RESERVOIR SYSTEM MODELLING USING NONDOMINATED SORTING GENETIC ALGORITHM IN THE FRAMEWORK OF CLIMATE CHANGE

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ABSTRAK

Sistem takungan memerlukan pembangunan model yang berterusan untuk mendapatkan operasi yang optima dalam konteks perubahan iklim pada masa akan datang. Statistik bagi variasi perubahan iklim dan percambahan kaedah evolusi telah mendorong pembangunan sistem operasi takungan mampan dan jangka panjang. Matlamat kajian ini ialah untuk membentuk dan merumuskan satu sistem operasi dan pengurusan takungan jangka panjang yang mampan bersesuaian dengan perubahan iklim menggunakan model yang bersepadu. Model ini terdiri daripada kaedah Tidak Dominasi Pengisihan Algoritma Genetik jenis II (NSGA-II), Pengaturcaraan Linear (LP), model Penurunan Skala Statistik (SDSM) dengan Kepelbagaian Linear Kolerasi Matrik (M-CM), model hidrologi dan model tanaman. Terdapat dua kumpulan model dicadangkan dikenali sebagai Model A dan Model B. Model A adalah gabungan kaedah NSGA-II dengan M-CM, model hidrologi dan model tanaman yang mengambilkira variasi iklim. Manakala, Model B pula tidak mengambilkira faktor perubahan iklim dengan menggunakan kaedah Valencia Schaake (VS) dan kaedah Thomas Fiering (TF). Kebolehpercayaan, keanjalan, dan kelemahan model tersebut telah dinilai. Model-model ini telah diaplikasikan keatas sistem takungan Pedu-Muda yang berfungsi membekalkan air untuk tujuan pertanian bagi Rancangan Pengairan Muda, Kedah, Malaysia. Kemasukkan M-CM sebagai alat penyaringan di dalam model SDSM adalah berjaya menghasilkan nilai yang rendah dalam purata ralat mutlak (MAE = 4mm/hari), purata ralat kuasa dua (MSE = 29mm/hari), and sisihan piawai (St.D = 1mm/hari). Dijangkakan hujan dan suhu masa depan akan meningkat sebanyak 4% dan 0.2^{o}C pada setiap dekad. Keperluan isipadu air untuk penanaman padi dijangka akan menurun sebanyak 0.9 % setiap dekad. Ini kerana peningkatan kuantiti hujan dan air larian tidak terkawal ke bendang. Aliran masuk sintetik yang dijana menggunakan model VS dan TF menghasilkan perbezaan sebanyak +0.4% dan -1.3% daripada rekod sejarah. Model NSGA-II dan LP juga telah berjaya membentuk sistem operasi takungan yang mampan bagi jangka masa panjang. Tambahan lagi, model NSGA-II telah berjaya memenuhi kepelbagaian permintaan dalam objektif dan menyediakan satu set penyelesaian alternatif dalam bentuk lengkung Pareto optima dengan mengambilkira corak iklim. Pembentukan corak lengkung operasi bagi Model A adalah lebih tinggi secara konsisten daripada Model B dengan julat 1% hingga 5%. Penilaian kebolehpercayaan, keanjalan, dan kelemahan menunjukkan kaedah Model A-NSGA-II adalah baik dan berpotensi untuk dijadikan sebagai panduan operasi bagi bekalan air yang mencukupi sepanjang tahun. Model B (VS) adalah model kedua terbaik diikuti Model B (TF). Kesimpulannya, penemuan ini menyumbang kepada pembangunan model dengan menggunakan evolusi algoritma dan kaedah statistik bagi merancang dan mengurus sumber air secara mampan dalam konteks perubahan iklim masa hadapan.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

P, r_k	-	quantity of rainfall (mm)
t_k	-	Temperature reading (^{0}C)
Cov	-	covariance
N	-	number of variable / population
$\overline{xy}$	-	mean variables
s_x	-	standard deviation for *x*
s_y	-	standard deviation for *y*
S_k	-	soil moisture index
r_{xy}	-	correlation matrix
u_k , P_e, P_{eff}	-	effective rainfall (mm)
τ_w	-	Catchment drying time constant
R	-	reference temperature (^{0}C)
C	-	proportion of rainfall
f	-	temperature modulation factors
x_k	-	streamflow (MCM)
D	-	Determination coefficient
Y_t	-	Seasonal flow (MCM/month)
Q_t	-	Annual flow (MCM/year)
I_t	-	value of random deviate
W_{irr}	-	irrigation water requirement
W_{lp}	-	water required for land preparation
W_{ps}	-	persolation and seepage losses
W_t	-	water required to establish standing water layer
K_c	-	crop coefficient

e_s	-	saturation of water vapour
e_a	-	actual water vapour
Δ	-	slope
u_2	-	wind speed
G	-	soil heat flux density
γ	-	psychrometric constant
R_n	-	radiation
R_t	-	Water release
S_t	-	reservoir storage
D_t	-	Water demand
I_t	-	water inflow
Sp_t	-	water spill
S_{muda}	-	water storage in the Muda reservoir
Eva_t	-	Evaporation
See_t	-	Evaporation

