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CONTENTS

Prolegomena..... xxi

Preface..... xxiii

Invited Lectures

NONSTATIONARITY OF HYDROLOGICAL RECORDS AND RECENT TRENDS IN TREND ANALYSIS: A STATE-OF-THE-ART REVIEW
Mehmetcik BAYAZIT…… *3*

RIVER BASIN MANAGEMENT: WHAT DO WE REALLY WANT?
Kurt FEDRA…… *5*

QUANTIFYING SYSTEM SUSTAINABILITY IN WATER RESOURCES MANAGEMENT VS. QUALITATIVE DEFINITION OF THAT TERM
Janusz KINDLER…… *7*

WATER WORKS OF FOUR MILLENIA IN TURKEY
Ünal ÖZİŞ…… *9*

MANAGING WATER RESOURCES UNDER GLOBAL CHANGE: METHODS AND TOOLS FOR A SYSTEMS APPROACH
Slobodan P. SIMONOVIC……*11*

ENTROPY THEORY FOR STREAMFLOW FORECASTING
Vijay P. SINGH & Huijuan CUI…… *15*

SOCIAL RESPONSES TO WATER MANAGEMENT DECISIONS
Warren E. WALKER, Daniel P. LOUCKS, Gemma CARR…… *17*

THE STATUS OF THE EUROPEAN WATERS IN 2015: A REVIEW
George TSAKIRIS…… *19*

Abstracts

Conference I: Hydrological Processes and Evolving Hazards

METEOROLOGICAL DROUGHT FREQUENCY ANALYSIS BASED ON THE COPULAS APPROACH
George TSAKIRIS, Nikos KORDALIS, Dimitris TIGKAS & Harris VANGELIS…….. *25*

FORECASTING OF DAILY REFERENCE EVAPOTRANSPIRATION FROM LIMITED DATA USING SIMPLE REGRESSION ON SIMPLIFIED FORMULAS OF PENMAN'S EQUATION
John D. VALIANTZAS…… *27*

CHANGES IN SNOWMELT RUNOFF FOR MOUNTAIN REGIONS OF EASTERN ANATOLIA TURKEY
Ismail YUCEL, Abdulkadir GUVENTURK & Omer L. SEN…….. *29*

ANN, DECISION TREE AND REGRESSION METHODS FOR FORECASTING MONTHLY LAGGED LAKE WATER LEVEL
Babak VAHEDDOOST, Hafzullah AKSOY, Hirad ABGHARI & Saieed ZARE NAGHADEH…….. *31*

DERIVATION OF CRITICAL RAINFALL THRESHOLDS FOR SHALLOW LANDSLIDES: AN APPLICATION TO SICILY
Domenico CARACCIOLO, Elisa ARNONE & Leonardo V. NOTO……... *33*

PERFORMANCE-WEIGHTED METHODS FOR ESTIMATING MONTHLY STREAMFLOW: AN APPLICATION FOR MIDDLE EUPHRATES BASIN
Mustafa Utku YILMAZ & Bihrat ONOZ…… *35*

FLOOD SCENARIOS DETERMINATION USING NON-STATIONARY FLOOD FREQUENCY ANALYSIS IN COASTAL AREAS
Mohammad KARAMOUZ, Forough AHMADVAND & Mohammad FERESHTEHPOUR…….. *37*

COMPUTATION OF SEDIMENT GRAPHS IN EVROS RIVER BASIN
Kyriakos VAVALOS, Vasileios KITSIKOUDIS & Vlassios HRISSANTHOU.... *39*

AN ESTIMATION OF THE SUSPENDED SEDIMENT LOAD USING SUPPORT VECTOR MACHINE AND ARTIFICIAL NEURAL NETWORK MODELS
Meral BUYUKYILDIZ & Yurdagul KUMCU…….. *41*

SPI AND DROUGHT ASSESSMENT UNDER LONG-TERM PRECIPITATION VARIABILITY
Ana PAULO, Diogo MARTINS, Elsa MOREIRA & Luís Santos PEREIRA…….. 43

APPLICATION OF THE SPI TO THE DROUGHT ANALYSIS IN SLOVAKIA. DROUGHT REGIONALIZATION AND EMPORAL EVOLUTION OF THE DROUGHT AREA
Maria Manuela PORTELA, Martina ZELEŇÁKOVÁ, João Filipe SANTOS, Pavol PURCZ, Artur Tiago SILVA & Helena HLAVATÁ..... 45

ANALYSIS OF BASIN DROUGHT FOR THE GEDIZ RIVER
Aslı ULKE & Alyar Boustani HEZARANI…….... 47

PRECIPITATION TREND DETECTION FOR SLOVAKIA
Martina ZELEŇÁKOVÁ, Maria Manuela PORTELA, Pavol PURCZ, Artur Tiago SILVA, Helena HLAVATÁ & João Filipe SANTOS..... 49

RIVER FLOW ROUTING IN PRISMATIC TRAPEZOIDAL GEOMETRY BY AN ADAPTIVE TIME DELAY METHOD
Long Duc NGUYEN, Divas KARIMANZIRA, Thomas RAUSCHENBACH, & Lars RIBBE…….. 51

FLASH FLOOD SIMULATION IN SMALL CATCHMENTS BASED ON COMBINED HYDRODYNAMIC AND HYDROLOGIC APPROACH
George TSAKIRIS & Vasilis BELLOS…….. 53

INVESTIGATION OF METEOROLOGICAL INDICATORS AND NORTH ATLANTIC OSCILLATION VARIABILITY ON THE EGIRDIR LAKE LEVELS IN TURKEY
Mustafa DOGAN & Aysegul OZGENC AKSOY…….. 55

ANALYSIS OF FLOOD AND DROUGHT CHARACTERISTICS OF ÇORUH RIVER BASIN
Ezgi Guzey DIKER,Ahmet BUYUKSARGUT,Yagmur NAMLI&Bihrat ONOZ.. 57

TESTING THE GOODNESS OF FIT BY INFORMATIONAL ENTROPY
T. BARAN & F. BARBAROS…… 59

COMPARISON OF LINEAR REGRESSION, NON LINEAR REGRESSION AND ARTIFICIAL NEURAL NETWORK MODEL FOR DOWNSCALING OF RAINFALL AT SUBANSIRI RIVER BASIN, ASSAM, INDIA.
Swapnali BARMAN & R.K. BHATTACHARJYA…….. 61

TRENDS OF REFERENCE EVAPOTRANSPIRATION OVER GREECE IN A FUTURE CLIMATE
Gianna KITSARA Georgia PAPAIOANNOU, Eirini ZYGOURA, Christos GIANNAKOPOULOS & Petros KERKIDES…… 63

EVAPORATION AND CROP EVAPOTRANSPIRATION ESTIMATES OVER THESSALY PLAIN, GREECE, BASED ON REGIONAL CLIMATE MODELS' SIMULATIONS
S. KOTSOPOULOS , P. NASTOS, S. POULOS, I. ALEXIOU, J. KAPSOMENAKIS, …….. 65

ESTIMATING TEMPORAL CHANGES IN EXTREME RAINFALL IN SICILY REGION
Brunella BONACCORSO & Giuseppe Tito ARONICA…….. 67

TIME SERIES BEHAVIOURAL ANALYSIS OF OCEAN WIND SPEED – A CHAOTIC APPROACH
Vinayakam JOTHIPRAKASH & Krishna DHANYA…… 69

A PROBABILISTIC APPROACH TO ASSESS THE STANDARDIZED PRECIPITATION INDEX IN A REGION OF SOUTHERN ITALY
Gabriele BUTTAFUOCO & Tommaso CALOIERO…… 71

SPATIALLY DISTRIBUTED RECHARGE IN KARST GROUNDWATER MODELING
Konstantina KAVOURI & George P. KARATZAS…….. 73

MODELING AND COMPARISON OF WATER WAVES CAUSED BY LANDSLIDES INTO RESERVOIRS
Vafa KHOOLOSI & Sedat KABDASLI…….. 75

HYDROLOGICAL AND MECHANICAL EFFECTS OF ROOTS IN SHALLOW LANDSLIDE ANALYSIS: A PHYSICALLY-BASED APPROACH
Elisa ARNONE, Domenico CARACCIOLO, Leonardo V. NOTO, Federico PRETI & Rafael L. BRAS …….. 77

FLOOD DAMAGE RISK ASSESSMENT OPTIMIZING A FLOOD MITIGATION SYSTEM
Sara FRONGIA, Saverio LIBERATORE & Giovanni M. SECH..... 79

THE GLOBAL OPTIMISATION APPROACH FOR CALIBRATING HYDROLOGICAL MODELS: THE CASE OF MEDBASIN-D MODEL
Dimitris TIGKAS, Vasileios CHRISTELIS & George TSAKIRIS …… 81

COMPARISON OF MONTHLY STREAMFLOW FORECASTING TECHNIQUES
Meral BUYUKYILDIZ & Chelang A. ARSLAN…….. 83

FLOODING RISK ASSESSMENT IN MOUNTAIN RIVERS
Mike G. SPILIOTIS & Constantine V. BELLOS……..…. 85

OPTIMIZATION OF HEDGING RULES FOR RESERVOIR OPERATION DURING DROUGHTS BASED ON PARTICLE SWARM OPTIMIZATION
Mike SPILIOTIS, Luis MEDIERO & Luis GARROTE……..…..... 87

SIMULATION OF SEA WATER LEVEL VARIATIONS USING DATA DRIVEN MODELS: A CASE STUDY OF NEW YORK BAY
Mohammad KARAMOUZ, Zahra ZAHMATKESH & Mohammad Ali OLYAEI 89

IMPACT OF LAND USE AND CLIMATE CHANGE ON HYDROLOGICAL PROCESSES: AN INTEGRATED MODELING APPROACH
Danielle MARCEAU, Babak FARJAD, Nishad WIJESEKARA, Majeed POOYANDEH, & Anil GUPTA ……..…… 91

MODELLING THE WATER AND NITRATE BUDGET USING SWAT
Mehmet Ali AKGÜL, Suha BERBEROGLU, Mahmut CETIN, Hayriye İBRİKÇİ, Takanori NAGANO, Jumpei KUBOTA & Manfred FINK……..…… 93

DISAGGREGATION MODELLING OF DAILY STREAMFLOWS USING A NEW APPROACH OF THE METHOD OF FRAGMENTS
Maria Manuela PORTELA & Artur Tiago SILVA..... 95

HYDROLOGICAL PROCESSES UNDER SCENARIOS OF LAND-USE/COVER AND CLIMATE CHANGE
Babak FARJAD, Anil GUPTA & Danielle MARCEAU…….. 97

INTEGRATED MODELING APPROACH TO STUDY THE IMPACT OF RESERVOIRS IN THE WATERSHED: THE CASE STUDY OF THE SORRAIA RIVER BASIN
Carina ALMEIDA, João SOBRINHO, Eduardo JAUCH, & Ramiro NEVES… 99

PUMPING OPTIMIZATION OF COASTAL AQUIFERS USING RADIAL BASIS FUNCTION METAMODELS
V. CHRISTELIS & A. MANTOGLOU……..……101

VARIATION OF TOTAL SUSPENDED SOLIDS VERSUS NEPHELOMETRIC TURBIDITY IN THE STREAM DEĞIRMENDERE, SOUTHEASTERN BLACK SEA
Ugur SATILMIS & Adem BAYRAM…… 103

DOWNSCALING MONSOON RAINFALL OVER RIVER GODAVARI UNDER DIFFERENT SCENARIOS
Jew DAS & Umamahesh V. NANDURI…….. 105

RECONSIDERATION OF SEDIMENT INCIPIENT MOTION CRITERION: A FUZZY SET APPROACH
Vasileios KITSIKOUDIS, Mike SPILIOTIS & Vlassios HRISSANTHOU….. 107

HYDROLOGIC MODELLING CALIBRATION FOR OPERATIONAL FLOOD FORECASTING
Juliana MENDES & Rodrigo MAIA..... 109

EXPLORING THE POTENTIAL AND THE BOUNDARIES OF THE ROLLING HORIZON APPROACH FOR RESERVOIR MANAGEMENT
Claudio ARENA, Marcella CANNAROZZO & Mario Rosario MAZZOLA..... 111

RAINFALL-RUNOFF MODEL CONSIDERING MICROTOPOGRAPHY SIMULATED IN A LABORATORY EROSION FLUME
Hafzullah AKSOY, Abdullah GEDIKLI, N. Erdem UNAL, Ebru ERIS, Jaeyoung YOON, Murat YILMAZ & Gokmen TAYFUR…… 113

STUDY OF FINAL SCOUR DEPTHS AROUND CIRCULAR BRIDGE PIERS IN CLEAR WATER CONDITIONS
Fırat GUMGUM, Aysegul O. AKSOY & M. Sukru GUNEY…… 115

NUMERICAL SIMULATION OF FLOOD WAVE SPREADING IN 2D IN DENSELY POPULATED URBAN AREAS DUE TO DAM BREAK
Sebnem ELCI, Gokmen TAYFUR & Ismail HALTAS…….. 117

SIMULATION OF GROUNDWATER FLOW IN THE GEDIZ RIVER BASIN
Alper ELÇI, Celalettin SIMSEK, Orhan GUNDUZ, Alper BABA, Sezen ACINAN, Nilgün YILDIZER & Alim MURATHAN…… 119

DEVELOPMENT AND APPLICATION OF A WATER LEVEL ZONE DECISION METHOD FOR LONG-TERM RESERVOIR OPERATION USING THE DYNAMICALLY DIMENSIONED SEARCH ALGORITHM
Sangho LEE, Shinuk KANG , Taeuk KANG & Eun-Sung CHUNG……..….121

PREPARATION OF INUNDATION AND FLOOD HAZARD MAPS AT THE CITY CENTER OF GIRESUN USING 1D/2D HYDRAULIC MODEL
Dr. Burak TURAN, Dr. Emre AKÇALI, Bora TURAN, Ufuk ŞAHİN, Salih BABAGİRAY, Orhan AKDENİZ & Hüseyin KUDUBAN……..123

HYDROMETRIC DATA BANK DATABASE STRUCTURE
Ihsan KARAGÖZ ……..125

TRENDS OF MEAN AND EXTREME PRECIPITATION IN SOUTHERN ITALY
Tommaso CALOIERO, Roberto COSCARELLI & Ennio FERRARI..... 127

COMPARISON OF TEMPORAL VARIABILITY OF ANNUAL DAILY WATER LEVELS OF THE FIVE NORTH AMERICAN GREAT LAKES FROM 1918 TO 2012
Ouassila AZOUAOUI, Ali ASSANI & Jean-Jacques FRENETTE…… 129

RUNOFF SIMULATION USING THE GAMMA TEST (CASE STUDY: AMAMEH WATERSHED, IRAN)
Alireza SHARIFI, Yagob DINPASHOH & Alireza MOGHADDAMNIA……. 131

PREDICTING AVULSION POTENTIAL ON ALLUVIAL FANS USING FLO-2D MODEL- A CASE STUDY
Zeinab MOLLAEI, Hamid MADANI, Hamid MOGHIMZADEH, Alireza FARIDHOSSEINI & Farid FARIDANI…… 133

ESTIMATION OF DAILY STREAMFLOWS AND FLOW DURATION CURVES AT UNGAUGED SITES
Pelin Lale KALE & Bihrat ONOZ…… 135

ESTIMATION OF SEDIMENT YIELD IN THE MELLEGUE WATERSHED, ALGERIA
Kaouther SELMI & Kamel KHANCHOUL…….. 137

COMPARISON OF INHERENT PERFORMANCE OF SEVEN DROUGHT INDICES IN DROUGHT MITIGATION USING A MONTE CARLO SIMULATION APPROACH
Babak AMIRATAEE& Majid MONTASERI…… 139

TREND ANALYSIS OF SPATIAL AND TEMPORAL DRY AND WET PERIODS BASED ON SPI AND PNPI DROUGHT INDICES IN NORTHWEST OF IRAN
Babak AMIRATAEE& Majid MONTASERI…… 141

REGIONAL IRRIGATION MANAGEMENT WITH THE USE OF AN AGRO-HYDROLOGICAL MODEL
Dimitris GOTSIS, Dimitris ALEXAKIS, Spyros GIAKOUMAKIS & Dimitra GAMVROULA…… 143

GROUNDWATER QUALITY CHARACTERISTICS OF THE ENVIRONMENTALLY SENSITIVE PINIOS RIVER DELTA, CENTRAL GREECE
V. PISINARAS, C. PARASKEVAS, A. ILIAS, A. PANAGOPOULOS, G. ARAMPATZIS, S. KOTSOPOULOS & S. POULOS …….. 145

INVESTIGATION OF CLIMATE CHANGE EFFECTS IN AGRICULTURAL WATER MANAGEMENT OF PINIOS RIVER DELTA, CENTRAL GREECE
V. PISINARAS,C. PARASKEVAS,A. ILIAS,A. PANAGOPOULOS,G. ARAMPATZIS,I. ALEXIOU, S. KOTSOPOULOS,S. POULOS&P. NASTOS 147

INVESTIGATING THE COASTAL AQUIFER RESPONSE TO DROUGHT SCENARIOS IN MEDITERRANEAN ISLANDS
George KOPSIAFTIS, Dimitris TIGKAS, Vasileios CHRISTELIS & Harris VANGELIS…… 149

FLOOD RISK MANAGEMENT PLAN FOR THE SARDINIA HYDROGRAPHIC DISTRICT
Sara FRONGIA, Marco MELIS, Giovanni M. SECHI & Roberto SILVANO... 151

IMPACT OF CLIMATE CHANGE SCENARIOS ON MEDITERRANEAN DROUGHT CONDITIONS
Harris VANGELIS & Eugenia KASSIOU…… 153

FUTURE CHANGES OF REFERENCE EVAPOTRANSPIRATION OVER THESSALY PLAIN, GREECE, BASED ON REGIONAL CLIMATE MODELS' SIMULATIONS
Panagiotis NASTOS, John KAPSOMENAKIS, Spyros KOTSOPOULOS & Serafim POULOS…… 155

INTRODUCTION OF NIMR HYDROMETEOROLOGICAL INFORMATION ANALYSIS AND PREDICTION SYSTEM BASED ON ENSEMBLE MODELS
Hyedeuk BAE, Heesook JI, Yoon-Jin LIM, Young RYU & Baek-Jo KIM…… 157

Conference II: Geo-information and Water Resources

INFLUENCE OF DEM RESOLUTION ON GIS-BASED INUNDATION ANALYSIS
Gulsah TULGER & Orhan GUNDUZ…….. 161

THE CORRELATION BETWEEN STATISTICALLY DOWNSCALED PRECIPITATION DATA AND GROUNDWATER LEVEL RECORDS IN NORTH-WESTERN TURKEY
Okan FISTIKOGLU, Orhan GUNDUZ & Celalettin SİMSEK…… 163

ASSESSING THE HYDROPOWER POTENTIAL OF HISTORICAL HYDRO SITES USING A GEO-INFORMATION SYSTEM AND HYDROLOGICAL MODELING IN POORLY GAUGED AREAS
Konstantinos X. SOULIS, Dimitris MANOLAKOS, John ANAGNOSTOPOULOS & Dimitris PAPANTONIS…… 165

DISTRIBUTIVE MODELLING OF HYDROLOGICAL DYNAMICS IN THE LOWER SEYHAN PLAIN – APPLICATION IN THE AKARSU IRRIGATION DISTRICT
Hendrik GOHMANN, Manfred FINK Mahmut CETIN, Hayriye IBRIKCI, Ebru KARNEZ & Suha BERBEROGLU…… 167

SOIL WATER BALANCE IN THE PRESENCE OF A SHALLOW WATER TABLE
George BOURAZANIS, Spiros RIZOS, & Petros KERKIDES…….. 169

DASYMETRIC MAPPING OF FLOOD IMPACT TO THE POPULATION IN SERBIA
Nikola KRUNIĆ, Saša MILIJIĆ, Jasmina ĐURĐEVIĆ, Olgica BAKIĆ & Vladica KRSTIĆ..... 171

WATER FOOTPRINT ASSESSMENT IN RIVER BASIN SCALE USING GIS TECHNOLOGY
Eleftheria MARINI, Maria P. PAPADOPOULOU & Vassiliki TSOUKALA… 173

AN INTEGRATED MONITORING AND MANAGEMENT SYSTEM FOR QUANTITY AND QUALITY ASSESSMENT OF WATER RESOURCES IN RURAL BASINS
L. VASILLIADES, P. SIDIROPOULOS, J. TZABIRAS, K. KOKKINOS, M. SPILIOTOPOULOS, G. PAPAIOANNOU, C. FAFOUTIS, K. MICHAILIDOU, G. TZIATZIOS, A. LOUKAS, N. MYLOPOULOS…… 175

SPATIAL ESTIMATION OF WATER FOOTPRINT OF CROPS AND AGRICULTURAL PRODUCTION– THE CASE OF MAGNESIA PREFECTURE, GREECE
Kalliopi MICHAILIDOU, Athanasios LOUKAS & Nikitas MYLOPOULOS.. 177

DETERMINATION OF BASIN CHARACTERISTICS AND OBTAINING SYNTHETIC UNIT HYDROGRAPHS BY USING GIS
Mustafa Utku YILMAZ, Evren OZGUR & E. Beyhan YEGEN…….. 179

USING TRMM SATELLITE BASED PRECIPITATION PRODUCTS FOR FLOOD MONITORING OVER RIYADH CITY IN KINGDOM OF SAUDI ARABIA
Ahmet Emre TEKELI, Hesham FOULI & Abdulaziz S. AL-TURBAK.....181

SPATIAL DOWNSCALING OF TRMM PRECIPITATION USING SATELLITE REMOTE SENSING PRODUCTS
D.D ALEXAKIS & I.K TSANIS…… 183

GIS - BASED DRASTIC MODEL FOR ASSESSING THE VULNERABILITY OF GAZA GROUNDWATER AQUIFER TO FERTILIZERS
Mohamed NAJAR & Islam FALOUJI…….. 185

USING GIS AND DEM TO IDENTIFY SUITABLE RAINWATER HARVESTING SITES IN RIYADH REGION OF SAUDI ARABIA
Bashar BASHIR,Hesham FOULI,Abdulaziz AL-TURBAK&Oumar A. LONI, 187

FLOOD HYDROGRAPH MODELING STUDIES BY USING GIS AND HEC-HMS FOR DAKAR, SENEGAL
Erkan ALKAN & Mustafa Yılmaz KILINÇ…….. 189

A SPATIAL ATTEMPT FOR CONSTRUCTING RESTRICTION ZONES AROUND WATER RESERVOIRS FOR PROTECTING WATER QUALITY
Ali GUL & Gulay ONUSLUEL GUL…… 191

REMOTE SENSING (rs) AND GEOGRAPHICAL INFORMATION SYSTEMS (GIS) USAGE FOR CLIMATE CHANGE EFFECTS
Gül USLU, Ayşenur USLU & Erdem Emin MARAŞ ……..193

MANAGEMENT OF A SEWER NETWORK BY COUPLING GIS AND HYDRAULIC MODELING: A CASE STUDY OF THE NEW UNIVERSITY IN TLEMCEN, ALGERIA
Chérifa ABDELBAKI, Boucherit ROUISSAT, Ismail CHAREF, Abderezzak HADJ ABDELKADER & Abdelhadi AMMARI…….. 195

