling tools	60
3.5.1	Regression analysis	60
3.5.2	Statistical downscaling model (SDSM)	62
3.5.3	Structure of SDSM for calibration and downscaling	62
3.6	ET _o computed from meteorological data (Indirect method)	67
3.7	Calculating ET _o using ET _o Calculator (version 3.1 January 2009)	68
3.8	Modeling ET _o of future periods using ANN	69

3.8.1	Artificial Neural Network (ANN) model	71
3.8.2	Modelling ANN in MATLAB	73
3.9	Performance functions	78
3.10	Developing ANN for predicting ET_o	78
3.11	Evaluating ANN and HGS models	81
4	RESULTS AND DISCUSSION	82
4.1	Metrological data for calculating ET_o	82
4.2	Calculating ET_o using PM methods (1961-1990)	84
4.3	Estimating ET_o using ANN and comparing to ET_o of PM method for the period of 1961-1990	85
4.4	Calculating ET_o using HGS method and comparing to ET_o of PM method for the period of 1961 to 1990	92
4.5	Calibrating SDSM model	93
4.5.1	Selecting the appropriate predictor	94
4.5.2	Evaluating observed and modelled statistical parameters	94
4.5.3	Time series analysis of observed and modelled temperature	95
4.5.4	Frequency analysis of observed and modelled temperature	97
4.6	Generating future temperature using SDSM model	98
4.6.1	Changes of monthly temperature	98
4.6.2	Time series analysis of temperature	100
4.7	Predicting futuristic ET_o	103
4.8	Uncertainty analysis of ET_o	110
5	SUMMARY, CONCLUSION AND RECOMMENDATIONS	116
5.1	Summary and conclusion	116
5.2	Recommendations for future studies	119
	REFERENCES	121
	APPENDIX	130
	BIODATA OF STUDENT	137