LIST OF ABBREVIATIONS

MADA	-	Muda Agriculture Development Authority
NSGA	-	Nondominated sorting genetic algorithm
LP	-	Linear Programming
NLP	-	Non-linear Programming
TF	-	Thomas Fiering
GCM	-	General circulation model
RCM	-	Regional Climate Model
NCEP	-	National Centers for Environmental Prediction
SWG	-	Stochastic Weather Generator
WT	-	Weather Typing
DP	-	Dynamical programming
SD	-	Statistical Downscaling
CLS	-	Classical Least Square
MLR	-	Multiple Linear Relationship
AR	-	Autoregression
ARMA	-	Autoregression Moving Average
CWR	-	Crop Water Requirement
CWD	-	Crop Water Demand
ET	-	Evapotranspiration
ETc	-	Evapotranspiration of crop
MOEA	-	Multi-objective evolutionary algorithm
MSL	-	Mean sea level
KOD	-	Kodiang
JIT	-	Jitra
LTP	-	Ladang Tanjung Pauh

KN	-	Kuala Nerang
AP	-	Ampang Pedu
GM	-	Gajah Mati
TC	-	Teluk Chengai
KT	-	Keretapi Tokai
KS	-	Kuala Sala
Kg.LB	-	Kampung Lubuk Badak
LH	-	Ladang Henrietta
SL	-	Sungai Limau
KP	-	Kedah Peak
SG	-	Sungai Gurun
SIK	-	Sik
Kg.LS	-	Kampung Lubuk Segintah
PEN	-	Pendang
IBT	-	Ibu Bekalan Tupah
KSS	-	Kota Sarang Semut
Kg.T	-	Kampung Terabak
mlsp	-	mean sea level pressure
p_f	-	surface airflow strength
p_u	-	surface zonal velocity
p_v	-	surface meridional velocity
p_z	-	surface vorticity
p_th	-	surface wind direction
p_zh	-	surface divergence
p5_f	-	500hpa airflow strength
p5_u	-	500hpa zonal velocity
p5_v	-	500hpa meridional velocity
p5_z	-	500hpa vorticity
p500	-	500hpa geopotential height
p5th	-	500hpa wind direction
p5zh	-	500hpa divergence
p8_f	-	850hpa airflow strength
p8_u	-	850hpa zonal velocity

p8_v	-	850hpa meridional velocity
p8_z	-	850hpa vorticity
p850	-	850hpa geopotential height
p8th	-	850hpa wind direction
p8zh	-	850hpa divergence
r500	-	relative humidity at 500hpa
r850	-	relative humidity at 850hpa
rhum	-	near surface relative humidity
shum	-	surface specific humidity
temp	-	mean temperature
MCM	-	$x10^6$ cubic meter
MAE	-	Mean absolute error
MSE	-	Mean square error
StD	-	Standard deviation
N-E	-	North-East monsoon
S-W	-	South-West monsoon
M-CM	-	multi-correlation matrix
ARPE	-	Average Relative Parameter Error (%)

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Introduction and Background

Global climate change is a pressing issue that needs an aggressive attention and action from the global authorities. Karl *et al*. (2009) classified the climate warm as unequivocal and had become greater than over the last century. Increment of the greenhouse gases emission such as carbon dioxide, methane, nitrous oxide, sulphur hexafluoride, CFC, and water vapor into the atmosphere could ruin the earth's life year by year. A major contaminant is carbon dioxide (CO_2) that comes from human activities such as burning of fossil fuel, clearing forest, animal husbandry and agricultural practices at least 5 times greater than natural effects from the sunrise. A report by United States Environmental Protection Agency (EPA) stated that the electricity is the largest single source of CO_2 in range 38 % followed by transportation (31 %), industry (14 %), residential & commercial (10 %) and others (6 %) during year 1990 to 2011. This is supported by a report from National Oceanic and Atmospheric Administration (NOAA) which stated that the increment of monthly CO_2 achieved 395 ppm in August 2013, 45 ppm higher than CO_2 safety limit while an annual reading of year 2012 is 394 ppm (+0.6 % than year 2011).

Intergovernmental Panel on Climate Change AR4 (IPCC, 2007) reported that the global average surface temperature for the past 100 years had increased from 0.6 ^{o}C (1901 - 2000) to 0.74 ^{o}C (1906 - 2005). The World Meteorological Organization (WMO) claimed that the year of 2010 is the warmest year achieved with temperature of 1.2 ^{o}C to 1.4 ^{o}C especially in Africa, parts of Asia and parts of the Arctic.