KARST GROUNDWATER INVESTIGATION, EXPLOITATION AND PROTECTION: THE ROLE OF REMOTE SENSING AND GIS
Hamza JAKAD,Zhihua CHEN,Mingming LUO,Tao WANG&Hong ZHOU… 197

EVALUATING MULTI-TEMPORAL HIGH RESOLUTION SATELLITE CHLOROPHYLL– α MAPS IN SENSITIVE SHALLOW INLAND WATER SYSTEMS: THE CASE OF LAKE KARLA
Ioanna THEOLOGOU, Ifigenia KAGALOU, Maria P. Papadopoulou & Konstantinos KARANTZALOS……199

CLASSIFICATION OF DRAINAGE BASINS BASED ON READILY AVAILABLE INFORMATION
Ino PAPAGEORGAKI & Ioannis NALBANTIS…….. 201

TREND ANALYSIS OF METEOROLOGICAL DROUGHT INDICES IN CATCHMENTS OF BELGIUM
Eleftheria SAFIOLEA, Vasileios-Kaisar TSAKIRIS, Harris VANGELIS, Boud VERBEIREN & Marijke HUYSMANS…….. 203

REMOTE SENSING METEOROLOGICAL DATA FUSION FOR EFFECTIVE FLOOD MITIGATION AND FORECASTING OVER MEDITERRANEAN
I.K. TSANIS, H.A. FLOCAS, D.D ALEXAKIS, A.E.K VOZINAKI, G. KATAVOUTAS, V IORDANIDOU, I. PALOGOS, G.GIANNAKIS, S. PANAKOULIA, G. MORIANOU, P. PAPPA &V PAPADAKIS…… 205

Conference III: Technological Advances in Water Distribution, Purification and Desalination

AUTOMATED IRRIGATION SCHEDULING IN DRIP IRRIGATION SYSTEMS: OPTIMUM SOIL MOISTURE SENSORS POSITIONING
Konstantinos X. SOULIS & Stamatios ELMALOGLOU…… 209

INCLUDING LEAKAGE AS PRESSURE DRIVEN DEMANDS IN OPTIMAL DESIGN OF WATER DISTRIBUTION NETWORKS
Rajesh GUPTA, Abhijith. G. R. & Lindell ORMSBEE…… 211

SENSOR PLACEMENT FOR INTERMITTENT WATER DISTRIBUTION NETWORK SECURITY
Shweta RATHI,Swapnil KAMBLE,Aabha SARGAONKAR&Rajesh GUPTA 213

LOCATIONAL VARIABILITY OF EMERGING DISINFECTION BY-PRODUCTS IN DRINKING WATER
Manuel J. RODRIGUEZ, Christelle LEGAY, Stéphanie GUILHERME, Anna SCHEILI & Sabrina SIMARD…… 215

A COST-SIMULATION APPROACH FINDING ECONOMIC OPTIMALITY IN COMPLEX SUPPLY SYSTEMS RENOVATION STRATEGY
Giovanni M. SECHI & Riccardo ZUCCA…… 217

CALIBRATION OF WATER DISTRIBUTION NETWORKS WITH FIRE FLOW TESTS
Ayşenur USLU & Gülfem BAKAN…… 219

ECONOMIC LEAKAGE LEVEL ANALYSIS IN a WATER DISTRIBUTION SYSTEM
Vasilis KANAKOUDIS & Konstantinos GONELAS…… 221

PRACTICAL APPLICATION OF PENALTY-FREE EVOLUTIONARY MULTI-OBJECTIVE OPTIMISATION OF WATER DISTRIBUTION SYSTEMS
Alemtsehay G. SEYOUM, Tiku T. TANYIMBOH & Calvin SIEW…… 223

SECURING WATER SUPPLY IN ADELAIDE OVER THE NEXT CENTURY BALANCING DESALINATED AND MURRAY-DARLING BASIN WATER
Michael G. PORTER, Zohid ASKAROV, Sarah HILBORN, Oz SAHIN…… 225

NIREUS: APPLICATION OF THE NEW SOFTWARE FOR THE ANALYSIS OF PRESSURIZED COLLECTIVE IRRIGATION NETWORKS OPERATING ON-DEMAND
A. STEFOPOULOU & N. DERCAS……227

PERFORMANCE INDICATORS FOR DAMAGED WATER DISTRIBUTION SYSTEMS
Abdullah Cem KOC, Selcuk TOPRAK, Umut Sakine YILDIRIM & Engin NACAROGLU…… 229

MULTI-DIRECTIONAL SEARCH STRATEGY TO OPTIMAL DESIGNS OF WATER DISTRIBUTION SYSTEMS
Salah H. A. SALEH & Tiku T. TANYIMBOH…… 231

HYDROLOGICAL CONTRIBUTION TOWARD SEA WATER INTRUSION PHENOMENON IN TERENGGANU, MALAYSIA
Muhd. Barzani GASIM, Mohd Ekhwan TORIMAN, Hafizan JUAHIR, Mohd KHAIRUL Amri KAMARUDIN, Azman AZID, & Haniff MUHAMAD…… 233

WATER LOSSES DURING DISTRIBUTION AND APPLICATION IN COLLECTIVE IRRIGATION NETWORKS
Dimitra ZORMPA, Chris TZIMOPOULOS & Chris EVAGELIDES……235

USE OF CLAY MINERALS TO REDUCE AMMONIUM CONCENTRATION IN GROUNDWATER
G. PANAGOPOULOS, D. PAPOULIS, M. ZAMPARAS, V. BEKIARI & D. PANAGIOTARAS..... 237

REVIEW OF PIPE DETERIORATION, FAILURE, CONDITION ASSESSMENT TECHNIQUES IN WDS
Ayşenur USLU, Aslı ULKE & Neslihan BEDEN…… 239

USING CLAY-SUPPORTED NANOSCALE ZERO-VALENT IRON FOR REMOVAL OF Ni FROM CONTAMINATED WATERS
Mostafa EMADI & Mohammadali Bahmanyar …… 241

Conference IV: Water Pollution and Eco-systems Conservancy

DETERMINATION OF CLEANER (SUSTAINABLE) PRODUCTION OPPORTUNITIES IN METAL PROCESSING (COATING) INDUSTRY
Tarık KOTAN & Gülfem BAKAN…… 245

METAL WORKING FLUID RECYCLING AND WASTE REDUCTION OPPORTUNITIES IN METAL PROCESSING INDUSTRY
Gulfem BAKAN, İlknur Damla BEYTEKIN & Tarık KOTAN…… 247

CLIMATE CHANGE IMPACT ON HEAVY METAL RELEASE IN A RECLAIMED COASTAL AQUIFER
Nicolò COLOMBANI, Micòl MASTROCICCO & Enrico DINELLI..... 249

IRRIGATION-INDUCED GROUNDWATER NITRATE POLLUTION IN MEDITERRANEAN AGRICULTURE
Hayriye IBRIKCI, Mahmut CETIN, Suha BERBEROGLU, Hande SAGIR, Ebru KARNEZ, Takanori NAGANO, Manfred FINK, Jumpei KUBOTA & Hendrik GOEHMANN.....251

AN EMPIRICAL RELATIONSHIP BETWEEN BULK ELECTRICAL CONDUCTIVITY OF SOIL SATURATED PASTE AND THE ELECTRICAL CONDUCTIVITY OF SATURATED PASTE EXTRACT
G. KARGAS , DEMETRIOU V., MARATHEFTIS A., PETSETIDOU A., KARIDAS E., BOURAZANIS G & P. KERKIDES..... 253

3D NUMERICAL MODELLING OF WIND DRIVEN CIRCULATION AND HORIZONTAL DISPERSION IN A RECONSTRUCTED SHALLOW LAKE
Kyriakos KOPASAKIS, Chrysi LASPIDOU, Marios SPILIOTOPOULOS, Dimitrios KOFINAS & Nikolaos MELLIOS 255

CHLORIDE TRANSPORT PARAMETERS PREDICTION IN A CLAY LOAM SOIL COLUMN
George BOURAZANIS, MARIA PSYCHOGIOU *Vasiliki BALAFOUTI & Petros KERKIDES…… 257*

GROUNDWATER CONTAMINATION BY HEAVY METALS DUE TO STEEL INDUSTRIES IN PLAIN OF ARDAKAN – YAZD
Mojtaba MERAT & Hadi JAFARI…….. 259

EVALUATION OF WATER QUALITY INDICES FOR LAKES IN THE MEDITERRANEAN
Dimitris ALEXAKIS, Vassilios A. TSIHRINTZIS, George TSAKIRIS & Georgios D. GIKAS…… 261

ASSESSMENT OF POLLUTANT LOADINGS FROM WASTEWATER TREATMENT PLANTS IN KAVALA GULF
P. MELIDIS & G. SYLAIOS…….. 263

"WHAT IFs" IN LAKE KARLA
Dionissios LATINOPOULOS, Ifigeneia KAGALOU, Dimitris KOFINAS, Nikolaos MELLIOS, Theodoti PAPADIMITRIOU, Stylianos MIMIS & Chrysi LASPIDOU…… 265

TREATMENT OF UNIVERSITY CAMPUS WASTEWATER WITH THE USE OF PILOT-SCALE VERTICAL FLOW CONSTRUCTED WETLANDS
Vasiliki A. PAPAEVANGELOU, Georgios D. GIKAS & Vassilios A. TSIHRINTZIS……267

EFFECTS OF DAMS ON THE WATER PARAMETERS OF THE DOWNSTREAM REACH
João Nuno FERNANDES, Ana Estela BARBOSA & Ana Leonor DAMAS….. 269

DEVELOPMENT OF AN IMPROVED METHODOLOGY FOR POLLUTION SOURCE IDENTIFICATION BY USING ANN-MT3DMS-GA BASED SIMULATION-OPTIMIZATION MODEL
Triptimoni BORAH & Rajib Kumar BHATTACHARJYA…… 271

IDENTIFICATION OF UNKNOWN GROUNDWATER POLLUTION SOURCES AND SIMULTANEOUS DESIGN OF MONITORING NETWORK USING ANN-GA BASED SIMULATION OPTIMIZATION MODEL.
Sophia LEICHOMBAM & Rajib Kumar BHATTACHARJYA……273

PARTICIPATION OF FARMERS IN THE MANAGEMENT OF DUCKWEED IN THE JORDAN VALLEY
Maisa'a W. SHAMMOUT, Hana ZAKARIA & Muhammad SHATANAWI…. 275

THE PROTECTION OF GROUNDWATER DEPENDENT ECOSYSTEMS THAT ARE EXTERNAL TO GROUNDWATER BODIES IN SPAIN
A. de la HERA & J.M. FORNÉS..... 277

SPECIATION OF METALS IN AWALI RIVER SEDIMENTS: RISK ASSESSMENT
Samira I. KORFALI & Bassam KHADAJ…… 279

IMPACT OF BORÇKA DAM ON TOTAL SUSPENDED SOLIDS CARRIED BY THE ÇORUH RIVER AND THE MURGUL STREAM, NORTHEAST TURKEY
Meltem KENANOGLU & Adem BAYRAM…… 281

METHODOLOGY AND APPLICATION OF THE COMBINED SWAT-HSPF MODEL
Igbal ALI & Michael BRUEN…… 283

ASSESSMENT OF ECOLOGICAL RISK BASED ON PROJECTED HYDROLOGICAL ALTERATION
Vanessa RAMOS, Rodrigo MAIA, Nuno FORMIGO & Bruno OLIVEIRA..... 285

A METHOD FOR DETERMINING ENVIRONMENTAL FLOWS BASED ON INDICATORS OF HYDROLOGICAL ALTERATION
D. J. PERES & A. CANCELLIERE.....287

LANDUSE IMPACT ON THE ECOLOGY AND ENVIRONMENT
Mustafa Yılmaz KILINÇ & Erkan ALKAN…… 289

A NEW APPROACH FOR DETERMINING THE ENVIRONMENTAL FLOW REGIME IN A GREEK RIVER
Christina PAPADAKI,Konstantinos SOULIS,Rafael MUÑOZ-MAS,Lazaros NTOANIDIS,Stamatis ZOGARIS,Nicholas DERCAS&Elias DIMITRIOU …. 291

HABITAT BANKING IN SWEDISH RIVERS AND WATER BODIES: A CONCEPT PAPER ON IMPLEMENTING THE EU WATER FRAMEWORK DIRECTIVE
Jesper STAGE.....293

HYDROCHEMICAL GROUNDWATER STATUS IN LAS TABLAS DE DAIMIEL NATIONAL PARK WETLAND (CENTRAL SPAIN) AFTER A LONG OVEREXPLOITATION PERIOD
Silvino CASTAÑO, Almudena de la LOSA, Rosa MEDIAVILLA, Juan Ignacio SANTISTEBAN & Pedro Martínez-SANTOS..... 295

TRANSPORT OF DENSE COLLOIDS IN POROUS MEDIA
Constantinos V. CHRYSIKOPOULOS, Vasileios E. KATZOURAKIS & Vasiliki I. SYNGOUNA …… 297

IMPACTS OF URBANIZATION, AGRICULTURE AND TOURISTIC DEVELOPMENT ON GROUNDWATER RESOURCES IN THE EASTERN PART OF THERMAIKOS GULF, NORTH GREECE
P. VENETSANOU, K. VOUDOURIS & N. KAZAKIS…… 299

ANTIBIOTIC RESISTANT BACTERIA FOUND IN MUNICPAL DRINKING WATER
Sadia KHAN, Charles W. KNAPP & Tara K. BEATTIE…… 301

COASTAL DUNES FEATURES OF ENDEMIC IPOMOEO STOLONIFERAE – SPOROBOLUS VIRGINICUS ASSOCIATION
Ahmet SERTESER……303

MULTIVARIATE STATISTICAL TECHNIQUES FOR ASSESMENT OF SURFACE SEDIMENT QUALITY AT THE MID-BLACK SEA COAST OF TURKEY
Sema ARIMAN & Gulfem BAKAN……305

Conference V: Multicriteria Sustainability of Water Systems

SCENARIO-OPTIMIZATION OF PUMPING SCHEDULES IN COMPLEX WATER SUPPLY SYSTEM CONSIDERING A MULTICRITERIA COST-RISK BALANCING PROBLEM
Jacopo NAPOLITANO, Giovanni M. SECHI & Paola ZUDDAS.....309

MULTICRITERA EVALUATION OF COMBINE SEWER OVERFLOW IMPACTS IN COASTAL CITIES
Mohammad KARAMOUZ, Helieh ABBASI , Mohammad FERESHTEHPOUR & Gh. R. Nabi BIDHENDI …… 311

SUSTAINABILITY OF AGRICULTURAL WATER MANAGEMENT IN LARGE SCALE IRRIGATION SCHEMES: A CASE STUDY IN TURKEY
Mahmut CETIN,Hayriye IBRIKCI,Suha BERBEROGLU,Manfred FINK, Takanori NAGANO, M. Said GOLPINAR, Jumpei KUBOTA & Hendrik GOHMANN.. 313

MULTIPURPOSE PLANS FOR THE SUSTAINABILITY OF THE GREEK LAKES
Dionissis LATINOPOULOS,Chrysoula NTISLIDOU&Ifigeneia KAGALOU. 315

REDUCING VULNERABILITY OF ALGIERS WATER SUPPLY: MANAGEMENT CHALLENGES
Meriem Naimi AIT-AOUDIA & Ewa BEREZOWSKA-AZZAG…… 317

SENSITIVITY OF IRRIGATION REQUIREMENTS TO IMPROVEMENT IN IRRIGATION EFFICIENCY IN CLIMATE-INDUCED CHANGES: EXAMPLE OF A TRANSBOUNDARY WATERSHED
Furat A.M. Al-FARAJ, Dimitris TIGKAS & Miklas SCHOLZ…… 319

INDICATORS FOR SUSTAINABLE WATER USE WITH A REGRET-BASED DECISION MAKING APPROACH FOR HYDROLOGIC UNITS IN SOUTH KOREA
Yeonjoo KIM & Inhye KONG…… 321

AN INTEGRATED MODELLING SYSTEM FOR ASSESSING WATER RESOURCES MANAGEMENT PRACTICES
L. VASILIADES, P. SIDIROPOULOS, J. TZABIRAS, G. PAPAIOANNOU, K. KOKKINOS, A. LOUKAS & N. MYLOPOULOS……323

ADAPTATION OF WATER RESOURCES MANAGEMENT STRATEGIES TO OVERTURN CLIMATE CHANGE IMPACTS. THE LAKE KARLA WATERSHED CASE, CENTRAL GREECE
John TZABIRAS, Lampros VASILIADES , Pantelis SIDIROPOULOS , Athanasios LOUKAS & Nikitas MYLOPOULOS…… 325

A NESTED OPTIMIZATION APPROACH FOR THE CAPACITY EXPANSION OF MULTIQUALITY WATER SUPPLY SYSTEMS UNDER UNCERTAINTY
João VIEIRA & Maria da Conceição CUNHA…… 327

COMBINED OPTIMIZATION OF RESERVOIR-AQUIFER OF LAKE KARLA UNDER ENVIRONMENTAL CONSTRICTIONS
Pantelis SIDIROPOULOS, Nikitas MYLOPOULOS & Athanasios LOUKAS. 329

SEISMIC DAMAGES IN PIPELINES IN THE LIGHT OF PREVENTIVE MAINTENANCE
Selcuk TOPRAK, Engin NACAROGLU, Abdullah Cem KOC, Murat SARI & Umüt Sakine YILDIRIM…… 331

A METHODOLOGY FOR CLIMATE CHANGE INTEGRATION IN WATER RESOURCES MANAGEMENT. APPLICATION TO THE PORTUGUESE PART OF GUADIANA RIVER BASIN
Rodrigo MAIA, Bruno OLIVEIRA, Vanessa RAMOS, Levi BREKKE , Ricardo SERRALHEIRO, Mário CARVALHO & Pedro VALVERDE.....333

EVALUATING JOINT WATER DEVELOPMENT IN THE LOWER JORDAN RIVER BASIN USING MULTI-CRITERIA DECISION ANALYSIS
Rola QUBA'A, Mutasem El-FADEL, Majdi Abou NAJM & Ibrahim ALAMEDDINE…… 335

WATER ALLOCATION MECHANISMS IN SUPPORT OF WATER SECURITY
Cem P. CETINKAYA & Nilgun B.HARMANCIOGLU…… *337*

CONFLICT RESOLUTION IN RESERVOIR OPERATION PROBLEMS USING MULTI-OBJECTIVE STOCHASTIC DYNAMIC PROGRAMMING
B. TALUKDAR & D.K. SRIVASTAVA…… 339

RELIABILITY BASED SIMULATION FOR POWER POTENTIAL STUDY OF A HYDROELECTRIC PROJECT
Navanita CHOUDHURY & Bipul TALUKDAR…… 341

ZEOLITITE AMENDED AGRICULTURAL FIELD EXPERIMENT TO IMPROVE WATER SAVING
Micòl MASTROCICCO, Nicolò COLOMBANI, Dario Di GIUSEPPE, Barbara FACCINI, Giacomo FERRETTI & Massimo COLTORTI..... 343

INFORMING DROUGHT MANAGEMENT: A NEW APPROACH TO ESTIMATE VULNERABILITY LEVELS IN WATER SUPPLY SYSTEMS
Mike SPILIOTIS, Ana IGLESIAS & Luis GARROTE…… 345

EFFECT OF GRANITIC BASEMENT RADIOACTIVITY ON GROUNDWATER RESOURCE IN SHIRKOOH AREA - YAZD PROVINCE OF IRAN
Mojtaba MERAT & Afshin QISHLAQI……347

BUILDING RESILIENCE IN THE WATER SUPPLY NETWORK OF MAURITIUS
Virendra PROAG ..…… 349

INTEGRATION OF CLIMATIC VARIABILITY AND CHANGE INTO COASTAL WATER MANAGEMENT OF THE ŠIBENIK-KNIN COUNTY – CROATIA
Jure MARGETA &Martina BAUČIĆ…… 351

Conference VI: Social, Political, Institutional and Legislative Aspects

INSTITUTIONAL CHALLENGES FOR ACHIEVING A WHOLE OF WATER APPROACH – THE CITY OF SYDNEY RESPONSE
Pierre MUKHEIBIR & Lisa CURRIE…… 355

THE EUROPEAN FLOOD DIRECTIVE: CURRENT IMPLEMENTATION AND TECHNICAL ISSUES
Eleni ELEFTHERIADOU, Ioanna. GIANNOPOULOU & Stavros YANNOPOULOS.....357

ASSESSING WATER AVAILABILITY IN EUROPE: A COMPARATIVE STUDY
Luis GARROTE, Alfredo GRANADO & Ana IGLESIAS..... 359

APPROACHES FOR THE DETERMINATION OF MICRO HYDROPOWER POTENTIAL OF TURKEY
Onur ABAY, Nesrin BAYKAN & N. Orhan BAYKAN…… 361

EVALUATION OF GOLF TOURISM ACTIVITIES FROM WATER CONSUMPTION PERSPECTIVE IN THE NOTHERN CYPRUS
Ibrahim BAY, Ayşen TURKMAN & O. YENIGUN…… 363

TURKEY'S DRAFT WATER LAW AND WFD IMPLEMENTATION: AN ANALYSIS
Aysegul KIBAROGLU & Vakur SUMER…… 365

AMBITIOUS GOALS AND AMBIGUOUS ISSUES: INTEGRATING WATER AND ENERGY CONCERNS IN THE NORWEGIAN HYDROPOWER SECTOR
Jonida ABAZAJ, Audun RUUD & Øystein MOEN.....367

WATER MANAGEMENT IN THE MEDITERRANEAN REGION: CONCEPTS AND POLICIES
Burak SELMIN & Margat JEAN…… 369

MODELLING SECTORALLY DIFFERENTIATED WATER PRICES IN A COMPUTABLE GENERAL EQUILIBRIUM MODEL
Jonas LUCKMANN, Dorothee FLAIG, Harald GRETHE, Scott MCDONALD & Khalid SIDDIG …… 371

AGRICULTURAL WATER MANAGEMENT IN DROUGHT CONDITION, CASE STUDY
Mehrdad FALSAFIOUN & Hamid R. SAFAVI…… 373

"THINK ABOUT NEW AGRICULTURAL PRACTICES, DRAIN LAKE KARLA": SOCIO-ECONOMIC INSUFFICIENCIES OF A LAKE RESTORATION PROJECT IN THESSALY, GREECE.
Stelios GIALIS, Chrysostomos FAFOUTIS, Nikitas MYLOPOULOS & Athanasios LOUKAS…… 375

RESILIENCE POLICIES AGAINST FLOOD RISK IN THE PARIS REGION: AN ECONOMIC ANALYSIS using COBAYE
Virendra PROAG & Satya-Lekh PROAG…… 377

BEYOND YES AND NO: PRIVATIZATION AND PUBLIC RESISTANCE IN JAKARTA'S WATER SUPPLY
Leong CHING…… 379

A NEW INTEGRATED APPROACH FOR WATER EDUCATION IN TURKEY
Goksen CAPAR, Cigdem COSKUN DILCAN, Suleyman KODAL & Tayfun CINAR…… 381

LEGISLATIVE ASPECTS OF FLOOD HAZARD PREVENTION AND RESILIENCE IN NON-EU MEMBER EUROPEAN COUNTRIES
V.S. Ozgur KIRCA Hafzullah AKSOY, Konstantinos PAPATHEODOROU & Katia STEPANOVA..... 383

WILLINGNESS TO PAY TO IMPROVE WATER SUPPLY SERVICES IN RURAL KAZAKHSTAN: APPLICATION OF CONTINGENT VALUATION METHOD
Kamshat TUSSUPOVA, Ronny BERNDTSSON & Torleif BRAMRYD..... 385

PERCEPTIONS OF CITIZENS TOWARD WATER MANAGEMENT IN A RESIDENTIAL COMMUNITY: CASE STUDY FROM AL-MAFRAQ – JORDAN
Naji K. Al-MEFLEH , Saad M. ALAYYASH & Fatima A. Bani KHALED..... 387

DRINKADRIA PROJECT: FROM AN IDEA TO POLICY RECOMMENDATION – A COMMON APPROACH DEVELOPMENT, TOWARDS WATER RESOURCES MANAGEMENT AND SUPPLY, ACROSS ADRIATIC SEA COUNTRIES
Vasilis KANAKOUDIS, Anastasia PAPADOPOULOU, Stavroula TSITSIFLI, Enrico ALTRAN, Barbara CENCUR CURK, Barbara KARLEUSA, Branislava MATIC & Primoz BANOVEC..... 389

INSTITUTIONAL AND LEGISLATIVE STATUS OF SURFACE WATER MANAGEMENT IN TURKEY AS AN ACCESSION COUNTRY TO EUROPEAN UNION
Cem Polat ÇETİNKAYA..... 391

Prolegomena

The 9th World Congress of the European Water Resources Association is held in Istanbul (June 2015) following a unanimous decision of the General Assembly during the EWRA Conference in Porto (June 2013). This selection, among others, shows the firm determination of European scientists to spread the European principles and approaches in Water Resources Management to other countries of the world and, at the same time, to learn from the diverse experiences of scientists from a number of countries.

As known, 2015 is the benchmark year for the comprehensive evaluation on the progress of implementation of the Water Framework Directive (WFD) and its daughter directives. The European member states have completed the first phase of WFD implementation for fulfilling its environmental objectives using new criteria, innovative approaches and cutting edge methodologies.

As the title of the Congress indicates, "*Water Resources Management in a Changing World: Challenges and Opportunities*", the main interest of the Congress lies on a "changing world" and the associated challenges and opportunities in the water sector and the environment.

From the presentations selected, I am sure that the Congress will be a benchmark scientific event, addressing a number of key issues in the area of water resources management. The presentations are organised in six Conferences with particular focus on hydrological processes and hazards, geo-information and water resources, the technological advances in water distribution, purification and desalination, water pollution and ecosystems conservancy, multicriteria sustainability of water systems, and social, political, industrial and legislative aspects.

Hundreds of scientists and engineers are gathered in Istanbul for this important international water event. Fruitful discussions are expected to advance existing knowledge on critical issues in water resources

management and have significant impacts on the current practices worldwide.

On behalf of the Executive Committee of EWRA, I have to sincerely thank the Organising Committee for their excellent organisation, the Conveners of the Conferences and the Scientific Committee for their devoted reviewing process. Their work has led to the selection of high level presentations in the Congress. I wish also to deeply thank the Dokuz Eylul University (DEU), the National Technical University of Athens (NTUA) and the Istanbul Technical University (ITU), for organizing this international event, and all the authors and participants for their contributions.

I wish to all fruitful discussions and enjoyable stay in Istanbul.

George TSAKIRIS

President of the European Water Resources Association

Preface

Up-to-date, European Water Resources Association (EWRA) has organized 8 international conferences, focusing particularly on water resources management in a globally changing context of emerging risks, challenges and opportunities. The major theme of the 9th EWRA event is similarly "Water Resources Management in a Changing World: Challenges and Opportunities" but with some distinct perspectives that differentiate the meeting from past conferences.

First, the event is held in June 2015, the year which marks an important deadline in terms of EU Water Framework Directive (WFD) implementation. The planning cycle within WFD foresaw development of River Basin Management Plans by EU Member States between 2009 and 2015 so that 2015 is the year when a European overview and Member State specific assessments will be available. Thus, the 9th EWRA meeting provides a timely platform to assess the adoption of basin management plans at European level and to share these experiences between scientists and professionals both from the Member States and from other regions around the world facing similar challenges related to water resources management.

Second, the meeting is held in the transcontinental global city of Istanbul which constitutes a bridge between Europe and Asia through the famous Bosphorus, one of the world's busiest waterways. Istanbul is the largest city in Turkey, constituting the country's economic, cultural, and historical heart. With a population of 14.1 million, the city forms one of the largest urban agglomerations in Europe, second largest in the Middle East and the third-largest city in the world by population within city limits. Istanbul is a superb site for meetings conferences and conventions and has hosted big "water" events like the 5th World Water Forum in 2009 and International Istanbul Water Forums in 2009, 2011 and 2014. Thus, the nature of the selected location facilitated EWRA to expand the structure of its biannual conferences from an "*International Conference*" to a "*World Congress".* Eventually, Istanbul Congress attracted high participation from the Asian countries

and other continents in addition to European countries so that water problems and solutions are discussed at a global scale. Participants from 5 continents, including 49 countries, applied to take part in the Congress, meaning that the universal problems of water crisis and water-food-energy nexus are considered at a large extent.

Third, the 9th World Congress encompasses 6 different conferences, instead of a single conference, to cover a wide range of topics relevant to water resources and the environment. This significantly contributes to the multidisciplinary and global context of the Congress, and thereby the multidisciplinary and global nature of water problems, so that scientists from various disciplines and countries have interacted for more fruitful solutions. The conferences are as follows:

I. Hydrological Processes and Evolving Hazards
II. Geo-information and Water Resources
III. Technological Advances in Water Distribution, Purification and Desalination
IV. Water Pollution and Eco-systems Conservancy
V. Multicriteria Sustainability of Water Systems
VI. Social, Political, Institutional and Legislative Aspects

Each conference is run in parallel sessions, and the participants have chosen to attend that conference which directly related to their area of expertise and experiences. This has ensured the realization of more focused sessions, ending up in more effective discussions and solutions. Eventually, the Congress has become a prominent activity by bringing together participants' experience, sharing their know-how and contributing to the international water community while enjoying the wonderful setting of Istanbul.
This book includes the abstracts of papers (keynotes, oral and poster papers) presented at the Congress, as well as the full papers collected in a CD of Proceedings. The abstracts and full papers are presented on the basis of six Conferences.

The editors would like to thank the President of EWRA and EWRA General Assembly at the 8th International Conference of EWRA in Porto for proposing and selecting Istanbul as the venue for the 9th World Congress. They would also like to express their deepest gratitude to the Conveners of the Conferences and the Scientific Committee for their valuable reviews of all papers. They also wish to thank the Dokuz Eylul University (DEU), DEU Water Resources Management Research and Application Center (SUMER), the National Technical University of Athens (NTUA) and the Istanbul Technical University (ITU), for organizing and supporting this Congress. Finally, our deepest thanks go to all the authors and participants for their valuable contributions.

Prof.Dr. Nilgun B. Harmancioglu,

President, 9th World Congress Istanbul

Invited lectures

NONSTATIONARITY OF HYDROLOGICAL RECORDS AND RECENT TRENDS IN TREND ANALYSIS: A STATE-OF-THE-ART REVIEW

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ABSTRACT

Recent climate change due to global warming has given an impetus to trend analysis of hydrological time series. Climate change as well as low-frequency climate variability and human intervention in river basins violate the assumption of stationarity, which is claimed to be dead by some researchers. In a changing world, decision making in water resources management requires long-term projections of hydrological time series that include trend due to anthropogenic intervention and climate change. Detailed climate models and long hydrological records are needed to predict the future conditions in a changing world. A stationary model is sometimes preferable to a nonstationary one when the evolution in time of hydrological processes cannot be predicted reliably. The statistical significance of a trend can be detected by means of statistical tests such as Mann-Kendall test, which must be modified when there is serial correlation, possibly by prewhitening. It may be more important to increase the power of a test so that errors of estimation that may lead to damages due to inadequate protection are prevented. Frequency analysis of nonstationary processes can be made by fitting a trend to the parameters of the probability distribution. Design concepts such as return period and hydrological risk should be redefined in a changing world. In management decisions of water structures, a risk-based approach should be used where errors that result in under-preparedness are considered as well as those resulting in over-preparedness.

HIGHLIGHTS

- Climate change and human intervention cause nonstationarity in hydrologic records. A trend test can cause the important aspect of the trend magnitude to be lost.
- An observed trend cannot be used for predicting the future unless its physical mechanism is explained. Climate variability can be confused for trend.
- Frequency analysis and revised definitions of return period and risk are now available to be used for hydrologic design in a changing world

- Not only the cost of over-preparation but also that of under-preparation should be considered in risk-based nonstationary water resources design studies.

RIVER BASIN MANAGEMENT: WHAT DO WE REALLY WANT?

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ABSTRACT

River basin management, or Integrated Water Resources Management (IWRM) is subject to the European Directive 200/60/EC and amendments. These define management "objectives" as: preventing and reducing pollution; promoting sustainable water usage; environmental protection; improving aquatic ecosystems and mitigating the effects of floods and droughts. The ultimate objective is to achieve "good ecological and chemical status" for all Community waters by 2015. These are all noble and laudable goals, hard to disagree with, but they do not necessarily cover everything that "stakeholders" in water resources management (which is more or less everybody) really want.

I claim we really want is to maximize net benefit from the operation and use any water resources system, get as close to some "UTOPIA" as possible. Net benefit here is not meant in any narrow economic, monetary sense, but as a measure of all the goods and benefits, countable monetary but also qualitative, perceived, spiritual, whatever is "worth" anything to us. UTOPIA is the (theoretical) state of a system that combines all the "best values" for all criteria considered. Implementation of this view revolves around the simple concept of mass conservation, dynamic water budget modelling, that tells us how much water is or will be available where and when, and describes the dynamic balance of demand and supply together with water quality, and whatever "valued" attribute of the system we may glean from a model description, the metric for the degree to which various objectives are met.

A multi-attribute approach measures how close we can get to UTOPIA in a "normalized" achievement space of any number of criteria. The optimization tries to find the set of policies, measures, and technologies with their costs and efficiencies, that will get us as close to UTOPIA as possible. This involves trade-off between objectives (and stakeholders), give and take, but leads to cooperative games that should (given reasonable stakeholders) result in win-win solutions. This assumes that "to win" in some tangible sense, to be better off than "before", is what we really want. Application examples from several Mediterranean river basins illustrate methodology and implementation.

HIGHLIGHTS

- A simulation-based multi-criteria optimization of river basin management was developed and tested;
- The approach combines dynamic water budget modelling with "participatory" valuation of costs and benefits of water management;
- The non-linear multi-criteria optimization uses a reference point approach with an interactive web-based interface for easy stakeholder participation.
- Test cases for several river basins around the Mediterranean illustrate the approach and demonstrate optimization results

QUANTIFYING SYSTEM SUSTAINABILITY IN WATER RESOURCES MANAGEMENT VS. QUALITATIVE DEFINITION OF THAT TERM

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ABSTRACT

Although sustainable planning, development and management are rational and morally well justified, in case of water resource systems we have to recognize that even our best intentions to preserve and enhance the current state of natural water resources for future generations are always clouded by uncertainty. In fact, we need more than preservation - we should rather try to balance traditional human values with the new technological advances remembering that water is not only a means to other goals but it is important as an end in itself. Ever since the concept of sustainability was introduced by the Brundtland report, professionals from many disciplines have been trying to measure it, often using commonly applied multiple risk criteria like reliability, resilience and others. Unfortunately almost all of these methodological works did not end up with real world applications. At the background of these proposals, the paper will discuss the opposite view that sustainability, is not something that one could be numerically accurate about. Conclusions remain to be presented in the paper.

HIGHLIGHTS

- Sustainability in water resources planning, development and management
- Origin and importance of sustainability concept
- Related uncertainties
- Can that be measured?

WATER WORKS OF FOUR MILLENIA IN TURKEY

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ABSTRACT

Turkey is one of the foremost open-air museums of the world with regard to historical water works from the last four thousand years. Some of them are still in operation after several centuries or even several millennia. There are remains of dams, irrigation canals, and water collection structures dating back to the IInd millennium BC, the Hittite period in Central Anatolia. Several dams, irrigation canals, qanats date back to the first half of the Ist millennium BC, the Urartu period in Eastern Anatolia. Long-distance water conveyance systems, pipes, masonry canals, inverted siphons, tunnels, dams date back to the second half of the Ist millennium BC and the Ist millennium AD, the Hellenistic, Roman and Byzantine periods in Western and Southern Anatolia. Some dams, canals, watermills date back to the 11th to 14th centuries, the Seljukide period in Central and Eastern Anatolia. Several dams, irrigation canals, long distance water conveyance systems date back to the 14th to early 20th centuries, the Ottoman period in Turkey. Based on this tradition from four millennia, the modern Republic of Turkey, founded in 1923, is continuing to develop her water resources. The Southeastern Anatolia Project, encompassing the Euphrates-Tigris basin in Turkey, is the most interesting example.

HIGHLIGHTS

- Turkey is one of the foremost open-air museums of the world with regard to historical water works.
- They include dams, irrigation schemes, water conveyance systems, pipes, masonry canals, aqueducts, inverted siphons, qanats, tunnels, watermills.
- Some of them are still in operation after several centuries or even several millennia.
- Based on this tradition, the modern Republic of Turkey is continuing to develop her water resources.

MANAGING WATER RESOURCES UNDER GLOBAL CHANGE: METHODS AND TOOLS FOR A SYSTEMS APPROACH

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ABSTRACT

Concern about projected global climate change and other pressures on natural, social, and built environments have focused particular attention on the role of freshwater availability and reliability in the future development. Freshwater sustains life and all social and environmental processes. Yet freshwater systems are imperiled, and this threatens both human well-being and the health of ecological systems. This crisis us caused by the ways in which we *mismanage* water. As a result, there is a growing need for modeling and analyses tools that can provide quantitative insights into these issues while representing the full integration of the climate system with its socioeconomic drivers, hydrology and water supplies, water use sectors, and management strategies (Simonovic, 2009a).

During the past five decades we have witnessed a tremendous evolution in water resources systems management (Simonovic, 2009b). Three of the characteristics of this evolution should be noted in particular. *First*, the application of the systems approach to complex water management problems has been established as one of the most important advances in the field of water resources management. The systems approach draws on the fields of operations research and economics to create skills in engineering problem solving. A primary emphasis of systems analysis in water resources management is on providing an improved basis for decision-making. A large number of analytical, computer-based tools, from simulation and optimization to multi-objective analysis, are available for formulating, analyzing and solving water resources planning, design and operational problems. *Second*, the past four decades have brought a remarkable transformation of attitude by the water resources management community towards environmental concerns, and of action to deal with them. Water, together with land and air, is under significant pressure from a growing population, and the associated needs for food production and rapid urbanization. There are many examples of initiatives taken for environmental assessment and planning, as well as considerable investment in environmental technologies and new processes designed to recover or eliminate pollutants. Water resources management has faced an uphill battle with the regulatory approaches that are used in many countries around the world. They have not been conducive to the systems approach that is inherent in simulation and optimization

management models. Fortunately, recent trends in regulation include consideration of the entire river basin system, explicit consideration of all costs and benefits, elaboration of a large number of alternatives that reduce the amount of pollution generated, and the greater participation of all stakeholders in decision-making. Systems approaches based on simulation, optimization and multi-objective analyses have great potential for providing appropriate support for effective management in this emerging context. In 1987, with the publication of the Brundtland Commission's report Our Common Future, decision-making in many fields began to be influenced by a sustainability paradigm. It can safely be assumed that sustainability is now the major unifying concept promoted, accepted and discussed by governments throughout most of the world. The original report introduced the concept of sustainable development as 'the ability to meet the needs of the present without compromising the needs of future generations'. This concept was the *third* main evolutionary step to affect water resources systems management in the last five decades.

Two paradigms are identified that are shaping new tools for water resources systems management. The first focuses on the *complexity* of the water resources domain, and the complexity of the modelling tools, in an environment characterized by continuous, rapid technological development. Domain complexity is increasing. Further population growth, climate variability and regulatory requirements are factors that increase the complexity of water resources problems. In the same time we are witnessing the rapid increase in the processing power of computers. Whether they take the form of a laptop personal computers or a desktop multi-processing workstations is not important any more. It is important that the computer is used as a partner in more effective water resources decision-making. The additional component of the complexity paradigm is the reduction in the complexity of tools used in water management. During the evolution of systems analysis in water management, it has become apparent that more complex analytical optimization algorithms are being replaced by simpler and more robust search tools. Advances in computer software have also led to considerable simplification in the development of simulation models.

The second paradigm deals with water related data availability, and the natural variability of domain variables in time and space that affect the *uncertainty* of water resources decision-making. The current water resources management is characterized by the increase in all elements of uncertainty in time and space. Uncertainty in water management can be divided into two basic forms: uncertainty caused by inherent hydrologic variability, and uncertainty caused by a fundamental lack of knowledge. At many locations around the world, the data availability is on the decline due to a high cost of continuous monitoring of many variables of importance for effective management of water resources. Uncertainty of water resources decision-making rises with the increase in natural variability of water availability. Water flow exhibits both temporal (between years and seasons) and spatial variation. This variation, which can be crucial for water availability to domestic, agricultural or industrial use, is not detected if the selected timescale for water balance analyses is longer than the periods of such fluctuation.

Two examples are presented here to illustrate advantages of systems approach in dealing with complexity and uncertainty of water resources decision-making under global change.

(1) ANEMI – an integrated model of society-biosphere-climate system (Davies and Simonovic, 2010). ANEMI model is developed for the integrated assessment of climate and global change. It reproduces the main characteristics of eight sectors of the – climate, carbon cycle, land use, population, surface water flow, water use, water quality, and the economy – and explores the manner in which interactions, or feedbacks, between these components determine the behaviour of the whole. The model's reference behaviour forms the basis of comparison for the set of experiments undertaken with the model.

(2) A flood risk assessment to municipal infrastructure due to changing climate (Bowering et al, 2013; Peck et al, 2013). Extreme rainfall events that are occurring more frequently as an effect of climate change and variability are causing increasing damages to municipal infrastructure. A methodology is developed to quantify the risk to municipal infrastructure from climate change-related flooding. The risk is measured using a combination of flow/frequency, stage/damage and damage/frequency curves. The measure of risk is termed the Risk Index and calculated for each infrastructure element within a municipality. The risk is aggregated and summed by spatial unit and presented in the form of risk tables and maps. The risk index takes into account both quantitative and qualitative information obtained from research and interviews with technical experts. The results from the application of the methodology to a municipality will lead to better policy and informed decision making.

HIGHLIGHTS

- Management of water resources is challenged by changing global conditions.
- The systems approach offers possible solutions.
- Two paradigms are shaping new tools: complexity and uncertainty

ENTROPY THEORY FOR STREAMFLOW FORECASTING

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ABSTRACT

Streamflow forecasting is used in river training and management, river restoration, reservoir operation, power generation, irrigation, and navigation. In hydrology, streamflow forecasting is often done using time series analysis. Although monthly streamflow time series are stochastic, they exhibit seasonal and periodic patterns. Therefore, streamflow forecasting entails modeling two main aspects: seasonality and correlation structure. Spectral analysis can be employed to characterize patterns of streamflow variation and identify the periodicity of streamflow. That is, it permits to extract significant information for understanding the streamflow process and prediction thereof. For forecasting streamflow, spectral analysis has, however, not yet been widely applied. Streamflow spectra can be determined using entropy theory. There are three ways to employ entropy theory: (1) Burg entropy, (2) configurational entropy, and (3) relative entropy. In either way, the methodology involves determination of spectral density, determination of parameters, and extension of autocorrelation function. This paper reviews the methods of spectral analysis using the entropy theory and tests them using streamflow data.

HIGHLIGHTS

- Streamflow forecasting is done by entropy-based spectral analysis.
- For entropy-based spectral analysis, the random variable can be either frequency or spectral power.
- Depending on the choice of random variable, entropy-based spectral analysis can be of five types: (1) based on Burg entropy, (2) based on configuration entropy (two types), and (3) based on relative entropy (two types).
- Both configurational entropy theory and relative entropy theory based spectral analyses yield satisfactory streamflow forecasts.
- Entropy theory provides a powerful tool for flow forecasting up to 5 years in advance

SOCIAL RESPONSES TO WATER MANAGEMENT DECISIONS

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ABSTRACT

We suggest that those involved with environmental and water resources planning and management need to consider the social responses as well as the economic and environmental impacts of our decisions. But predicting such responses now, and especially in the future, will not be possible. All we know about the future is that it will differ from the present. This includes the goals or objectives society wishes to achieve. But, in spite of this, decisions have to be made today that shape or influence the future we think we will want. What can policymakers do to better insure that a policy is able to achieve society's objectives over time? One way is to include members of society (or at least their behavior) in the policymaking process. Another way is to make the policy adaptive and include monitoring and learning so that new actions can be taken when conditions change. That is, policies should include provisions for being prepared for changes.

In this paper we offer a conceptual model of a coupled social-water system, each component influencing decisions that affect the other over time. We give some examples of just how hard it is to attempt predictions, why, and what can go wrong if those predictions are wrong. And we offer some analytic approaches to policymaking that do not depend on such predictions. These approaches include the use of (1) agent-based models that simulate the behavior of individual or collective entities, (2) stakeholders who represent the social component interacting with computer models of the water systems within a decision support framework or within the framework of a 'smart game, or (3) dynamic adaptive policies, which rely on monitoring and adapting rather than implementing a fixed policy. All of these approaches can be used to gain insights and understanding of the coupled social and natural components of water resource systems.

HIGHLIGHTS

- Focus on how to meet social objectives when it is impossible to predict social responses.
- Identify approaches for considering likely social responses to environmental and water management decisions.
- Offer some analytic approaches to policymaking that do not depend on predicting social responses but do depend on monitoring and adapting.
- Offer examples of how hard it is to attempt predictions, suggest why, and highlight what can go wrong if those predictions are wrong.

THE STATUS OF THE EUROPEAN WATERS IN 2015: A REVIEW

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ABSTRACT

The paper aims at presenting the recent European developments in water resources management. The paper particularly focuses on the EU policies and their implementation which are related to floods, droughts and ecosystems. In this context the Water Framework Directive (WFD), the Flood Directive and the Communication on Water Scarcity and Droughts are critically presented and analysed. Also the main methodologies, endorsed by the member states for the implementation of EU directives, such as the DPSIR (Driver-Pressure-State-Impact-Response), the risk assessment and the CEA (Cost-Effectiveness Analysis) are briefly discussed. Further the first account of the implementation of the EU directives by the member states is presented, together with the statistics resulted from the first River Basin Management Plans of WFD and the first results from the Flood Directive. It is concluded that despite the significant progress achieved up to now for the fulfillment of the environmental objectives, there is still a long way to go particularly for the new member states of the EU. Enhanced integration of all related policies and better coordination is still required for improving the effectiveness of the Programmes of Measures (PoMs) in the River Basin Districts of the EU territory. Finally future amendments in European policies on water resources, are discussed which will lead to revised environmental objectives for the second and third stage applications of the water directives by the EU member states.

HIGHLIGHTS

- Presentation of EU water directives
- Discussion on the methodologies DPSIR, risk assessment and CEA
- Accounts and statistics of WFD implementation
- Amendments in EU policies on water resources

Abstracts

Conference 1

Hydrological Processes and Evolving Hazards

METEOROLOGICAL DROUGHT FREQUENCY ANALYSIS BASED ON THE COPULAS APPROACH

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ABSTRACT

Meteorological drought can be considered as a multidimensional hazard characterised by severity, duration and areal extent. Several attempts have been made in the past for replacing the three dimensions by one. Conventionally, meteorological drought events are assessed for their severity, using drought indices such as SPI, RDI, PDSI and many others. This approach may be extended to incorporate the modelling of the other two dimensions, the duration and the areal extent. Since the marginal distributions describing the three dimensions of drought are often different, no simple multivariate distribution can be used for the multivariate frequency analysis. The same applies to the case in which the meteorological droughts are analysed as bivariate events (severity and duration, or severity and areal extent). The Copulas approach seems to be the most suitable approach for this type of analysis. In this paper the Gumbel-Hougaard copulas from the Archimedean family are used for the frequency analysis of droughts as bivariate events of severity and areal extent. Annual data on droughts from Eastern Crete are analysed for their severity (based on RDI) and areal extent (number of mesh squares) using mixed probability distributions incorporating Gumbel marginal probability functions. Useful conclusions are derived for estimating the «OR» return period of droughts.

HIGHLIGHTS

- The frequency analysis of meteorological droughts as multidimensional events.
- The selection of the copulas family appropriate for the case of droughts.
- The application of bivariate Gumbel-Hougaard copulas on the 2D drought events.
- The application of this type of frequency analysis in regions of Greece.

FORECASTING OF DAILY REFERENCE EVAPOTRANSPIRATION FROM LIMITED DATA USING SIMPLE REGRESSION ON SIMPLIFIED FORMULAS OF PENMAN'S EQUATION

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ABSTRACT

Accurate estimations of reference evapotranspiration (ET_0) are crucial for efficient planning and management of water resources. The FAO-56 Penman Monteith (ET_0^{PM-56}) computational sequence scheme is widely recommended for estimating ET_0 and evaluating other methods. However, modeling ET_0 at local scale, the ET_0^{PM-56} cannot be applied in many situations, because climate records are totally or partially not available or reliable. A classical approach for local modeling ET_0 is based on simple parametric local calibration (usually linear) of various limited data empirical ET_0 formulas. More sophisticated tools as the artificial neural networks (ANNs) are also applied. In this paper, a new procedure is developed for local modeling ET_0 when wind speed and/or solar radiation data are missing. Recently in a series of papers, simple algebraic formulas, equivalent in accuracy to the Penman equation are derived by Valiantzas for computing ET_0 from readily available measured data. The derivation of the formulas is based on simplifications made to the "standardized" form of the various terms of the Penman equation. The proposed procedure developed for local modeling ET_0 is based on the regression of the simplified forms of the Penman equation. The proposed procedure is not a simple parametric calibration of the limited data simplified Penman ET_0 formulas but it is based on the local development of intrinsic relationships between the various terms of Penman ET_0 formulas and the measured hydrological parameters. Evaluation of the suggested procedure and comparisons with other methods (classical parametric calibration of empirical ET_0 formulas and ANNs) using daily meteorological data from various stations is also made.

HIGHLIGHTS

- A new procedure is developed for local modeling ET0 based on the regression of the simplified forms of the Penman equation.

- The proposed procedure is not a simple parametric calibration of the limited data simplified Penman ET0 formulas but it is based on the local development of intrinsic relationships between the various terms of Penman ET0 formulas and the measured hydrological parameters.
- Evaluation of the suggested procedure and comparisons with other methods (classical parametric calibration of empirical ET0 formulas and ANNs) using daily meteorological data from various stations is also made.

CHANGES IN SNOWMELT RUNOFF FOR MOUNTAIN REGIONS OF EASTERN ANATOLIA TURKEY

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ABSTRACT

Mountain snowpack and spring runoff are critical for surface water resources as they serve an important and regionally integrated indicators of climate variability and change. The decreasing snow cover depth, especially in the spring, is of critical importance because of the effect of the timing and magnitude of spring snowmelt runoff to regional hydrologic systems. This study investigates whether mountain snowmelt for the selected 15 streamflow stations located in Euphrates, Tigris, Aras, and Çoruh basins in eastern Anatolia Turkey has shown a consistent hydrologic response to global climatic changes over the past several decades. Eastern Anatolia is characterized by mountainous terrain and a dry climate, where winter snow storage provides snowmelt runoff during the spring and early summer which usually constitutes 50–80% of the total annual runoff in the region. Analysis is made using the streamflow and meteorological data from 1970 to 2010 available within the study area to identify spatial and temporal patterns of trends in the seasonality of streamflow, snowmelt runoff, temperature and precipitation. Findings suggest that significant temperature increases to date have affected mountain snowmelt runoff simultaneously on the regional scale with there is no significant increase in annual precipitation. However, the nature of the effect is strongly dependent on geographic location and elevation. The streamflow timings in the mountainous basins are found to be shifting to earlier days in the year and this suggesting earlier spring melting of snowpack due to increased temperatures in the last decade. An important increase in the discharges takes place during the first half of March. In the region, eight among fifteen stream gauge stations in Euphrates, Tigris and Aras basins showed significant time shifts in snowmelt runoff according to statistical trend tests. With continued warming, regional climate simulations suggest that annual surface runoff is projected to decline around 25-30 % in mountainous basins particularly with an increase in winter runoff and decrease in spring runoff by the end of the century. This indicates further shift in the snowmelt-derived streamflow timing to earlier days.

ANN, DECİSİON TREE AND REGRESSİON METHODS FOR FORECASTİNG MONTHLY LAGGED LAKE WATER LEVEL

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ABSTRACT

The forecasting of lake fluctuations with previously observed data is a necessary task in closed basin lake hydrologic analysis. Known as a hyper-saline lake, Lake Urmia is dealing with atrophy and mismanagement through recent years. In this investigation, nine methods in the category of parametric and nonparametric approaches were applied for modelling Lake water level. Eleven months in the form of monthly lagged data were used as independent variables and used arbitrarily for each tested model. The present situation of the lake was considered as the dependent variable. The parametric approaches, used in modelling were multi linear regression (MLR), nonlinear regression (NLR) and decision tree (DT). Nonparametric approaches applied in the modelling were artificial neural networks (ANN) with different functions. Generalized regression neural network (GRNN), radial base function (RBF) and feed forward back propagation (FFBP) were used as ANN models. Three criteria of coefficient of determination, Lin's concordance correlation coefficient and root mean square percentage error were used in comparison of the results. Each model was given a grade through each criteria of the measurement in the magnitude of zero to ten for comparison. The summation of the grades for each method was accepted as the prosperity of each method. Results show that the NLR is the superior method of all, while GRNN shows the worst results.

HIGHLIGHTS

- ANN methods are superior methods in forecasting lake elevation while the FFBP methods are the best methods among them. DT and GRN methods fail to estimate the elevation due to low results of determination coefficient, root mean square percentage error and concordance correlation coefficient, while decision tree is still superior to GRN.
- DT, as a forecasting method which uses classification for data treatment, fails to forecast the trend of data while no random selection is considered.

DERIVATION OF CRITICAL RAINFALL THRESHOLDS FOR SHALLOW LANDSLIDES: AN APPLICATION TO SICILY

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ABSTRACT

Rainfall is one of the primary trigger of shallow landslides that can cause fatalities, damage to properties and economic losses. For this reason, determining the rainfall amount/intensity responsible for landslides occurrence is important, and may contribute to mitigate the related risk and save lives. Efforts have been made in different countries to investigate triggering conditions in order to define landslide-triggering rainfall thresholds. The rainfall thresholds are generally described by a functional power law between cumulated or intensity event rainfall and duration, whose parameters are estimated empirically from the analysis of historical rainfall events that triggered landslides.

The aim of this paper is the derivation of critical rainfall thresholds for landslide occurrence in Sicily, southern Italy, by focusing particularly on the role of the antecedent wet conditions. The creation of the appropriate landslide-rainfall database likely represents one of main efforts in this type of analysis. For this work, historical landslide events occurred in Sicily from 1916 to 2001 were selected from the archive of the Sistema Informativo sulle Catastrofi Idrogeologiche, developed under the project Aree Vulnerabili Italiane. The corresponding triggering precipitations were screened from the raingauges network in Sicily, maintained by the Osservatorio delle Acque - Agenzia Regionale per i Rifiuti e le Acque. In particular, a detailed analysis was carried out to identify and reconstruct the hourly rainfall events that caused the selected landslides.

A statistical technique was used to determine the uncertainties associated with the threshold parameters. The rainfall thresholds at different exceedance probability levels, 1%, 5% and 50%, were defined in terms of cumulated rainfall event, E, and rainfall duration, D. The role of rainfall prior to the landslide events was taken into account by including in the analysis the rainfall occurred 5, 15 and 30 days before each landslide. The antecedent rainfall turned out to be particularly important in triggering landslides. The rainfall thresholds obtained for the Sicily were compared with the regional curves proposed by various authors confirming a good agreement with these.

HIGHLIGHTS

- The creation of the appropriate database required to derive the landslides-rainfall thresholds may represent one of main efforts in this type of analysis.
- The antecedent rainfall turned out to be particularly important in triggering landslides.
- The rainfall thresholds obtained for the Sicily were compared with the regional curves proposed by various authors demonstrating good results.
- The rainfall thresholds found in this work can be the basis to assess risk and set up warning systems.

PERFORMANCE-WEIGHTED METHODS FOR ESTIMATING MONTHLY STREAMFLOW: AN APPLICATION FOR MIDDLE EUPHRATES BASIN

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ABSTRACT

In this study, it was intended to estimate monthly streamflow measurements with the help of new methods, taking into account the difficulty of providing data in our country. Monthly streamflow data was studied at five streamflow gauging stations in the Middle Euphrates basin, which was selected as the area for case study. Each streamflow station spans a 31-year period from 1970 to 2000. Three different classes of flow transfer techniques were used: the drainage area ratio (DAR), standardization by means (SM), and standardization by mean and standard deviation (SMS). Linear regression was used to estimate the mean and standard deviation of the annual and monthly flows at the ungauged sites for the SM and SMS methods. In linear regression equations two separate variables were used: drainage area (A), drainage area and basin elevation (A+E). The statistics of prediction performance, namely the Nash-Sutcliffe efficiency (NSE) and the root mean square error (RMSE) were used for performance evaluation of estimation techniques. It was shown that the performances of both SM and SMS methods that use regression were generally superior to the performance of DAR method. In regression, methods that use drainage area and basin elevation (A+E) variables were shown to have better prediction performance than methods which use the drainage area (A) variable.

HIGHLIGHTS

- This study has demonstrated that simple statistical methods can be used successfully to estimate monthly streamflow records at ungauged sites.
- Reliable streamflow data in ungauged sites obtained with the use of these methods will provide an important contribution to water resources planning.
- The performances of both SM and SMS methods that use regression were generally superior to the performance of the DAR method.

FLOOD SCENARIOS DETERMINATION USING NON-STATIONARY FLOOD FREQUENCY ANALYSIS IN COASTAL AREAS

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ABSTRACT

Among natural disasters, floods have the economic loss. Flooding could be devastating when it happens in urban area of the coastal regions. Floods in coastal region resulting from heavy rainfalls and storm surge have become a serious concern in recent years. This situation has been intensified by climate change resulting in sea level rise and an increase in storm frequency and intensity. The issue of data stationary has also been debated due to climate variability and climate change. In this study, the data stationary of rainfall and storm surge are investigated and non-stationary frequency analysis is performed to determine the extreme flood events in term of maximum water level depth with different return periods. The non-stationary statistical approach is based on the generalized extreme value (GEV) distribution and an L-moment parameter estimation. This approach has been utilized to determine the flood inundation (maximum water depth) in New York City. The study is an effort to provide an approach for a more reliable estimation of the design return flood for engineering aims. The results are also compared with common stationary methods. In addition, some definitions and methods for testing on stationary or non-stationary are discussed. All the methods are applied to the annual maximum water levels and rainfall from 1920 to 2013 in New York City. The results show that the non-stationary GEV approach is suitable for determining coastal design water levels.

HIGHLIGHTS

- Joint probability distribution in simultaneous evaluation of storm surge and rainfall.
- Frequency analysis of non-stationary rainfall and sea level data.

COMPUTATION OF SEDIMENT GRAPHS IN EVROS RIVER BASIN

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ABSTRACT

Evros River basin is a transboundary basin which extends in three countries: Bulgaria, Greece and Turkey. The whole basin area is about 53000 km2. 66% of the basin area belong to Bulgaria, 28% to Turkey and 6% to Greece. Evros River length in Bulgaria (Maritsa River) is about 321 km, in Greece about 218 km, while 203 km are the natural border between Greece and Turkey. In this study, continuous sediment graphs, due to continuous hyetographs and hydrographs of the time period January 2003 – January 2007, were computed at the outlets of the sub-basins of Evros River by means of the well-known hydrologic software HEC-HMS in combination with the soil erosion model of Poesen (1985) and the sediment transport model of Yang and Stall (1976). In concrete terms, the Bulgarian part of Evros (Maritsa) River basin was divided into 27 sub-basins and the Greek part into 13 sub-basins. Apart from that, the basin of Tountza River, which is a tributary of Evros River flowing through Bulgaria and Turkey, was divided into three sub-basins. Finally, the basin of Erythropotamos River, which is a tributary of Evros River flowing through Bulgaria and Greece, was also considered. The comparison results between the computed and the measured mean annual value of sediment transport at two certain gauge stations in Bulgaria (Belovo and Parvomay) are relatively satisfactory.

HIGHLIGHTS

- Continuous sediment graphs, due to continuous hyetographs and hydrographs of the time period January 2003 – January 2007, were computed at the outlets of Evros River sub-basins.
- The comparison results between the computed and the measured mean annual value of sediment transport at two certain gauge stations in Bulgaria (Belovo and Parvomay) are relatively satisfactory.

AN ESTIMATION OF THE SUSPENDED SEDIMENT LOAD USING SUPPORT VECTOR MACHINE AND ARTIFICIAL NEURAL NETWORK MODELS

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ABSTRACT

Sediment transport in streams and rivers takes two forms as suspended load and bed load. Suspended load comprises sand + silt + clay-sized particles that are held in suspension due to the turbulence and will only settle when the stream velocity decreases, such as when the streambed becomes flatter, or the streamflow into a pond or lake. The sources of the suspended sediments are the sediments transported from the river basin by runoff or wind and the eroded sediments of the river bed and banks. Suspended-sediment load is a key indicator for assessing the effect of land use changes, water quality studies and engineering practices in watercourses.
Measuring suspended sediment in streams is real sampling and the collection process is both complex and expensive. In recent years, artificial intelligence has been used as a predictor for hydrological phenomenon namely to estimate the amount of suspended sediment.
In this paper the abilities of Support Vector Machine (SVM) and Artificial Neural Network (ANN) models to predict suspended sediment load (SSL) will be investigated to estimate the suspended sediment load in Ispir Bridge gauging station on Coruh River (station number: 2316). Coruh River is located in the northern east part of Turkey and it is one of the world's the fastest, the deepest and the largest rivers of the Coruh Basin. In this study, in order to estimate the suspended sediment load, different combinations of the streamflow and the suspended sediment load were used as the model inputs. Its results accuracy was compared with the results of conventional correlation coefficient analysis between input and output variables and the best combination was identified. Finally, in order to predict SSL, the SVM and various ANN models were used. The reliability of SVM and ANN models were determined based on performance criteria such as Root Mean Square Error (RMSE), Mean Absolute Error (MAE), Efficiency Coefficient (EC) and Determination Coefficient (R^2).

HIGHLIGHTS

- Suspended sediment load is estimated by SVM and ANN models

- Different combinations of the streamflow and the suspended sediment load were used as the model inputs.
- The accuracy of the model results was compared with the results of conventional correlation coefficient analysis.
- The reliability of SVM and ANN models were determined based on performance criteria.

SPI AND DROUGHT ASSESSMENT UNDER LONG-TERM PRECIPITATION VARIABILITY

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ABSTRACT

Drought indices are used to quantify drought severity and evaluate the departure from normal conditions. The use of the SPI as a universal drought index is recommended by WMO since 2009. Due to its probabilistic and standardized nature a given value of SPI computed in distinct time periods or locations indicates the same relative drought severity but corresponds to different amounts of precipitation. The inversion of the SPI statistical and computational algorithm allows the estimation of the amount of precipitation relative to a given index value. The present study aims at contributing for a comprehensive analysis of the influence of long-term precipitation variability on drought assessment by the SPI. Long records of monthly precipitation spanning from 1863 to 2007 in several locations across Portugal were divided into sub-periods and the SPI-12 was computed within each sub-period and for the entire record. The structural stability of the complete precipitation and SPI-12 time series was analysed. Thresholds relative to the upper limits of SPI-12 drought classes were obtained and the influence of time period was investigated. For the majority of the locations lower values of the 12-month cumulated precipitation SPI relative to severe drought category in the more recent period were found. A common pattern of drought aggravation from the initial until the more recent period was not detected.

HIGHLIGHTS

- The influence of long-term precipitation variability is reflected on the SPI drought class precipitation thresholds in different reference periods.
- Lower values of the 12-month cumulated precipitation SPI relative to severe drought category in the more recent period 1976-2007 was apparent.
- Precipitation thresholds relative to SPI drought categories along with observed precipitation are useful information for water managers.

APPLICATION OF THE SPI TO THE DROUGHT ANALYSIS IN SLOVAKIA. DROUGHT REGIONALIZATION AND EMPORAL EVOLUTION OF THE DROUGHT AREA

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ABSTRACT

Based on the rainfall records from the Slovak Hydrometeorological Institute at a large number of climatic stations over a considerable span of time, a comprehensive drought analysis for the entire Slovakia is being carried out. Some of methods applied as well as some of the results achieved are briefly mentioned in this paper, namely (i) the treatment of the monthly rainfall series (filling of the gaps), (ii) the assessment of the regional drought modes by applying Principal Component Analysis (PCA) and Varimax rotation to the Standardized Precipitation Index (SPI) computed at the three months' time scale (SPI3), and (iii) the temporal evolution of the area under drought in each one of the homogenous regions previously identified. For the time scale adopted, the study showed that it is possible to clearly identify four homogenous regions in terms of drought temporal patterns. It also showed that the droughts are recurrent in Slovakia. Some of the more extreme drought events affecting the whole country were identified.

HIGHLIGHTS

- A contribution to characterize drought for the entire Slovakia.
- A comprehensive application of the SPI as a fundamental index to assess the drought.
- Demonstration of the capability of the SPI index to quantify the drought episodes at different time scales, thus enabling to address the different type of droughts (meteorological, agricultural and hydrological), as well as to understand the historical behaviour of droughts in the region.
- A proposal of regionalization of Slovakia regarding droughts.

- An analysis of the temporal evolution of the area affected by droughts in Slovakia.

ANALYSIS OF BASIN DROUGHT FOR THE GEDIZ RIVER

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ABSTRACT

Drought is a natural and reversible feature of climate and occurs almost in all climatic regimes, and its effects are not restricted simply to arid and semi-arid areas. Drought can also occur in areas with high precipitation in each season of year and cause considerable damages to agricultural and industrial sectors and to cities. In the present study, drought of the Gediz river basin was investigated according to the total monthly precipitation data obtained from synoptic stations in the region, using Precipitation Index Percent of Normal (PNPI) and Standardized Precipitation Index (SPI) in four time scales (3, 6, 12, and 24 months). The results show that short-term scales response quickly to rainfall changes, while drought is continued more in long-term scales. That's why drought frequencies in long-term series (scales) minimize. In addition, by comparing the time scales, it is found that a region may be in wet conditions in a time scale, while be in dry conditions in another time scale simultaneously.

PRECIPITATION TREND DETECTION FOR SLOVAKIA

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ABSTRACT

The study of climatological and hydrological data is performed with goal to reduce impacts of droughts and floods. The trend analysis applied to climatological time series can contribute to understand the behaviour of those series and to establish connections between such behaviour and the climate variability. The aim of this study was to apply a trend analysis to precipitation data at climatic stations in Slovakia. The present study area is prone to extreme climate events such as drought and flood. For that purpose the Mann–Kendall non-parametric statistical test coupled with the Sen' slope estimator were applied. The results of trend analysis applied to precipitation monthly data are presented for the hydrological year (from November to October). The length of the periods analyzed were 33 years (1980-2013). It was found increasing trends in precipitation time series in the most of stations in Slovakia. The results proved previous climatic studies in the area of middle Europe.

HIGHLIGHTS

- Most of the recent studies about climate change suggest that the behaviour of some of the climatological variables has already changed and will continue to change towards increasing or decreasing magnitudes and frequencies, depending on the type of variable.
- Increased rainfall and floods are expected in some regions while other regions will experience smaller rainfall and longer droughts, meaning water scarcity.

- The Mann-Kendall test coupled with the Sen's slope was applied to identity the significant trends, as well as the increasing or decreasing trend and the magnitude of those trends.
- The results achieved for precipitation ure revealed more frequent significant increasing trends, thus confirming previous climate studies for the region.

RIVER FLOW ROUTING IN PRISMATIC TRAPEZOIDAL GEOMETRY BY AN ADAPTIVE TIME DELAY METHOD

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ABSTRACT

Simplified flow routing model is favourably used for control-based application because it does not only present acceptable results but also is computationally inexpensive. Recently, the Time Delay model (TD) with two parameters, time constant and time delay has been developed in order to approximate the river flow in a very wide rectangular profile. This paper presents an advancement we thereafter call Adaptive Time Delay model (ATD) that expands the application scope of the TD Model by simulating the flow using a prismatic trapezoidal geometry. Firstly, the mathematical representation of the ATD model and the linearized Saint Venant model (SVE) are defined. Secondly, the transfer functions of the ATD model and the complex hydraulic model (SVE) are obtained by Laplace transformation. Finally, the Taylor expansion technique is used to find cumulants of the two transfer functions, and consequently equating the cumulants to derive time constant and time delay of the ATD model as functions of the complex hydraulic model parameters. By applying the fourth order Runge Kutta numerical scheme the flow rate and water level at downstream reach end are simulated. The innovation of this research is that both water stage and flow rate are derived through optimization. The performance of the ATD Model is also presented and compared to the TD Model in a case study. The extension of the time delay model does not only issue more accurate results but also introduces more outcomes like flow rate, and relation curves between time delay and time constant with discharge that might be useful in flood forecasting and other purposes in water resources operation.

HIGHLIGHTS

- An upgrade for time delay model of river flow is introduced.

- The variation of lag time and time constant in response to stage and rate of flow are estimated.

FLASH FLOOD SIMULATION IN SMALL CATCHMENTS BASED ON COMBINED HYDRODYNAMIC AND HYDROLOGIC APPROACH

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ABSTRACT

In this study, the simulation of a flash flood event in a small catchment is presented using two methods: a) a hybrid hydrological/hydrodynamic method based on the unit hydrograph theory and b) a fully hydrodynamic method. For this purpose an improved version of the hydrodynamic FLOW-R2D model is devised. The FLOW-R2D model is based on the Shallow Water Equations in two-dimensions (2D-SWE), solved by a modified McCormack numerical scheme (Finite Difference Method) incorporating artificial viscosity in the 2D-SWE. In this study, precipitation and infiltration processes are modelled in the simulation of floods leading to a new enhanced version of the model. This is achieved through the addition of source and sink terms in the Continuity Equation of the 2D-Shallow Water Equations. The enhanced model is applied with the two methods for the simulation of an extreme event which occurred in a small catchment of the Halandri stream, in a suburb of Athens-Greece, in February of 2013. The output is the flood hydrograph at the catchment outlet using rainfall data of the specific episode recorded at the meteorological station in the area. The results from the implementation of the two methods are compared with the measured data at the hydrometric station at the outlet of the catchment. It is noticed that the hybrid method requires much less computational time from the hydrodynamic method which for many long events is prohibitive. However based on the case study, this hybrid model does not seem to capture the peak flow adequately, probably due to the choice of infiltration modelling.

HIGHLIGHTS

- Simulation of flash flood events based on a combined hydrologic and hydrodynamic approach
- 2D flash flood modelling incorporating precipitation and infiltration losses
- FLOW-R2D model improvement

- Derivation of unit hydrograph of small catchments, using deterministic physically-based models

INVESTIGATION OF METEOROLOGICAL INDICATORS AND NORTH ATLANTIC OSCILLATION VARIABILITY ON THE EGIRDIR LAKE LEVELS IN TURKEY

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ABSTRACT

Lake levels may be changeable during different periods depending on various variables such as rainfall, recharge, evaporation and outflow etc. Predictable periodic movements occur significant portion of the factors caused short-term changes. Nevertheless, global climate changes and so encountered big climate events have a significant impact on the lake levels in recent years.

In this study relation between meteorological parameters, NAOI and lake levels of Egirdir lake were investigated. This process will be evaluated not only with climate indicators but also with the time variations of the meteorological data. According to the Mann-Kendall test results it is revealed that the meteorological parameters are affected strongly from North Atlantic Oscillation at Isparta station. It is also revealed that the levels of Egirdir lake are affected inversely from North Atlantic Oscillation.

ANALYSIS OF FLOOD AND DROUGHT CHARACTERISTICS OF ÇORUH RIVER BASIN

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ABSTRACT

The flood and drought characteristics of Çoruh River Basin No.23 were analysed. Three Flow Stations, Station 2304, Station 2305, and Station 2316, belonging to the Basin were examined individually via several different statistical methods as well as being examined regionally to get a better idea of the flood and drought characteristics of the basin as a whole. This research was significant since the world is going through major climate changes and thus floods and droughts are major concerns in the present day. In addition, the main purpose of this investigation was to determine whether the River Basin's Flow Stations' features and statistical characteristics could be used to determine an effective solution for Flood Control and Drought Management at Çoruh River Basin. The data obtained consisted of several decades of "Annual Maximum", "7-Day Minimum", and "Annual Mean Flow in a Year" for the individual stations. The Flood Analysis was performed based on the Annual Maximum Flow Data and Drought Analysis was performed based on the Annual 7-Day Minimum Flow Data. After applying Probability Distribution Models, Trend Analysis, PPCC Test, Run Analysis, and 7-day Minimum Flow Analysis to the stations, several outcomes were obtained. In conclusion, it was apparent that the Flood and Drought Characteristics of the three stations belonging to one basin showed characteristic features and were not necessarily similar even though they resided in relatively close areas.
The conclusions obtained from this study are significant since Design Engineers could benefit from these statistical results with combination of other stations' analyses to create Flood Control and Drought Management Systems for Coruh River Basin area, which is an area of a Development Plan that consists of the construction of thirteen large hydroelectric dams.

HIGHLIGHTS

- Similar statistical characteristics of Flow Stations can be used to develop an efficient System Design for Flood and Drought Management Control.

- For an ungauged station, data obtained from Regional Analysis on a basin could be used to design a Flood Control and Drought Management System for that specific station.

TESTING THE GOODNESS OF FIT BY INFORMATIONAL ENTROPY

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ABSTRACT

Water resources planning and management had become more important in parallel to increasing populations and higher emissions from human activities, including industrial wastes. Efficient use of water resources appeared to be a necessity due to increasing pollution levels and exposure to management problems on clean water resources. For this purpose, the task of information gathering in improved quantities and rapidly about water resources gained bigger importance, where more useful and easily applicable methods have been studied. In water resources planning and management, the characteristics of the variable must be known for developing water resources systems. The main characteristic of the system can be defined by the best-fitting of probability distributions to the observed data. Hence, testing the goodness of fit is an essential part of the data analysis to define the distribution function of the population. The testing methods, like as Chi-square, Kolmogorov Smirnov and Probability Plot Correlation Coefficient have different incompatible strong/weak features. For this reason, various methods are used to test the goodness of fit. The scope of the presented study is to test the goodness of fit by entropy based method. To this end, 41 different precipitation gauging stations are used in the study area - Gediz Basin, which is selected because of increased problems in agricultural water use and domestic water supply throughout the basin. The results showed that, Informational Entropy Method – in other words, Entropy Based Method - can be used as an acceptable test of "goodness of fit" with regard to its own power.

HIGHLIGHTS

- In probability analysis, best fitting probability distribution is investigated for all precipitation gauging station in Gediz Basin.
- Informational entropy method is seemed to be fitted for all precipitation gauging stations in normal distributions, as Kolmogorov-Smirnov test.
- The results are shown that informational entropy method can be used as a "*goodness of fit*" test.

COMPARISON OF LINEAR REGRESSION, NON LINEAR REGRESSION AND ARTIFICIAL NEURAL NETWORK MODEL FOR DOWNSCALING OF RAINFALL AT SUBANSIRI RIVER BASIN, ASSAM, INDIA.

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ABSTRACT

Covering a total length of 520 km and a drainage area of approximately 34,000 sq. km. up to the confluence of the River Brahmaputra, the river Subansiri is considered as the largest tributary of Brahmaputra. Recently a series of hydropower dams have been planned on this tributary of River Brahmaputra. One of the projects is already under construction. Considering the construction of these important projects, it is necessary to evaluate the possible impact of climate change on the flow scenario of the river. Rainfall plays an important role in variation of discharge. In this study, an attempt has been made to downscale the rainfall at Subansiri river basin using multiple linear, non-linear regression based statistical downscaling method and Artificial Neural Network model. APHRODITE gridded rainfall data available at 025˚ x 0.25˚ resolutions from 1960 to 2007 at 24 different points have been used as the predictand and climatic parameters of HadCM3 GCM of resolution 2.5˚ x 3.75˚ (latitude by longitude) have been used as the predictors. The predictor selection has been done by Pearson Correlation. The forecasting ability of these models has been assessed on the basis of Mean Square Error (MSE), Mean Absolute Error (MAE) and Root Mean Square Error (RMSE). It has been observed from this study that multiple non-linear regression based statistical downscaling method gives better result than linear regression and ANN.

HIGHLIGHTS

- The multiple non-linear regression method gave better prediction than multiple linear regression and Artificial Neural Network.
- Due to its high resolution, APHRODITE rainfall data can efficiently be used as predictand
- All the three methods show an increase of precipitation in future.

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TRENDS OF REFERENCE EVAPOTRANSPIRATION OVER GREECE IN A FUTURE CLIMATE

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ABSTRACT

In this study, estimates of reference evapotranspiration (ET) trends from the locally calibrated ''Reference evapotranspiration Model for Complex Terrains'' (REMCT) are investigated. Pan evaporation measurements (Epan) and ET estimates based on the calibrated REMCT model are analysed in 13 stations in Greece during the period 1979-2004. ET estimates from Penman-Monteith method are also considered, for comparison reasons. Similarities between magnitudes and trends of Epan and ET either from the calibrated REMCT model (ET_{DB}) or the Penman- Monteith (ET_{PM}) method are examined on monthly, seasonal and annual basis for investigating the use of ET_{DB} as an ET formulation based on minimum data, in order to predict changes in ET in a future climate. Epan and ET_{DB} (or ET_{PM}) have been found well correlated with similarities between the magnitudes and signs of their trends (in various time scales). The use of projections or corrected projections of the parameters acquired in the calibrated REMCT model is verified through comparisons with ET_{DB} estimates based on observations during a control period. Daily projections of temperature and precipitation from the RACMO2 regional climate model are employed in REMCT model to estimate reference evapotranspiration ($ET_{DB\ proj}$) in 29 stations in Greece during 1979-2004 (control period). The DBS (Distribution Based Scaling) method is used for the bias corrections of temperature and precipitation projections and the corrected values are used in the estimation of ET_{DB} ($ET_{DB\ cor}$). Furthermore, the corrected projections of the RACMO2 model are employed in the calibrated REMCT model and $ET_{DB\ cor}$ trends are also estimated for the future period (2011-2100) and compared with the corresponding ones of the control period. Positive trends are found for $ET_{DB\ cor}$, accompanied mostly with negative precipitation trends and increasing temperatures.

HIGHLIGHTS

- Similarities between the magnitudes and signs of ET_{PM}, ET_{DIOBEL} and Epan trends are found on yearly seasonal and monthly basis.
- Projected climate model outputs employed in ET_{DIOBEL} can be used to estimate changes in future ET.
- The method DBS (Distribution Based Scaling) improved the bias correction of temperature and precipitation projections.
- ET_{DIOBEL} trends are positive during 2011-2100.

EVAPORATION AND CROP EVAPOTRANSPIRATION ESTIMATES OVER THESSALY PLAIN, GREECE, BASED ON REGIONAL CLIMATE MODELS' SIMULATIONS

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ABSTRACT

Evaporation and crop evapotranspiration consist the most significant processes of the water cycle on which irrigated agriculture is based in the areas across the Mediterranean. These processes, related to a great extent to the prevailing climate conditions, are expected to change in future as a result of the projected increase in air temperature due to global warming and will affect the availability of water resources and eventually will modify agricultural practices. The present study investigates the effects of climate change on evaporation and crop evapotranspiration losses of the Thessaly Plain located in Central Greece. This plain is dominated by agriculture and irrigated crops sustain economically the local population. Presently, the mostly cultivated irrigated crops are maize, cotton, alfalfa, vegetable crops, vineyards and deciduous fruits and nuts. As a result of the present agricultural practices, the sustainability of the area will depend on how fresh water supplies meet crop water needs - evaporation and evapotranspiration losses. These losses are estimated and the modified FAO 56 Penman-Monteith formula is utilized, based on simulations of daily meteorological data (temperature, humidity, wind speed, solar radiation), from a number of six Regional Climate Models (RCMs), within the ENSEMBLE European Project. All six RCMs have spatial resolution 0.22° x 0.22° (approximately 25km x 25km). The simulations of the six RCMs for the near future (2021-2050) and the far future (2071-2100) were made under the A1B emissions scenario, while the simulations for the reference period (1961-1990) were made under the 20C3M emissions scenario, which represents a 20th century simulation using historical GHG concentrations. The results of the performed analysis would help regional stake

holders to understand the impacts of climate change on crop evapotranspiration and crop water requirements, particularly in the agricultural regions prone to water scarcity in order to adapt crops to future conditions and mitigate the consequences of climate change.

ESTIMATING TEMPORAL CHANGES IN EXTREME RAINFALL IN SICILY REGION

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ABSTRACT

Several studies investigating long term changes in rainfall pattern over the Mediterranean area, have shown that the average number of rainy days is decreased during the last decades, whereas precipitation intensity is increased at the same time, as more and more heavy rainfall occur in shorter periods. In particular, an intensification of extreme rain events have recently characterized several areas of peninsular and insular Italy. In the present study temporal changes in 1-, 3-, 6-, 12- and 24-hours annual maxima rainfall series from more than 200 sites between 1928 and 2009 in Sicily region (Italy) are examined. For a more accurate analysis of extreme events, annual maxima series are first treated according to a standard regional frequency analysis to produce growth curves for homogeneous regions.
First a cluster analysis using at-site characteristics is used to determine homogeneous rainfall regions. Then, L-moments are applied to test the homogeneity of the clusters, and to derive regional growth curves. Four commonly applied distributions, namely the Lognormal (LN3), Generalized Extreme Value (GEV), Generalized Pareto (GPA) and Pearson type III (PE3), were investigated. Hence, potential changes in regional growth curve parameters and L-moment ratios during the observation period are analysed using a 10 year moving window and by splitting the records into separate decades. In addition, a bootstrap technique is used to assess uncertainty in the fitted growth curves and to identify significant trends in both distribution parameters and quantile estimates.

HIGHLIGHTS

- Cluster analysis using at-site characteristics is used to determine homogeneous rainfall regions in Sicily, based on both K-means and Ward's methods.
- Regional frequency analysis is carried out on 1-, 3-, 6-, 12- and 24-hours annual maxima series according to L-moments approach.
- Bootstrap technique is used to assess uncertainty in the regional growth curves.

- Changes in regional growth curve parameters and L-moment ratios are analysed using a 10 year moving window approach and by comparing quantile estimates among different decades.

TIME SERIES BEHAVIOURAL ANALYSIS OF OCEAN WIND SPEED – A CHAOTIC APPROACH

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ABSTRACT

The study of chaos (nonlinear chaotic analysis) helps us to identify the minimum number of dimensions sufficient to model the nonlinear dynamics of the hydrological systems. Even though many hydrological processes are proved to be chaotic, oceanographic parameters especially wind speed are yet to be studied for its behavior using chaotic approach. Correlation dimension method is most widely used for analysis. The present study presents the details of the data analysis of ocean wind speed and the application of correlation dimension method to find the chaotic behavior of ocean wind speed. Eleven year of data collected from ECMWF data Server has been used in the analysis.From the chaotic behaviour it is found that the ocean wind speed is showing chaotic behavior at high time lag but unpredictable behavior at low time lag.

A PROBABILISTIC APPROACH TO ASSESS THE STANDARDIZED PRECIPITATION INDEX IN A REGION OF SOUTHERN ITALY

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ABSTRACT

Drought is a normal, recurrent feature of climate that may occur everywhere, even though its characteristics and impacts vary significantly from region to region. Drought indices are useful for monitoring and assessing drought; however, these indices are calculated at sites and it is generally required to estimate the spatial distribution of drought in the forms of maps with a proper spatial accuracy. Geostatistical methods allow to interpolate and map spatially georeferenced data. In this study a probabilistic approach, based on the acceptance of uncertainty and a finite probability of making errors in SPI estimation, is presented as an alternative to traditional mapping methodology. The approach utilises geostatistical techniques of stochastic simulation to identify and model the spatial continuity of SPI and to develop alternate plausible simulations of SPI values in the Calabria Region. First, the SPI values have been evaluated using a daily homogeneous and gap-filled precipitation dataset. Then, five hundred simulations of SPI values were produced, using the turning bands simulation method. As a result, probabilistic summaries of the simulations provided tools for (1) estimating the range of plausible estimates of SPI at unsampled locations, (2) identify the locations of the boundaries between significant portions of the Calabria Region with different SPI values, (3) estimating the uncertainty in SPI values and evaluate the consequences of data uncertainty in decision making. Results suggest that the probabilistic prediction of SPI is a necessary pre-requisite for rational management of environment.

HIGHLIGHTS

- SPI values have been evaluated using a daily homogeneous and gap-filled rainfall dataset of 129 rain gauges with more than 50 years.
- A probabilistic approach is presented as an alternative to traditional mapping methodology.

- Five hundred simulations of SPI values were produced, using the sequential Gaussian simulation method
- Uncertainty in SPI values has been estimated and the consequences of overestimation and underestimation in decision making have been evaluated.

SPATIALLY DISTRIBUTED RECHARGE IN KARST GROUNDWATER MODELING

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ABSTRACT

In the modelling of unconfined aquifers, recharge due to infiltration is usually considered as uniformly distributed over the entire domain. In order to take into consideration the duality of infiltration in karstic terrains, a zonally distributed recharge model is developed in this study. The aim is to examine different hypotheses on the spatial distribution of recharge zones in a typical karstic aquifer. First, a 3D transient model is developed using the finite element code FEFLOW which allows for the integration of discrete features such as channels in a porous matrix. Special attention is given to the realistic representation of the dual character of karstic flow. Next, three scenarios for the spatial distribution of the recharge zones are examined. In the first scenario, the entire model domain receives the recharge. In the second scenario, recharge is introduced exclusively through faulted zones. In the third scenario, recharge is distributed in sub-areas selected based on geomorphological and hydrogeological criteria. For each scenario, simulation model results for the water table are compared with field measurements and discussed. The derived results indicate that greater model accuracy is achieved for Scenarios 1 and 3. Finally, a forth scenario, designed by combining Scenarios 1 and 3, exhibits the best fitting between simulation results and observation data. The methodology is applied to the karst aquifer of Palaikastro-Chochlakies in Eastern Crete, Greece, for the period 2008-2012.

HIGHLIGHTS

- The developed model performed well despite the large variation of the values of hydraulic heads within the model area.
- The optimal recharge water volumes were estimated for two scenarios regarding the recharge area extent. The overall scope of this study is to evaluate the sensitivity of recharge with respect to its spatial distribution.
- The proposed methodology introduces a more realistic approach to groundwater modeling of karstic aquifers.

MODELING AND COMPARISON OF WATER WAVES CAUSED BY LANDSLIDES INTO RESERVOIRS

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ABSTRACT

Landslides on the margins of dam reservoirs may generate large waves that can produce flooding over the banks or overtopping the dam crest. Therefore, the study of slope failures and the subsequent generation of water waves are of paramount importance for dam safety. In the present investigation, a boundary element model of a subaerial and submerge landslide is developed. Landslide generated waves are studied using a numerical model based on Navier-Stokes equations, with a VOF (volume of fluid) algorithm to track the interfaces. With this approach, the interaction between slide and water is implicitly solved. Validation is carried out by comparison between the computed prediction and experimental data of water waves generated by rigid body and by a deformable granular mass sliding into water, with the purpose of improving predictive simulations of landslide. The effects of bed slope angle, initial submergence, slide geometry, shape and deformation on impulse wave characteristics have been inspected. Impulse wave amplitude, period, energy are studied in this work. The effects of bed slope angle on energy conversion from slide into wave are also investigated, and the numerical model we will used in this study is the full three dimensional commercial code FLOW-3D. Results of the Navier-Stokes model show that waves generated are highly dependent upon the details of slide mechanism and kinematics. The calculated results show that the simulations agree well with experimental observation illustrating the potential of the proposed scheme.

HYDROLOGICAL AND MECHANICAL EFFECTS OF ROOTS IN SHALLOW LANDSLIDE ANALYSIS: A PHYSICALLY-BASED APPROACH

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ABSTRACT

This study provides the first insights of a methodology for estimating the additional cohesion exercised by vegetation roots in a hillslope landslide analysis within a coupled ecohydrological-stability model. The existing coupled system is able to simulate the spatial distribution and temporal dynamics of Factor of Safety (FS) as a function of soil moisture dynamics. The model takes into account the hydrological effects of vegetation which, through the root water uptaking, contributes in reducing the soil water content and, thus, in increasing the slope stability. The additional mechanical root cohesion is estimated in a Fiber Bundle Model (FBM) framework that allows for the evaluation of the root strength as a function of stress-strain relationships of populations of fibers. The use of such model requires the knowledge of the root architecture to evaluate the additional reinforcement from each root diameter class. In order to reproduce such characteristics, we adopted a branching topology model based on the Leonardo's rule that gives an estimation of the amount of root and the diameters distribution with depth at particular stage of plant life. The methodology has been tested in a simple synthetic hillslope with different configurations of vegetation types, i.e. tree and shrubs. The topological model has been calibrated using observed root area (AR) profiles of two considered vegetation types.

HIGHLIGHTS

- The simple case study allowed to carry out a deep investigation on the role of roots on slope stability, highlighting the importance of both the root

mechanical resistance and the root interactions with the main eco-hydrological processes.

- The hydrological effect of roots can be more significant than the mechanical one, especially for tree species on clayey soils.
- The root cohesion effect becomes particularly significant at low values of FS (i.e., ~1, failure proximity), especially for tree species.
- Further improvements of the work could take into account the weight of the plants, here neglected.

FLOOD DAMAGE RISK ASSESSMENT OPTIMIZING A FLOOD MITIGATION SYSTEM

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ABSTRACT

Flood risk management plan for potentially damaged areas is a main requirement from the European Directive 2007/60. Therefore, assessment and evaluation of the potential flood damages in quantitative terms need to be defined in mapped flood risk areas. Quantitative evaluation should be in agreement with the required cost-benefit analysis as a rational decision-making tool optimizing the flood mitigation system. In the first part of the paper, analyses are reported, based on recent flood events that had taken place in the Europe, in order to obtain depth-damage functions to apply in the Sardinia region (Italy). Flood damage functions are not still available for every European country and the paper analysed previous studies to define depth-damage functions for this region. The paper focuses then on the validation of the proposed depth-damage functions. The available flood data and reported damages of the massive storm happened in South-Est Sardinia the 22nd of October 2008 are analysed. Data analysis allows to compute the total economic losses for different land uses conditions and to compare with the evaluated ones. In the last part of the paper, expected damages evaluated using depth-damages functions are used for the Coghinas river lowlands valley. The regional Water District Authority defining the flood risk management plan considers this river basin as a pilot area. Applying hydraulic models to floodplain river flow allows evaluation of the expected flood damages using the depth-damage functions. Moreover, the procedure allows developing the cost-benefit analysis in order to justify different design scenarios and gives a rational decision-making tool optimizing the flood mitigation system

THE GLOBAL OPTIMISATION APPROACH FOR CALIBRATING HYDROLOGICAL MODELS: THE CASE OF MEDBASIN-D MODEL

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ABSTRACT

Conceptual hydrological models have been widely used as efficient tools for simulating the hydrological processes at river basin scale. Medbasin-D is a daily conceptual hydrological model included in the Medbasin software package. The model is oriented towards applications under the conditions of the Mediterranean. For a reliable prediction of streamflow, a successful calibration of the fourteen model parameters is required, based on measured streamflow data. Medbasin software includes a generic semi-automatic iterative calibration routine, based on the minimisation of a selected objective function. This procedure is time consuming, requires subjective decisions by the user and it is considered inefficient for exploring the optimal search space. It is the aim of this study to improve this calibration procedure by including a batch-processing module, to enable the implementation of coupled simulation-optimisation routines and the capability to interact with other widely used software packages. The enhanced Medbasin calibration module is presented in this paper along with a demonstration of the model calibration in a real world case study in the island of Crete (Greece). The Shuffled Complex Evolution (SCE) and the Genetic algorithms (GA) are two widely known global optimisation approaches that are tested with the Medbasin-D model. Several objective functions are used to test the performance of the calibration process under various hydrological conditions. Due to the stochastic nature of the global optimisers used for the calibration, a series of optimisation replicates are produced for assessing the statistics of each calibration procedure. Finally, the performance of the calibrated model over the validation period is assessed and discussed. Based on the case analysed, the results reveal that the SCE is more robust than the GA for all tested objective functions.

HIGHLIGHTS

- Medbasin hydrological software enhancement with batch-processing module for external calibration operation.
- Assessment of the performance of global optimisation algorithms for Medbasin-D model calibration.
- Evaluation of several objective functions for simulating various hydrological conditions.
- Medbasin-D model has most robust calibration results with the Shuffled Complex Evolution in comparison to the Genetic Algorithms.

COMPARISON OF MONTHLY STREAMFLOW FORECASTING TECHNIQUES

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ABSTRACT

Streamflow forecasting may provide many benefits to society such as improving the ability to plan and adapt to changing water supplies since the forecasting process is really related to the planning and operation of water resources system components activities. In this study a streamflow forecasting was researched on monthly streamflow data of Tigris River at Biji station in Iraq, Latitude: 34° 55′ 45″ N, Longitude: 43° 29′ 35″ E which was extended from 1931 to 2004. Different forecasting techniques were applied and compared for the above series. At first the traditional stochastic model Matalas which takes in consider the cross correlation between the streamflow values at nearby stations with the corresponding one (Lower Zab and Upper Zab stations) was applied. Then the Thomas Fiering model that deals with the streamflow as a single site variable also was tested, in addition to support vector regression (SVR) method. At last different artificial neural networks (ANN) algorithms were investigated. Each one of these methods has own properties which distinguish it from other methods or techniques therefore the comparison of the mentioned methods performance were achieved using the well-known parameters MAPE, MAE, E_{NASH}, R^2, R_{BIAS}.

HIGHLIGHTS

- In recent years, the importance of application of Artificial Intelligence techniques is very obvious for water quantity and quality management.
- We compared Matalas, Thomas Fiering, ANN and SVR methods for monthly streamflow prediction.
- The efficiency of different methods was demonstrated for Biji Station on Tigris River in the Iraq.

FLOODING RISK ASSESSMENT IN MOUNTAIN RIVERS

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ABSTRACT

The aim of this research work is to assess flooding risk in a mountain river section i.e. the determination of a relationship between water level peaks and the corresponding probability of non excedance for a location of interest. This computation takes into account the bed aggradation or erosion of sediment during the flood and the interval between floods. For this purpose fuzzy analysis is also used to strengthen the analysis of the existent data. The fuzziness is used to determine the morphological changes during the flood. The proposed fuzzy analysis includes the fuzzy linear regression analysis to determine the input variables, fuzzy extension principle together with an arithmetic scheme to determine the maximum water level and finally an fuzzy empirical probability distribution is applied to determine the risk. The results can be used to risk assessment of threatened areas with corresponding recurrence intervals.

HIGHLIGHTS

- Combined consideration of both the mass movement and more general the changed soil conditions with the hydraulic analysis
- Incorporation of the uncertainty by using hybrid probabilistic-fuzzy analysis
- Prediction of the flood propagation and sediment transport by using finite difference method.

OPTIMIZATION OF HEDGING RULES FOR RESERVOIR OPERATION DURING DROUGHTS BASED ON PARTICLE SWARM OPTIMIZATION

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ABSTRACT

This paper presents a methodology to achieve the identification of optimal hedging rules for operating reservoir systems, seeking to mitigate the drought impacts. The heuristic Particle Swarm Optimization (PSO) method is adopted as the optimization solver. This procedure establishes a two-phase method that combines PSO with the simulation of the water system, representing a system of reservoirs that are jointly operated to satisfy a set of demands with different priorities. The hedging rules are based on monthly storage levels that trigger restrictions on the demands. As model parameters, monthly rule activation thresholds and rationing factors were used for each type of demand. The optimization procedure minimizes an objective function that penalizes large deficits and assigns different weights to different demand types. Since the whole problem is quite complex, its dimensionality is reduced through: i) a set of candidate monthly activation thresholds are selected a priori associated to given risk conditions; and ii) the rationing factors are defined for every demand of each threshold throughout all months. In addition, an effort is made to avoid the trap in local optimums, whilst several other comments considering the application of the PSO method in the examined applications are provided. The procedure has been successfully applied to four water resource systems in Spain.

HIGHLIGHTS

- The formulation of optimal operating rules for reservoir systems under drought condition.
- The reduction of problem dimensionality based on risk analysis
- Convergence analysis of the PSO method
- Comparative results for five different reservoir systems

SIMULATION OF SEA WATER LEVEL VARIATIONS USING DATA DRIVEN MODELS: A CASE STUDY OF NEW YORK BAY

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ABSTRACT

New York City, surrounded by interconnected water bodies is prone to coastal flooding. Flooding in these coastal areas can be resulted from different causes including high tide sea level rise, and storms surges due to hurricanes and super storms. Manhattan, the most densely populated borough of New York City, is enclosed by water from all directions. Upper New York Bay, which is located in the south of Manhattan, is fed by Hudson River directly, is connected to the Lower New York Bay by the Narrows, to the Newark Bay by the Kill Van Kull, and to the Long Island Sound by the East River. The water level in the upper Bay is affected by interactions of all the aforementioned water bodies. In this study, the water level variation in the Upper New York Bay, based on the interactions among different water bodies, is simulated using a Monte Carlo based system dynamics model and then modified using data driven models. For this purpose, Artificial Neural Network (ANN) which is a data driven model is used. The capability of ANN for mapping a set of input/output data makes it a useful tool for modeling complex systems such as the modeling in this study. Several tidal, elevation and discharge gages are used in the model and the tidal station in the Upper NY Bay, Battery Park, is considered for the model calibration and validation. The results show the significant value of data driven models to simulate water level variation in the Upper New York Bay.

HIGHLIGHTS

- Dynamics in the NY bay system are modelled based on a data driven model.
- A neural network model is developed to simulate water level variations.
- Simulation of water level variations can be used to study the flooding from the storm surges in the region.

IMPACT OF LAND USE AND CLIMATE CHANGE ON HYDROLOGICAL PROCESSES: AN INTEGRATED MODELING APPROACH

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ABSTRACT

This paper describes an integrated environmental modelling system designed to investigate the potential impact of land-use and climate change scenarios on the hydrological processes of the Elbow River watershed in southern Alberta, Canada. This watershed is prone to drought in the summer and flooding in the spring, which resulted in extensive damages to the fast growing city of Calgary twice in the last decade. This system includes three models: a spatially-explicit land-use cellular automata, a distributed physically-based model (MIKE SHE/MIKE 11), and an agent-based model that allows the negotiation of stakeholders concerned by land development and water resources in the watershed. These models are linked and can be accessed through a web-based interface using a service oriented architecture that treats each model as a service and provides users with a unified experience that is platform independent. Simulation of four land-use change scenarios up to the year 2031 reveals that they affect the hydrology of the watershed differently. Simulation of hydrological processes under five climate change scenarios in the 2020s and 2050s indicates that the average annual and seasonal hydrological processes will be considerably modified. A shift in peak flow from late spring-early summer to middle spring will increase the risk of flooding, while the high flow season will become much shorter, increasing the risk of water shortage during periods of high demand. The integrated modelling system represents a unique simulation tool that could be used to guide watershed management.

HIGHLIGHTS

- An integrated modelling system was designed to simulate the impact of land use and climate change scenarios on hydrological processes.
- The hydrological processes will be considerably modified over the next 60 years.

- A shift in peak flow in middle spring-summer and a reduction of the high flow season will respectively increase the risk of flooding and water shortage.
- The integrated modelling system is a unique tool that could be used to guide watershed management.

MODELLING THE WATER AND NITRATE BUDGET USING SWAT

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ABSTRACT

Different types of models are used to simulate experimental conditions of agricultural catchments in which researchers can directly measure impacts of agricultural practices such as irrigation, fertilization etc. on the aquatic environments. Although direct measurement of outcomes under controlled conditions will always be more reliable than modelled estimations, a representative model of a catchment will enable those concerned to asses "what-if" scenarios. This study represents an application of the Soil and Water Assessment Tool (SWAT) to an agricultural catchment, covering a drainage area of 9 495 ha called Akarsu irrigation district, in the Lower Seyhan Plain, located at the Eastern Mediterranean region of Turkey. Therefore, main objective of this study was to introduce SWAT model and calibrate the model against daily drainage discharge and nitrate (NO3) concentrations derived from the field stations. The modelling period was covering the hydrological years of 2009 and 2010. Major input variables to run the model were climate data, soil type, land use, management practices and topography at watershed scale. Sequential Uncertainty Fitting (SUFI-2) linked to SWAT was utilized for calibration of the model. SUFI-2 is associated with SWAT in the Calibration Uncertainty Program called SWAT-CUP. Calibrations were conducted using the SWAT-CUP program and SUFI-2 algorithm. Calibration based on the Nash-Sutcliffe coefficient of efficiency (E) and R2 was done through using daily data. Interpretation of model calibration results led us to conclude that the simulated SWAT drainage flows and their corresponding nitrate loads were reasonably accurate for the Akarsu irrigation district.

HIGHLIGHTS

- Hydrologic distributed model, SWAT, was introduced successfully in the irrigated basin, and were be able to be calibrated satisfactorily.
- Drainage flow rates and their corresponding nitrate loads were simulated at the irrigation catchment level.
- Modelling results were calibrated and tested with ground measurements.

DISAGGREGATION MODELLING OF DAILY STREAMFLOWS USING A NEW APPROACH OF THE METHOD OF FRAGMENTS

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ABSTRACT

One of the possible ways to address the consequences of the temporal variability of the stream flows in the "performance" of some of hydraulic infrastructures uses synthetic flow series generated by a stochastic model. The stochastic generation of stream flows at a given time level can adopt two general approaches: (i) the generation at the required time level by applying an appropriate model directly to that level; or (ii) the generation of annual flows using an appropriate annual model, followed by the disaggregation of those annual flows into flows at the required time level. The first approach is feasible for a monthly level, but not for a daily level, while the second one can be applied to both levels. It also has the advantage of allowing the preservation of the historical statistical properties at both the upper time level (year) and the lower time level (month or day). Among the disaggregation models, one of the simpler is the method of fragments, which dates back to 1964. Based on the extensive application of the method of the fragments to the generation of monthly flow series in more than fifty Portuguese river gauges (Silva & Portela, 2011, 2012), it was possible to establish a criteria to define the classes of fragments and to select the fragments that proved to be very robust. Such method was slightly reformulated and applied to the generation of synthetic daily flows series, also with remarkable results. This paper describes the method, presents the results from its application and discusses its relevance to analyse the uncertainty due to the temporal variability of the flow regime.

HIGHLIGHTS

- Presentation of a new approach of the method of the fragments
- A contribution to the stochastic modelling of daily flows.
- A contribution towards the assessment of the uncertainty due to the temporal variability of the flow regime.

HYDROLOGICAL PROCESSES UNDER SCENARIOS OF LAND-USE/COVER AND CLIMATE CHANGE

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ABSTRACT

Climate change and population growth projections have increased concerns about the risk of flooding and the long-term sustainability of water resources in the Elbow River watershed in southern Alberta, Canada. This study was undertaken to investigate the responses of hydrological processes to the combined impact of climate and land-use/cover change in the watershed from 2011 to 2040. The physically-based, distributed MIKE SHE/MIKE 11 model was coupled with a land-use/land-cover cellular automata to simulate hydrological processes under five GCM-scenarios (NCARPCM-A1B, CGCM2-B2(3), HadCM3-A2(a), CCSRNIES-A1FI, and HadCM3-B2(b)). Simulations were conducted using the spatial distribution of land-use-based parameters extracted from the projected land-use maps of 2016, 2021, 2026, 2031, and 2036. Results reveal that most scenarios generate an increase in overland flow, baseflow, and evapotranspiration in the winter/spring, and a decrease in the summer/fall. The highest increase in streamflow occurs in mid-late spring (April-May) due to an increase in snowmelt and rain-on-snow events that may enhance the risk of flooding in these months. In addition, most scenarios reveal a reduction in the average annual overland flow and baseflow in the lowlands, in the eastern portion of the watershed adjacent to the fast growing City of Calgary, which might result in water scarcity, considering the projected future water demands. These substantial changes in the hydrological processes along with the snowpack reduction and graduated shift from snow to rain will alter the timing and frequency of peak flow in the watershed over the next 30 years.

HIGHLIGHTS

- The coupling of MIKE SHE/MIKE 11 and cellular automata models allowed the capture of the dynamical, physical, and distributed nature of the changes in the hydrological regime.
- Climate and land-use/cover changes significantly alter the seasonal and annual hydrological regime of the watershed.

INTEGRATED MODELING APPROACH TO STUDY THE IMPACT OF RESERVOIRS IN THE WATERSHED: THE CASE STUDY OF THE SORRAIA RIVER BASIN

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ABSTRACT

The construction of artificial reservoirs is growing due to the increasing agriculture activities, flood/drought events and energy needs. Reservoirs have usually socio-economic benefits, but negative environmental effects are usually pointed out by those opposing to the construction. In this context, integrated assessment of catchment functioning with and without reservoirs is essential to quantify their effect as stressors of ecological systems. Modeling is essential to allow multiple stressors scenario assessment.

This work is embedded into the FP7 project MARS, and its objectives are to implement and improve an integrated modeling approach (watershed and reservoir models) for characterization of the river basin, to improve a reservoir model to simulate the ecological processes in the reservoir, and to simulate the basin/reservoir under different scenarios of water scarcity combined with nutrient loads. The models implemented are the MOHID Land and MOHID Water. MOHID Land will simulate the Sorraia watershed, located in Portugal and the MOHID Water model will simulate the reservoirs Montargil and Maranhão. These models coupled can simulate the processes and scenarios needed to achieve the objectives of this work.

PUMPING OPTIMIZATION OF COASTAL AQUIFERS USING RADIAL BASIS FUNCTION METAMODELS

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ABSTRACT

Variable density flow and solute transport numerical models provide high-fidelity predictions of seawater intrusion at the expense of complex and time-intensive computer simulations. Using such models in pumping optimization problems of coastal aquifers, may lead to unreasonable computational burden. One of the methods to tackle this problem is to approximate the responses of the variable density numerical model to the input variables of interest, by using efficient data-driven models, often called surrogates or metamodels. In this paper, Radial Basis Function (RBF) models are proposed as surrogate models in coastal aquifer pumping optimization, for problems of moderate dimensionality. While RBF metamodels have been fairly utilized in many engineering optimization problems, their use has been neglected in coastal aquifer management. The optimization problem is first solved based on the variable density model, in order to set benchmark optimal solutions and computational time. Then the efficiency of surrogate models based on RBFs is investigated for two different metamodelling frameworks, namely, adaptive-recursive and metamodel-embedded evolution. In both frameworks, the "expensive" variable density model is selectively called to evaluate promising candidate solutions predicted by the RBF surrogate model. Results show that the metamodel-embedded evolution framework outperformed the adaptive-recursive approach while it successfully located the region of the global optimum. Furthermore, the computational savings are significant when a metamodel-embedded evolution strategy is followed, reducing by 96% the computational time associated with the variable density based optimization.

HIGHLIGHTS

- RBF models are investigated as metamodels for coastal aquifer management.
- Two different RBF-based optimization frameworks are assessed.
- RBF-based optimization located the global optimum with considerable computational savings.

VARIATION OF TOTAL SUSPENDED SOLIDS VERSUS NEPHELOMETRIC TURBIDITY IN THE STREAM DEĞIRMENDERE, SOUTHEASTERN BLACK SEA

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ABSTRACT

Suspended solids related studies based on direct measurements for Turkish rivers and streams are very few due to various reasons such as cost, time or fewer operational sediment gauging stations, and thus the researchers tend to look for indirect methods despite the fact that direct measurement of suspended solids is one of the most reliable methods. The Stream Değirmendere Watershed having a length of main branch of 55 km, a recharge area of 1,061 km^2, and a mean annual surface water potential over 550 hm^3 is of prime importance since domestic water demand of Trabzon people has been supplied by this watershed and it has economically exploitable but largely undeveloped hydropower potential. On the other hand, the watershed where a lot of run–of–river hydropower plants have been constructed and operated has been under pressure arising from the all kinds of anthropogenic activities such as construction regarding bridge, levee, and relocation of road and operation regarding drinking water treatment plants, concrete plants, crushing, screening and washing plants.
This paper aims to monitor the nephelometric turbidity (T) and determine the total suspended solids (TSS) in six stations selected on the main branch of Stream Değirmendere draining into the Southeastern Black Sea at the junction 41º 00′ 10.9″ N–39º 45′ 26.1″ E , and evaluate the semimonthly variation of TSS versus T from January to September 2014. The effects of the all kinds of anthropogenic activities on TSS and T are also investigated. Finally, it is focused on the suspended sediment transport to the Southeastern Black Sea and possible effects of this transport on Trabzon Harbour located at a distance of approximately 750 m far from the junction.

HIGHLIGHTS

- Based on the measuring results of nine-month from the first upstream station of the Southeastern Black Sea, it was determined that the SSC carried by the Stream Değirmendere to the Southeastern Black Sea was 360 mg/L and the

T was 310 NTU. Based on the SSC of 89 mg/L and the T of 58 NTU measured at the second upstream station, an increase of 306% in the SSC and 437% in the T were determined as a result of anthropogenic activities.

- The suspended sediment can accumulate in the entrance and inside of the Trabzon Harbor and cause a decrease in depth since the Stream Degirmendere has been draining into the Southeastern Black Sea at a distance of 150 m closer than the former point as a result of the Black Sea Coastal Road construction.

DOWNSCALING MONSOON RAINFALL OVER RIVER GODAVARI UNDER DIFFERENT SCENARIOS

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ABSTRACT

Climate change is considered to be the greatest challenge as distribution and circulation of waters become difficult to estimate because of additional uncertainty related to anthropogenic emission. Projecting the impact of climate change on hydrological cycle at river basin level is necessary to quantify the possible changes in the hydrological components. In the present study, Fuzzy clustering with multiple regression is used to downscale monthly monsoon precipitation over Godavari river basin, India. Mean sea level pressure, specific humidity and 500 hPa geopotential height are used as explanatory predictors. $1^o \times 1^o$ gridded rainfall data over Godavari river basin are collected from India Meteorological Department (IMD). Future scenario of monsoon rainfall over different IMD grid points over the basin is projected by applying the statistical downscaling to Canadian Earth System Model (CanESM2) simulations under the Representative Concentration Pathways 2.6, 4.5 and 8.5 (RCP 2.6, 4.5, 8.5) scenarios of Fifth Coupled Model Inter-Comparison Project (CMIP 5). Downscaling procedure is applied to all 25 IMD grid points over the basin to find out the spatial distribution of monsoon rainfall for the future scenarios. For 2.6 and 4.5 scenarios results show an increasing trend. For scenario 8.5 rainfall showed a mixed trend with rainfall decreasing in the first thirty years of forecast and then increasing gradually over the next sixty years.

HIGHLIGHTS

- The total monsoon rainfall over River Godavari is likely to increase under all the three future scenarios considered.
- The maximum increase in the average monsoon rainfall over the basin is observed under RCP4.5
- There is no significant variation in the spatial distribution of rainfall over the basin.

RECONSIDERATION OF SEDIMENT INCIPIENT MOTION CRITERION: A FUZZY SET APPROACH

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ABSTRACT

Uncertainties in the selection of critical shear stress, or other variable expressing the flow dynamics, may lead to large computational errors regarding sediment transport. The entrainment threshold is a vague concept that can be affected by the subjectivity of the researcher and his interpretation of what actually constitutes initiation of sediment transport. The pioneering work of Shields highlighted the statistical nature of the phenomenon and has been used by the majority of practitioners, in its original and revised forms during the last decades. However, the Shields diagram, as well as other criteria for the incipience of motion, operate under a general movement or no-movement concept and neglect some physical properties of the stream bed or the running water such as the particle positioning or the turbulent fluctuations, respectively. In order to avoid the ambiguity of selecting a threshold for the initiation of motion, and to provide a smoother transition to the state of general movement, this paper employs fuzzy regression and sets a lower and upper limit, that is, a fuzzy band, which correspond to weak sediment transport and general movement, respectively. Two approaches are used: the conventional fuzzy regression analysis and a goal programming based fuzzy regression. A significant improvement in this field is the modification of the fuzzy linear regression basis, which is made by establishing a distance (error) associated with the under estimation of the left-hand boundary and by the same way, a corresponding distance associated with the over estimation of the right-hand boundary. The total fuzziness and the total distance from the fuzzy band must be minimized in the optimization model. By following this approach the significant influence of the outliers can be avoided, contrary to the widely used fuzzy regression model. The implementation of the proposed fuzzy regression methods leads to curves in which the terms that contain the particle Reynolds number have not have no uncertainty, whilst the fuzziness appears in both the coefficient of the relative roughness and the constant terms.

HIGHLIGHTS

- The determination of the hydraulic conditions that lead to sediment incipient motion incorporating the uncertainty.
- Fuzzy set theory is used to model the initiation of sediment motion.
- A modified fuzzy regression model is used to avoid the significant influence of the outliers.

HYDROLOGIC MODELLING CALIBRATION FOR OPERATIONAL FLOOD FORECASTING

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ABSTRACT

Runoff prediction in flood forecasting depends on the use of hydrological simulation models and on the input of accurate precipitation forecasts. Reliability of predictions thus obtained hinges on proper calibration of the model. Moreover, when the model is intended to be used systematically in operational forecasting of streamflows, the calibration process must take into account the variation of the model parameters over time, namely in response to changing weather and hydrological conditions in the basin. The goal of the study was to build a process to predict, on a daily basis, the streamflow for the next 10 days period and, thereby, to forecast the occurrence of flood events. Towards this end, hydrological simulations using the HEC-HMS model were performed, using a 3 hours period time step. The present communication focuses on the hydrological model calibration and verification processes and on the evaluation of forecasts' accuracy. The procedure was applied to a part of the largest (full) Portuguese river basin, the Mondego river basin, corresponding to the Aguieira dam section watershed, which comprises an area of 3070 km^2. Four wet periods, associated with the occurrence of flooding, were selected for the calibration and verification of the model, by adjustment of the model parameters. The results of the study aim to define the optimal calibration parameters values to model the observed streamflow for various hydro-meteorological states, thus enabling adequate prediction of flow in flooding situations and proper application of the model in operational flood forecasting.

HIGHLIGHTS

- Hydrologic model calibration process that takes into account changing weather and hydrological basin conditions over time.
- A process to predict, on a daily basis, the streamflow for the next 10 days period, in order to use these results in operational flood forecasting.

EXPLORING THE POTENTIAL AND THE BOUNDARIES OF THE ROLLING HORIZON APPROACH FOR THE MANAGEMENT OF RESERVOIR SYSTEMS WITH OVER-YEAR CARRYOVER CAPACITY

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ABSTRACT

The paper presents a set of experiments on the Rolling Horizon Technique (RHT), applied to the management of a multi-reservoir, multipurpose water resources system with over-year carryover capacity. In the RHT, decisions on releases from reservoirs are taken for a number of time steps ahead (the Forecasting Horizon – FH) through an optimization model, based on the present water availability in reservoirs and on some forecasts of future inflows over the FH. Only the decision concerning the first time step (the current month) is then implemented, as new information on reservoir levels and forecasts becomes available so that the process can start again with updated information. The paper investigates how the quality of forecasts of future inflows and the length of the FH impact on the effectiveness of the decisions taken. The evaluation exercise is carried out considering some deficit-related indices, such as the sum of squared standardized deficits, over an Operation Horizon (OH) of forty years (water years from 1970/71 to 2010/11). Results show that in systems with large storage capacities compared to inflows, such as the ones designed for over-year river regulation, effective forecasts (here simulated through the best possible: actually occurred inflows from the current month up to the end of water year) seem to add little value to system's operation compared to the naivest forecast (average monthly values). A FH of 24 months seems to enhance significantly system's performances compared to a FH of 12 months, while FHs longer than two years produce marginal improvements in system's performances. The paper also tries to define the limits of a finite-Horizon operation technique such as the RHT by benchmarking it with an idealistic release schedule obtained by a model that performs allocation with Perfect Foresight over the whole Operation Horizon.

HIGHLIGHTS

- The temporal extent of droughts (several years of flows below long-term average) drastically reduces the scope for management and forecasting

- In systems with over-year carryover capacity, system's storage capacity controls the length of the appropriate decision horizon

RAINFALL-RUNOFF MODEL CONSIDERING MICROTOPOGRAPHY SIMULATED IN A LABORATORY EROSION FLUME

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ABSTRACT

Comprehensive rainfall-runoff models require detailed information for overland flow from both the interrill area and rill. Due to this fact, a process-based mathematical model for simulating overland flow generated on interrill areas and in rills of a hillslope is evaluated using a data set gathered from a laboratory experimental setup. A rainfall simulator has been constructed together with a 6.50 m x 1.36 m erosion flume that can be given adjustable slopes in both longitudinal and lateral directions. The model is calibrated and validated using experimental results from the setup of the flume having lateral and longitudinal slopes changing between 5% and 20% where rainfall intensities between 45 and 105 mm h-1 were induced with the use of nozzles. Results show that the model is capable of simulating the flow coming from the interrill areas and the rill for the rainfall intensities applied. It is found that the hillslope-scale model studied here can be used for better prediction of overland flow at the hillslope-scale.

HIGHLIGHTS

- Hillslope-scale rainfall-runoff models can be used as ground for watershed scale models.
- Laboratory-scale rainfall simulators are useful tools in producing data required for calibration and validation of analytical or numerical models.
- Rainfall-runoff models produce input data for sediment transport models.

STUDY OF FINAL SCOUR DEPTHS AROUND CIRCULAR BRIDGE PIERS IN CLEAR WATER CONDITIONS

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ABSTRACT

Failure of the bridges due to local scour around their piers can cause serious life losses and property damages and create significant environmental problems. In this experimental study, clear water scour depths around circular bridge piers were investigated within the scope of the project TUBİTAK 109M637. The experiments were carried out in a rectangular flume 80 cm wide, 18.6 m long and 75 cm high, existing in the Hydraulic Laboratory of the Civil Engineering Department within Dokuz Eylul University. The median diameter, geometric standard deviation and layer thickness of the uniform bed material were 3.47 mm, 1.39 and 25 cm, respectively. The circular bridge piers of diameters 4 cm, 8 cm, 15 cm and 20 cm were tested. The experiments were performed under steady state flow conditions, with four different constant discharges. Scour depths were measured by the indirect use of UVP (Ultrasonic Velocity Profiler) transducers which were located around circular bridge piers. Discharges were measured with electromagnetic flow-meter and flow depths were determined by ULS sensors. The experimental findings are interpreted in the light of available knowledge.

NUMERICAL SIMULATION OF FLOOD WAVE SPREADING IN 2D IN DENSELY POPULATED URBAN AREAS DUE TO DAM BREAK

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ABSTRACT

Dams are important structures having many functions such as water supply, flood control, hydroelectric power and recreation. Although dam break failures are very rare events, dams can fail with little warning and the damage at the downstream of the dam due to the floodwave can be catastrophic. During a dam failure, immense volume of water is mobilized at very high speed in avery short time. The momentum of the flood wave can turn to a very destructive impact force in residential areas. Therefore, from risk point of view, understanding the consequences of a possible dam failure is critically important. This study discusses a methodology utilized for predicting the flood wave occurring after the dam break and analyses the propagation of the flood wave downstream of the dam. The methodology used in this study includes creation of bathymetric, DEM and land use maps; routing of the flood wave along the valley using a 1D model; and two dimensional numerical modelling of the propagation and spreading of flood wave in two different urban areas. Such a methodology is a vital tool for decision making process since it takes into account the spatial heterogeneity of thebasin parameters to predict flood wave propagation downstream of the dam. Proposed methodology is applied to two dams; Porsuk dam located in Eskişehir and Alibey dam located in Istanbul, Turkey. Both dams are selected based on the fact that they have dense residential areas downstream and such a failure would be disastrous in both cases.

SIMULATION OF GROUNDWATER FLOW IN THE GEDIZ RIVER BASIN

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ABSTRACT

The objective of this paper is to present the approach and results of a groundwater flow modeling study that was conducted for the Gediz River Basin (GRB), located in western Turkey. The GRB is one of the most important, largest and stressed river basins in Turkey. This basin is agriculture-dominant; however significant competition for water exists among various stakeholders and sectors. The model is set up as a two-dimensional, finite-difference MODFLOW-2005 model that is solved for steady-state conditions, representing average annual groundwater flow in the basin. The main purpose of the groundwater flow model is to determine groundwater flow dynamics and water budget for the alluvial aquifers of the GRB. Pumping wells in the GRB predominantly withdraw water from these aquifers. A model-based estimate of the hydraulic conductivity distribution is also obtained. A two-stage modeling approach is taken to determine boundary conditions of the alluvial aquifer model domain. This approach results in two independently calibrated models that are referred as baseline and alluvial flow models. Modeled groundwater heads of both models provide an acceptable fit to observed data. The range of hydraulic conductivity (K) values is from 0.01 to 4451 m/d indicating a very heterogeneous aquifer. The median K value is 34.92 m/d and the standard deviation is 366.45 m/d. According to the baseline flow model budget, it can be concluded that the most significant groundwater input for the entire GRB is leakage from surface water such as dam reservoirs and the Gediz riverbed. In the alluvial aquifer, surface water still plays an important role in the water balance, however lateral flows across aquifer boundaries are the most important component. Also, groundwater extraction is larger than groundwater recharge by precipitation.

HIGHLIGHTS:

- First-ever groundwater flow modeling study for the Gediz River Basin (western Turkey) is presented.
- A two-stage modeling approach that comprises a baseline and an alluvial flow model is taken.
- Range of calibrated hydraulic conductivity values is large indicating a very heterogeneous aquifer.
- Baseline flow model budget indicates that most significant groundwater input for the entire basin is leakage from surface water.
- Groundwater extraction is larger than groundwater recharge by precipitation.

DEVELOPMENT AND APPLICATION OF A WATER LEVEL ZONE DECISION METHOD FOR LONG-TERM RESERVOIR OPERATION USING THE DYNAMICALLY DIMENSIONED SEARCH ALGORITHM

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ABSTRACT

The purpose of the study is to develop a long term reservoir operation method that is accessible to dam operators. The zone-based operation is a simple method to make operation decisions by rules established to storage zones. The reservoir storage levels dividing the reservoir storage, however, must be determined by some complicated procedures. Comparing heuristic methods of a genetic algorithm, the shuffled complex evolution-University Arizona, and the dynamically dimensioned search (DDS) method by test functions, we found that DSS might be useful for finding good global solutions of a problem with many decision variables. Hence, we applied the DDS method to determine series of water levels for zone division. The developed reservoir operation method was applied to Andong Dam in the Republic of Korea. We derived the zone boundaries using a generated dam inflow series and performed the zone-based operation for validation using the historical data under the assumption of known inflow data. The results showed the improvement in the water supply reliability and vulnerability compared with those from the historical data. The zone-based operation method derived from this research might be valuable in easiness to be understood and practicality.

HIGHLIGHTS

- We confirm that dynamically dimensioned search (DDS) method may be useful for finding good global solutions of a problem with many decision variables.
- Applying DDS method, we decided the reservoir storage levels for the zone-based operation of Andong Dam.

- The zone-based operation method derived from this research might improve the reliability and the vulnerability for water supply from Andong Dam.

PREPARATION OF INUNDATION AND FLOOD HAZARD MAPS AT THE CITY CENTER OF GİRESUN USING 1D/2D HYDRAULIC MODEL

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ABSTRACT

This paper presents a two-dimensional (2D) overland flow modelling application in simulating flood flows and dam break event in North Black Sea Region of Turkey. A 2D software package, SOBEK 1D/2D, has been utilized to extract inundation and flood hazard maps at the City Centers of Giresun. 500-yr and 1000-yr flood hydrograph is simulated in the hydraulic model as well as breach hydrograph resulting from dam break of Aslancık Dam in Giresun. 3D animations of flood flow propagation has been prepared in the scope of the study. Inundation and hazard maps produced during the course of the study are presented in this paper to show the simulated water surface levels and danger zones in the residential and commercial areas.

HYDROMETRIC DATA BANK DATABASE STRUCTURE

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ABSTRACT

Planning, design and operation of hydraulic structures require analysis of a considerable amount of hydrometric data. For this purpose, a Hydrometric Data Bank (HDB) has been designed to store, retrieve, modify, delete, print and analyze stream flow data. HDB contains information concerning gauging station, annual maximum and minimum discharges, annual mean discharge, rating curve and daily mean discharges. It also contains yearly total, year1y maximum, yearly minimum and yearly mean discharge of rivers. Furthermore, monthly total, maximum, minimum, mean discharges and monthly yield va1ues, and month1y stream flow depth are included to the database of HDB. One of the fourth generation programming languages (I4GL) has been chosen as the programming language for HDB software programs. I4GL is one of the Relational Database Model Systems (RDBMS) and it is making use of the structured query language (SQL). HDB is a menu-driven and user-friendly system. HDB is executable on microcomputers as well as on mainframes. All hydrometric data can be reported on the screen, printed or stored in a file for future use with different formats. Printed output has been designed so that it may be copied onto A4 or continuous size paper for easy inclusion in reports or Water-year book for stream flow and lake level measurements (Water-year book), Screen forms, menus and windows are designed for entering, searching, modifying, retrieving hydrometric data. While retrieving and reporting data, the user can specify different search criteria based on time and/or space.

TRENDS OF MEAN AND EXTREME PRECIPITATION IN SOUTHERN ITALY

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ABSTRACT

A modification in water cycle is one of the most noticeable consequences of global atmospheric warming. Precipitation is a key point in the hydrological process and the distribution of extreme rainfall is particularly important because it may impact on water management, soil erosion and flash floods. In this paper, an analysis of mean and extreme rainfall over a region of southern Italy (Calabria) has been carried using a daily homogeneous precipitation dataset of 129 rain gauges with more than 50 years of observation for the period 1916–2006. First, a statistical analysis was performed through the Mann-Kendall test in order to detect possible trends at annual, seasonal and monthly scale. Then, a set of indices derived from the daily homogeneous rainfall time series was defined and used to examine changes in extreme rainfall through non-parametric techniques. Results show a decreasing trend for annual and winter–autumn precipitation and an increasing trend for summer precipitation. Moreover, a prevailing decreasing trend of the various indices has been detected. These results appear to be in contrast with previous large scale studies which evidenced an increase in extreme rainfall and a decrease in the yearly totals, in other areas of Southern Europe. These differences in the behaviour of extreme rainfall suggest that a detailed regional analysis is always necessary because the distribution of extreme precipitation is often linked to the morphological settings of a territory (proximity to the sea, presence of reliefs, etc.).

HIGHLIGHTS

- A daily homogeneous precipitation dataset of 129 rain gauges with more than 50 years has been used.
- A trend analysis of mean and extreme rainfall has been carried using the Mann–Kendall nonparametric test.

- A decreasing trend for annual and winter–autumn rainfall and an increasing trend for summer precipitation have been detected.
- A general decreasing trend of the various extreme indices has also been detected.

COMPARISON OF TEMPORAL VARIABILITY OF ANNUAL DAILY WATER LEVELS OF THE FIVE NORTH AMERICAN GREAT LAKES FROM 1918 TO 2012

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ABSTRACT

The goal of this study is to examine whether the interconnected nature of the five North American Great Lakes results in similar temporal variability of their respective extreme water levels. To test this hypothesis, we applied the Lombard method to identify changes in mean and variance values of time series from 1918 to 2012. For annual daily maximum water levels, four shifts in mean (1932, 1948, 1968 and 1993) are identified for Lake Erie, one each for Lakes Ontario (1943) and Superior (1999), but none for Lake Michigan-Huron. For annual daily minimum water levels, three shifts in mean were detected for Lake Erie (1969, 1931 and 1998), two for Lake Ontario (1931 and 1943), a single one for Lake Superior (1998), but none for Lake Michigan-Huron. Finally, one shift in the variance of annual daily maximum water levels was detected for Lakes Superior (1997) and Ontario (1966), the latter also showing a shift in variance of annual daily minimum water levels in 1959. These shifts in mean and variance values result from the succession of wet and dry periods as well as human activity. The study shows that Lake Erie, the shallowest of the five Great Lakes, is the most sensitive to climate fluctuations and can therefore serve as indicator for monitoring the impacts of climate variability and change in this watershed.

HIGHLIGHTS

- Although the five North American Great Lakes are interconnected, their extreme water levels do not show the same temporal variability.
- Lake Erie is the Great Lake that is most affected by shits in mean values of water levels.
- No shift in mean values of water levels in Lake Michigan-Huron was detected.
- Little change in the variance of hydrological series is observed.

RUNOFF SIMULATION USING THE GAMMA TEST (CASE STUDY: AMAMEH WATERSHED, IRAN)

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ABSTRACT

Runoff from rainfall is a complex and non-linear process and therefore, its modelling is not so easy. The aim of this study was application of the Gamma test to select the optimal combination of input variables for runoff modelling at Amameh watershed. M-test was used to identify the optimal number of required data for modelling. Data of rainfall (P(t)) and runoff (R(t)) in daily time scale was used in the period of 2000 to 2009. Totally, eight input variables namely four variables of daily streamflow; lag-1 (R(t-1)), lag-2 (R(t-2)), lag-3 (R(t-3)) and lag-4 (R(t-4)) as well as four daily rainfall variables; without lag time (P(t)), lag-1 (P(t-1)), lag-2 (P(t-2)) and lag-3 (P(t-3)) were used. Streamflow modelling performed based on optimum number of the selected variables using the Artificial Neural Network (ANN) and Adaptive Neural-based Fuzzy Inference System (ANFIS) methods. The results showed the six variables of P(t), P(t-1), P(t-2), P(t-3), R(t-1) and R(t-2) were found to be the optimum combination of variables in streamflow modelling of mentioned watershed. Moreover, based on the M-test output, only 1405 points were found to be adequate for modelling in the training section. Results indicated the fact that the ANFIS methods had greater accuracy in training process compared to ANN. However, the ANN had large amount of accuracy in the model test.

HIGHLIGHTS

- Determination the appropriate input variables and optimum length of data in training and testing sections with Gamma Test (GT). Results showed GT is a good method and can reduce trial and error steps in modelling process.
- Develop the ANN and ANFIS models for runoff estimation using the input combination and optimum length of data and compare them.

PREDICTING AVULSION POTENTIAL ON ALLUVIAL FANS USING FLO-2D MODEL- A CASE STUDY

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ABSTRACT

Given the fact that location of flow paths on active alluvial fans is subject to a level of uncertainty, alluvial fan floods are more dangerous than riverine floods. The flood hazards coupled with the potential of channel shift, or avulsion, across the width of alluvial fans may cause substantial damages. Avulsion is the process of path change of a flow in a channel on alluvial fans. The earlier methods of determining avulsion on alluvial fans (such as FAN program model) received negative criticisms and failed to provide accurate results. Given the two-dimensionality of the flow on alluvial fans, FLO-2D model was used to identify the areas with avulsion potential in this research. The potential for avulsions were studied in two alluvial fans of Iran, one in the Northeast (Ferizy) and the other in the Southeast (Sarbaz).Using this model, the flow was simulated based on 100 and 500-year. Then, by plotting the results of the model on the recent aerial photographs of the alluvial fans, areas with avulsion potential were identified. The results of plotting showed that Sarbaz and Ferizy Fans had 6 avulsions. The results also revealed the occurrence of massive evulsions in the areas without any expectation of such a phenomenon. Thus, this method can help identify areas with avulsion risk with the aim of reducing the potential damages. The findings of this study proved the reliability of FLO-2D model in determining the avulsion on alluvial fans.

HIGHLIGHTS

- FLO-2D model can be a powerful tool for prediction of avulsions.
- This model is able to detect areas with high risk of avulsion that were formerly considered safe
- Since avulsion affect flood hazards on alluvial fans, its effect should be taken into account in flood hazards studies.
- Use of available topography mapping and fine grid size is necessary for getting accurate results in FLO-2D model

ESTIMATION OF DAILY STREAMFLOWS AND FLOW DURATION CURVES AT UNGAUGED SITES

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ABSTRACT

Flow duration curves (FDC) and daily streamflows are useful tools for characterizing the flow variability, hydrological regimes, installed capacity calculation and proper turbine selection for the run-off rivers. In this paper, the influence of the "parameterisation then generalisation (PG)" method on the empirically predicted FDCs is investigated for 5 gauging stations which are assumed as ungauged. Stations located across Murat River, Turkey are assumed as ungauged. 5 linear regression methods are applied in PG strategy and the appropriateness of the methods are compared for the estimation of daily streamflows and FDCs. These regression methods are called as; linear, log, cubic, squared and comb3. Stations stream flow datas between 1969-2009 years are provided from Devlet Su Isleri.
The streamflows are made dimensionless and standardized by dividing to mean flows. Jack-knife crosss validation method is used for the estimation of FDCs and daily streamflows at ungauged sites by using the catchment area characteristics. Results indicated that, the variety of the catchment area characteristics and station quantities affect the accuracy of the streamflow estimations at ungauged sites. Study shows that, comb3 method of the linear regression provides the most accurate values for the estimation of daily stream flows and FDCs in Murat River.

HIGHLIGHTS

- Comb3 method is the most accurate method of linear regression methods for the estimation of daily streamflows and FDC in Murat River.
- The variety of the catchment area characteristics has an influence on the accuracy of the estimations.

ESTIMATION OF SEDIMENT YIELD IN THE MELLEGUE WATERSHED, ALGERIA

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ABSTRACT

Soil erosion is one of the most important environmental problems. Soil erosion by water and the impact of sediment transport on lakes and streams, can seriously degrade soil and create problems for both agricultural land and water quality. The present study has been carried out to assess suspended sediment yield in Mellegue watershed (4575 km^2) located in the extreme northeast of Algeria to predict sediment yield in the basin. Regression analysis was used to establish a relationship between the instantaneous water discharge (Q) and the instantaneous suspended sediment concentration (C) based on all recorded data and seasonal ratings. Measured data of suspended sediment concentration and water discharge were available during a thirty-year period (1973/74-2002/03) in the Ouenza gauging station. The mean annual sediment yield during the 30 years of the study period was 590 T km^{-2} yr^{-1} in the Mellegue Catchment. The results show that the value of the average specific degradation is comparable to that found for other regions in similar hydrological regime. Optimization of rating curve method is validated by comparing the predicted against observed values on scatter plots.

HIGHLIGHTS

- A simple methodology to assess soil erosion as a problem is proposed.
- Sedimentation controls and impacts in the Mellegue Catchment .
- We investigated the impact of geomorphic factors disturbance on erosion and sedimentation.
- C–Q sediment rating curves for different seasons had different characters.

COMPARISON OF INHERENT PERFORMANCE OF SEVEN DROUGHT INDICES IN DROUGHT MITIGATION USING A MONTE CARLO SIMULATION APPROACH

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ABSTRACT

Drought indices have been commonly used to evaluation of water resource systems as a tool for monitoring drought and quantify drought conditions around the world. Most of the drought indices are developed for specific goals and geographic areas. Therefore, their usage without regarding the theoretical properties and weather conditions for a comprehensive and accurate analysis in other areas is with considerable doubt due to the inherent complexity of the drought phenomenon and different climate condition. Most of the studies are often based on historical time series or 20-30-year short time statistical periods and often has been done from one aspect or particular view. In the following research, Monte Carlo simulation method is used for monitoring Northwest of Iran's drought through using seven metrological drought indices, and the theoretical characterization and inherent performance of these indices have been studied. For this Purpose, 50 years of rainfall data from 11 synoptic stations were used in the study area to generate artificial rainfall data time series with the number of 1000 sample for monitoring drought and quantify the inherent characteristics of drought indices. The results indicate the comparative advantage of Standardized Precipitation Index (SPI) and non-normalized Standardized Precipitation Index (SPIo) indices for a more accurate and realistic analysis and Percent of Normal Precipitation Index (PNPI) index is non-spatial and so is the most inefficient index for drought monitoring.

HIGHLIGHTS

- The application of stochastic procedure will be indeed essential for drought events analysis.
- Use of the SPI and SPIo will result in relatively high advantage for a comprehensive and accurate analysis
- PNPI index is the most inefficient index for drought monitoring.

TREND ANALYSIS OF SPATIAL AND TEMPORAL DRY AND WET PERIODS BASED ON SPI AND PNPI DROUGHT INDICES IN NORTHWEST OF IRAN

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ABSTRACT

Assessment of rainfall variations in a region can have a significant role in the analysis of spatial and temporal variations of drought. In this study, using rainfall data from 39 synoptic stations located in the northwest of Iran, first the time series of dry and wet periods based on both SPI and PNPI drought indices were evaluated and analyzed, then the trends of dry and wet periods are discussed based on SPI and PNPI drought indices using Mann-Kendall nonparametric test with the removal of all significant effect of autocorrelation coefficients. The results also emphasizing the necessity of using the modified Mann-Kendall trend test in analyzing the trend of dry and wet periods, indicates the downward trend in most stations and significant negative trend at the 95% confidence level in western stations of study area. Also, the results showed that the both SPI and PNPI drought indices can solely be used to determine the trend of dry and wet periods, because of the high correlation between both of the above drought indices in the evaluation and determining the trend changes in dry and wet periods.

HIGHLIGHTS

- Removing the all significant effect of autocorrelation coefficients is necessary in analyzing the trend of time series using the Mann-Kendal trend test.
- Using the both SPI and PNPI drought indices can solely be used to determine the trend of dry and wet periods.
- The results indicate the downward trend in most stations of study area by using the modified Mann-Kendall test.

REGIONAL IRRIGATION MANAGEMENT WITH THE USE OF AN AGRO-HYDROLOGICAL MODEL

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ABSTRACT

In this study the management of a regional irrigation network is evaluated with the use of a dynamic agro-hydrological model. These models are useful for the simulation of different water management scenarios according to soil properties, crop water demands and contributions from shallow aquifer. The well-known SWAP (Soil-Water-Atmosphere-Plant) model has been applied. SWAP is a model which simulates the transport of water, heat and dissolved solids in unsaturated-saturated soils. The water demands for the major crops were estimated for the Agoulinitsa network, which is part of Alfeios river irrigation system in western Peloponnese (Greece). The region of Agoulinitsa is in fact an artificially drained lagoon with a shallow aquifer. The quality of irrigation water and soil properties in the area studied, were assessed using laboratory procedures. The experimental results were used as input data in the model in combination with meteorological and crop data. The model was calibrated in regional level, taking into account the monthly variation of drainage water effluents. The seasonal water demands for every crop were assessed after long term simulations. The optimal irrigation scenario for each crop was then compared with the calculated water demands in the region that were initially estimated with the Blaney and Criddle (B-C) evapotranspiration method. In conclusion, it is shown that there is a significant gap between the estimated values from SWAP model and those from B-C method, indicating the possibility for significant water savings.

HIGHLIGHTS

- A significant difference is observed between the initially estimated water demands and the simulated values from SWAP model.
- The upward movement of water from the shallow aquifer, through capillary rise that is simulated in SWAP, could potentially lead to fresh water savings.

- The crops yield under deficit irrigation can be assessed with the use of dynamic agro-hydrological models.

GROUNDWATER QUALITY CHARACTERISTICS OF THE ENVIRONMENTALLY SENSITIVE PINIOS RIVER DELTA, CENTRAL GREECE

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ABSTRACT

Pinios River basin is the largest fully developing basin in Greece, while it is also one of the highest productive basins of the country. Pinios River delta (PRD) has been included in the "special protection areas" and habitats network within the framework of Directives 79/409 and 92/43 (NATURA2000), respectively, and therefore is of high environmental and ecological importance. Nevertheless, significant pressures are identified in PRD due to the intensified agricultural and touristic activities developed in this area, which lacks detailed and systematic studies on the impacts imposed to its groundwater resources. This work aims to assess the impact of those activities in the groundwater quality of PRD and identify the hydro-geochemical processes based on 4 seasonal groundwater sampling campaigns conducted in a network of 28 wells, over which physicochemical parameters, major ions and nitrogen compound concentrations were determined. Both temporal variation and spatial distribution of hydrochemical parameters were investigated. Moreover, multivariate statistics and hydrogeochemical diagrams were used in order to identify the hydrochemical relations and hydrogeochemical processes observed in the aquifer system of PRD. Overall, the results of the analysis did not indicated significant seasonal variations in groundwater quality. Locally, high NO3- concentrations (up to 56.4 mg/L) both in irrigation wells and wells installed within the touristic settlements were determined, while increased salt loads were found in several groundwater samples with Electrical

Conductivity values ranging up to 6,500 μS/cm. The Piper diagrams indicated complex hydrogeochemical processes, while Principal Component Analysis resulted in factors describing both anthropogenic pollution and hydrogeochemical processes.

HIGHLIGHTS

- Agricultural activities and malpractices combined to waste water leaching from existing septic tanks are significantly increasing nitrogen compounds' concentrations.
- Groundwater samples of Na^{+}-Cl^{-} hydrochemical type were identified that indicate groundwater salinization processes.
- Higher salt loads were found in the deep aquifer despite the fact that groundwater abstractions from this aquifer are very limited.
- Efficient agricultural, urban and water resources management strategies have to be developed in order to protect PRD, especially in view of the anticipated climate changes.

INVESTIGATION OF CLIMATE CHANGE EFFECTS IN AGRICULTURAL WATER MANAGEMENT OF PINIOS RIVER DELTA, CENTRAL GREECE

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ABSTRACT

Climate change effects are expected to have a strong impact on agricultural sector, especially in Mediterranean region in which irrigated agriculture is already developed while water resources availability is expected to be decreased. This study aims to investigate the potential climate change effects in crop water demands and the corresponding impacts in crop yields for Pinios River delta-central Greece, which is protected from several environmental conventions, while the agricultural activities are dominant. For this, plot-scale crop distribution, current cultivation practices, meteorological and detailed soil data were introduced in SWAT model, which, for the purposes of the current study, was used as a tool for the simulation of the hydrologic budget and plant growth. Therefore, the study area was discretized in a large number of Hydrologic Response Units (HRU), in order to incorporate the high spatial heterogeneity of crop distribution in the study area. SWAT model parameters were properly adjusted in order to achieve sufficient fit between simulated crop water demand and the corresponding values estimated with the crop coefficient approach. In

order to assess climate change effects in crop water needs and yields, precipitation and temperature (min and max) data from 3 Regional Climate Models (RCMs) driven by several Global Circulation Models (GCMs) for CO2 emissions scenario A1B were fed in SWAT model. The results indicate a wide range of variation in future crop water needs which originates from the significant variation of precipitation and temperature between RCMs.

HIGHLIGHTS

- Significant drought periods were identified with subsequent increase in crop irrigation needs.
- Significant increase in temperature stress days was indicated for some periods and RCMs, which in some cases is strongly affecting crop yield.
- The extent and timing of crop water needs and crop yield affection by climate change is highly variable and therefore the implementation of more than one RCM is proposed.
- The results indicate the necessity for the development of climate change adaptation plans for the study area.

INVESTIGATING THE COASTAL AQUIFER RESPONSE TO DROUGHT SCENARIOS IN MEDITERRANEAN ISLANDS

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ABSTRACT

Drought is a recurring natural phenomenon caused mainly by a prolonged below-average precipitation and high evapotranspiration over a large area. This sustained water deficiency is propagated through the surface and groundwater systems affecting water availability for the various uses. The relationship between meteorological drought severity and the response of a coastal aquifer may be associated to seawater intrusion extent. The Reconnaissance Drought Index (RDI) is used to assess the meteorological drought severity, since it incorporates precipitation and potential evapotranspiration, which both affect the infiltration and recharge processes. The Medbasin-M monthly hydrological model is used for estimating the recharge volumes for different time series. The calculated recharge time series are used as input to a transient seawater intrusion numerical model. The popular seawater intrusion code SEAWAT is utilised to simulate the variable-density flow and dispersion mechanisms in coastal aquifers. Two typical Mediterranean island coastal aquifers are investigated based on the assumption that infiltration is the main recharge component. The main objective of the study is to determine the relation between drought severity and natural undisturbed coastal aquifer flow conditions at a temporal scale. An indicator based on the freshwater volume is used along with RDI index to assess the aquifer response to drought. The results show that the RDI index can be utilised successfully to associate the meteorological drought with aquifer conditions. Specifically, a reliable early prediction of the aquifer conditions at the end of the hydrological year can be achieved by the RDI of the first semester.

HIGHLIGHTS

- Drought scenarios are formulated based on the Reconnaissance Drought Index.
- A hydrological model (Medbasin) and a variable density seawater intrusion model (SEAWAT) are used.
- The aquifer response to drought scenarios is indicated by the extent of seawater intrusion.
- The methodology is tailored for a typical Mediterranean island coastal aquifer.

FLOOD RISK MANAGEMENT PLAN FOR THE SARDINIA HYDROGRAPHIC DISTRICT

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ABSTRACT

Following the European Council Floods Directive (2007/60/EC) and the Italian national legislation (DL n. 49/2010), the Sardinia (Italy) Hydrographic District Authority defined the main directives on the assessment and management of flood risk in related basins. This planning phase is subsequent of a detailed flood risk mapping and consequent identification of flood prone areas. Recent historical events highlighted on this necessity as the Sardinia region was affected by important floods, typical of the Mediterranean area. In December 2004 the territory of Eastern Sardinia was the scenario of a massive flood event characterised by 500 mm rained in five hours. In October 2008 a storm hit the South-Eastern territory and 350 mm of rain were gauged in less than 3 hours. More recently, in November 2013 the Cleopatra hurricane injured the North-Eastern Sardinia causing huge damages. Moving from these emergencies and legislation directives, Sardinian Hydrographic Authority is working on flood risk management plans involving researchers, communities and stakeholders. In this paper we focused on this planning framework describing the assessment of flood risk management plans, considering some pilot areas to define a decision support tool with priorities in mitigation measures. Preliminary results are illustrated for these pilot areas contemplating different mitigation options (structural and non-structural).

IMPACT OF CLIMATE CHANGE SCENARIOS ON MEDITERRANEAN DROUGHT CONDITIONS

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ABSTRACT

Climate change, which is mainly characterised by more extreme rainfall regimes and rising temperature, has widespread impacts on human and natural systems. Drought may be considered one of the most related natural disasters to climate change. In order to investigate the effect of climate change in meteorological and hydrological parameters associated with drought severity, various worldwide-accepted climatic change models and scenarios, developed by IPCC and other organisations, were examined. Parameters affecting future meteorological conditions were derived based on RACMO2 model nesting the A1B emissions scenario and timeseries of precipitation and temperature data for a time span of 150 years were obtained. Since meteorological data predictions are location specific, Mediterranean conditions were investigated in this paper selecting the Greek island of Crete as the application area. Meteorological drought was assessed based on two drought indices: the Standardized Precipitation Index (SPI) and the Reconnaissance Drought Index (RDI), the latter being also a composite climate index. Meteorological data were then fed into Medbasin rainfall-runoff model for the generation of streamflow data of the selected watershed. The Streamflow Drought Index (SDI) was calculated as the hydrological drought indicator. The results show that there are statistically significant drought trends dependent on the specific climatic scenario and the drought index selected.

HIGHLIGHTS

- The effect of climate change on drought for future horizons is investigated.
- Parameters are derived from various worldwide accepted climate change scenarios.
- Drought is assessed through a meteorological (RDI) and a hydrological (SDI) drought index.
- Results are based on an application at a large Mediterranean island (Crete).

FUTURE CHANGES OF REFERENCE EVAPOTRANSPIRATION OVER THESSALY PLAIN, GREECE, BASED ON REGIONAL CLIMATE MODELS' SIMULATIONS

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ABSTRACT

Evaporation and evapotranspiration are significant drivers of the water cycle in a changing climate, especially on coastal environments within the Mediterranean. The future projected increase in air temperature due to global warming will influence the evaporation and evapotranspiration processes, which in combination with the projected decrease in precipitation is likely to influence mostly the irrigation and water resources. The present study analyzes the impacts of climate change on reference evapotranspiration losses of the plain of Thessaly, Greece, a region which is characterized among the main sectors of agricultural production in Greece. These losses are estimated and the modified FAO 56 Penman-Monteith formula is utilized, based on simulations of daily meteorological data (temperature, humidity, wind speed, cloudiness), from a number of six Regional Climate Models (RCMs), within the ENSEMBLE European Project. The simulations of the six RCMs for the near future (2021-2050) and the far future (2071-2100) were made under the A1B emissions scenario, while the simulations for the reference period (1961-1990) were made under the 20C3M emissions scenario, which represents a 20th century simulation using historical GHG concentrations. Further, the projected changes of reference evapotranspiration losses between the reference period and the near and far future periods along with the inter-model standard deviations are presented based on the simulation results derived. The findings of the performed analysis would help regional stake holders to understand the impacts of climate change on the water cycle, particularly in vulnerable agricultural regions in order to mitigate the consequences and adapt crops to future conditions.

HIGHLIGHTS

- Reference evapotranspiration in the plain of Thessaly, Greece is estimated based on the modified FAO 56 Penman-Monteith formula.
- Simulations of daily meteorological data from a number of four Regional Climate Models, within the ENSEMBLE European Project.
- Changes of reference evapotranspiration between the reference period (1961-1990) and the near (2021-2050) and far (2071-2100) future periods.

INTRODUCTION OF NIMR HYDROMETEOROLOGICAL INFORMATION ANALYSIS AND PREDICTION SYSTEM BASED ON ENSEMBLE MODELS

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ABSTRACT

The characterization of the spatial and temporal variability of water and energy cycles is critical to improve our understanding of the land-surface-atmosphere interaction and the impact of land-surface processes on climate extremes. The National Institute of Meteorological Research (NIMR) have developed the ensemble LSMs based hydrometeorological information analysis and prediction system to generate the grid and basin based land surface variables over the Korean Peninsula. It consists of three land surface model including TOPLATS, Noah and DHSVM and modelling framework using observation and analysis data. In this study, the simulated results by the LSMs have been compared to NIMR hydrometeorological observation network data and LSM intercomparison study has been done. We generate LSMs based soil variables and energy flux data during the period from Oct. 2013 to Dec. 2014. LSMs have effectively reproduced the observed patterns of soil moisture and surface fluxes, but all models overestimate soil moisture and evapotranspiration compared to the observed data and especially the overestimation by Noah LSM is the largest over the Korean Peninsula. In addition, though each LSM has various land surface characteristics, its difference is relatively small compared to the observed. Comparison results of three model ensemble results will be shown in poster presentation. In conclusion, this result can be used as a background data for applying ensemble based hydrometeorological information analysis and prediction system and understanding LSM based water cycle in Korea.

HIGHLIGHTS

- Hydrometeorological information analysis and prediction system

Conference 11

Geo-information and Water Resources

INFLUENCE OF DEM RESOLUTION ON GIS-BASED INUNDATION ANALYSIS

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ABSTRACT

As a result of climate change and sea level rise, studies about the extent and depth of coastal inundation are becoming more important. Most of the coastal lands are becoming vulnerable to inundation as their elevation will likely be below the projected sea level rise. Geographic information system (GIS) provides a useful tool for simple inundation analysis where coastal flooding resulting from sea level rise are assessed. In this study, climate change related sea level rise is considered jointly with storm surge of different magnitudes and topographic data from a number of digital elevation models (DEM) with different resolutions are used to identify potential areas to be inundated. The study area is chosen from a coastal land where different DEM datasets (LIDAR, SRTM, ASTER-GDEM, GTOPO) are readily available. In this study, results these DEM datasets are quantitatively compared and the sensitivity of the analysis to DEM resolution is determined by using ArcGIS software. The results indicate that the resolution of DEM is a key factor to achieve accurate results. Significant under/over estimations in inundation extent and depth are probable with low resolution data, which can be a critical factor in conducting risk and vulnerability assessments.

HIGHLIGHTS

- GIS-based inundation analysis is sensitive to the resolution of DEM.
- Lower resolution underestimates the level of inundation.
- Hydrological connectivity is important to accurately delineate the inundated land.

THE CORRELATION BETWEEN STATISTICALLY DOWNSCALED PRECIPITATION DATA AND GROUNDWATER LEVEL RECORDS IN NORTH-WESTERN TURKEY

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ABSTRACT

Downscaling of atmospheric climate parameters is a sophisticated tool to develop statistical relationships between large-scale atmospheric variables and local-scale meteorological variables. In this study, the variables selected from the National Center for Environmental Prediction and National Center for Atmospheric Research (NCEP/NCAR) reanalysis data set were used as predictors for the downscaling of monthly precipitation in a watershed located in north-western Turkey where station records terminated two decades ago. An Artificial Neural Network (ANN) based approach was used to downscale global climate predictors that are positively correlated to the existing time frame of precipitation data in the basin. The downscaled precipitation information were used to extend the non-existing data from the meteorological station, which were later correlated with groundwater level data obtained from automatic pressure transducers that continuously record depth to groundwater. The results of the study showed that, among a large set of NCEP/NCAR parameters, surface precipitation data recorded at the meteorological station were strongly correlated with precipitation rate, air temperature and relative humidity at surface and air temperature at 850, 500, and 200 hPa pressure levels, and geopotential heights at 850 and 200 hPa pressure levels. The gaps in station data were then filled with the correlations obtained from NCEP/NCAR parameters and a complete precipitation data set was obtained that extended to current time line. This extended precipitation time series was later correlated with the existing groundwater level data from an alluvial plain in order to develop a general relationship that could be used in basin-wide water budget estimations. The proposed methodology is believed to serve the needs of engineers and basin planners who try to create a link between related hydrological variables under data-limited conditions.

HIGHLIGHTS

- ANN based statistical downscaling can be used to downscale coarse scale atmospheric parameters to local scale precipitation data.
- The coarse precipitation, sea level pressure and air temperature at surface and 850, 500, and 200 hPa pressure levels are the most explanatory atmospheric parameters.
- The developed correlation could then be used to extend and/or fill in data gaps in station based precipitation records.
- Extended precipitation data could eventually be correlated with groundwater level data obtained from a surface aquifer in an alluvial plain to serve the needs of water budget estimations.

ASSESSING THE HYDROPOWER POTENTIAL OF HISTORICAL HYDRO SITES USING A GEO-INFORMATION SYSTEM AND HYDROLOGICAL MODELING IN POORLY GAUGED AREAS

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ABSTRACT

Unrealized potential for small and micro hydropower generation exists in Europe's thousands of historic mills, water wheels, inoperative hydropower stations, weirs and other lateral structures in rivers. Repowering abandoned sites results in the generation of hydroelectric power, both for local use and for injection to the electrical grid. However, the evaluation of possible hydro sites, which are mostly located in rural and mountainous areas, requires large amounts of data. Especially in poorly gauged areas hydropower studies concerning the technical, economic and environmental feasibility of the possible hydro sites are difficult, costly, and time intensive. This paper presents a methodology for a large-scale preliminary evaluation of possible historical hydropower sites in poorly gauged areas and its application in Greece. The developed methodology automates the estimation of the main required parameters for the evaluation of each hydro site in a geo-information system (GIS). The core of the methodology is a fully spatially distributed continuous hydrological model embedded in the GIS, which estimates streamflow values at every point of the drainage network based on meteorological data series. At the same time the system automates the estimation of other important parameters like expected head, environmental sensitivity, grid connections etc. The results of this study highlight the ability of the developed methodology to provide the data required during the inception phase of small hydropower development planning in a cost and time efficient manner. In this

way expensive ground investigations are limited to the areas which are most likely to yield useful sites for hydropower development.

HIGHLIGHTS

- A methodology for a large-scale preliminary evaluation of possible historical hydropower sites in poorly gauged areas is presented.
- The developed methodology automates the estimation of the main required parameters for the evaluation of hydro sites in a geo-information system.
- The results highlight the ability of the methodology to provide the required data in a cost and time efficient manner.
- In this way expensive ground investigations are limited to the areas with the greatest potential.

DISTRIBUTIVE MODELLING OF HYDROLOGICAL DYNAMICS IN THE LOWER SEYHAN PLAIN – APPLICATION IN THE AKARSU IRRIGATION DISTRICT

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ABSTRACT

The Lower Seyhan Irrigation Plain (LSIP) south of Adana, Turkey, is an irrigation area subdivided into several irrigation districts equipped with irrigation water diversion and drainage infrastructure. Mediterranean climate conditions and fertile soils facilitate two cropping seasons per year. Due to dry summer conditions, irrigation is essential to gain substantial yields in the summer season, however affecting the hydrological characteristics tremendously. During the summer season the entire hydrological dynamics are dominated by irrigation and drainage water. In combination with the analysis of existing crop-rotations and irrigation techniques (mainly furrow and drip irrigation) the integrated system analysis provided sufficient data to derive hydrological response units (HRU) that represent the special situation of an irrigation district. These units were used to apply the distributive ecohydrological model JAMS/J2000-S for the entire Akarsu irrigation district (approx. 100 km²). The model was enhanced to cover basic irrigations processes occurring in the field, using process modules based on a demand-driven algorithm to distribute irrigation water to each single model entity. After calibrating the model, results have shown that the delineation approach of modelling entities as well as the model application within the enhancement of the hydrological processes were suitable to catch the inner-annual dynamics of the human impacts on the hydrological system. Rainfall and irrigation inputs are well represented and therefore the JAMS/J2000-S hydrological model is a suitable tool for modelling of irrigation-driven hydrological systems.

HIGHLIGHTS

- Delineation of crop-rotation on field scale using remote sensing techniques and GIS analysis.
- Modelling entities based cropping pattern and field geometries related to irrigation techniques.
- Enhanced JAMS/J2000s hydrological modelling suite covering irrigation techniques and representing both the natural and the hydrological dynamics cause by irrigation.

SOIL WATER BALANCE IN THE PRESENCE OF A SHALLOW WATER TABLE

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ABSTRACT

In this work the level of a shallow water table was determined in a daily basis via a dense piezometer network installed in a 0.5 ha olive grove. This water table is present during the rainy season. The use of Geographic Information System (GIS) and spatial analysis with Inverse Distance Weighted (IDW) interpolation method enabled the mapping of water table. Comparisons between successive water table surfaces (raster) were made. Meteorological data were obtained via a station installed in the area of the experimental field during the same period. The fluctuation of water table is due to vertical (rain-evapotranspiration) or lateral water movement into or out of the experimental field. The direction of water movement and the water volumes moved into or out of the groundwater in a daily basis were obtained by incorporating meteorological and soil porosity data. Quantitative comparisons were made between meteorological data and groundwater volumes added or removed. This work indicates that, in certain occasions, soil water balance components could be obtained independently by using GIS technology, thus contributing in a better understanding of the complex problem of soil water dynamics. A more detailed investigation could depict the 3-dimensional hydraulic head $h(\vec{r})$. If, in addition the soil moisture retention curve and the saturated hydraulic conductivity Ks-values, in certain locations of the field are determined, then, it would be attainable to acquire a comprehensive picture of soil water movement.

HIGHLIGHTS

- Shallow water tables' level measured via piezometers in a daily basis
- Direction of groundwater movement were obtained by using GIS
- Water table fluctuation and water volumes obtained by GIS
- Quantitative comparisons were made between meteorological and groundwater volumes data

DASYMETRIC MAPPING OF FLOOD IMPACT TO THE POPULATION IN SERBIA

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ABSTRACT

Severe flooding, often with catastrophic results and devastating impact to population, settlements, infrastructure and environment getting more frequent in the last few years in Serbia and other Western Balkans countries. The most recent floods, from the year 2014, raised the questions to the revision of actual assumptions about possible frequency and intensity of future floods. In this paper are analysed possible spatial impacts of floods to population, system of settlements and infrastructure, and also to the pollution. Publically available and very general dataset for Serbia are used within the advanced GIS tools and methods to analyse key spatial indicators: soil sealing, spatial distribution and density of population, road and infrastructure network, special purpose areas, terrain morphometry, vegetation and water regimes. Analytical maps are created showing high degree to the possible flooding of the existing spatial structures, and also their potential impact to the planned spatial development. Special contribution of this work is dasymetric map of spatial distribution of population in Serbia as basis for impact assessment of high waters to settlements and other spatial systems. Aim of this paper is to indicate importance of timely conducted integral flood impact assessment in Serbia on the general level for delimitation of the impact zones in the spatial plans, and to prevent future catastrophic consequences.

HIGHLIGHTS

- GIS based models of flood impact assessment to the population, spatial structures and environment are crucial for better management of the new generation spatial plans.
- Dasymetric mapping of population density is very useful tool for flood impact assessment.
- Better results in such mapping models can be achieved by using spatial predictors such are: soil sealing, road network, terrain morphometry, vegetation and water regimes.

WATER FOOTPRINT ASSESSMENT IN RIVER BASIN SCALE USING GIS TECHNOLOGY

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ABSTRACT

Lack of sufficient quantity and quality water, various and often-conflicting water uses, in conjunction with issues such as overpopulation, climate change effects, over-consumption and water pollution, require water policies that will guarantee the sustainable management and protection of fresh water resources. In terms of this need, Hoekstra introduced in 2002 Water Footprint (WF) concept as a consumption-based water use indicator. The WF indicator consists of three components: green, blue and grey. In this paper, the water district of Western Peloponnese (GR01) consisting of two river basins is selected in order to assess water consumption in various sectors using WF concept. WFs of crops, pastures, woodlands, livestock, urban and industrial sectors were spatially estimated using GIS technologies.
By estimating WF components for every land use and every aquatic system, it is possible to determine land uses that consume significant amounts of fresh water that is not used elsewhere or land uses that significantly contribute to environmental burden of an aquatic system. The analysis showed that areas with high total water footprint are not necessary the ones which will be suffered the most from a potential water shortage. A preliminary conclusion of this analysis is that in river basin scale the estimation of total WF may be misleading due to different land uses that were considered. So it is better to separately use WF components (green, blue, gray) in order to first determine water needs, consumption and pollution pressure to water receptors and then develop water management policy plans.

HIGHLIGHTS

- The Water Footprint (WF) indicator can lay the foundations for the development of practices and policies for for optimal water resources management.
- Water Footprint indicator provides clear spatiotemporal information relative to water quantity required for the different land uses.
- GIS technology provides spatial-temporal analysis of water footprint .
- Water footprint estimation requires a considerably amount of data.

AN INTEGRATED MONITORING AND MANAGEMENT SYSTEM FOR QUANTITY AND QUALITY ASSESSMENT OF WATER RESOURCES IN RURAL BASINS

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ABSTRACT

Natural and engineered water systems interact throughout watersheds and while there is clearly a link between watershed activities and the quantity and quality of water entering the engineered environment, these systems are considered distinct operational systems. As a result, the strategic approach to data management and modeling within the two systems is very different, leading to significant difficulties in integrating the two systems in order to make comprehensive watershed decisions. In this paper, we describe the "HYDROMENTOR" research project, a highly-structured data storage and exchange system that integrates multiple tools and models describing both natural and modified environments, to provide an integrated tool for management of water resources. Our underlying objective in presenting our conceptual design for this water information system is to develop an integrated and automated system that will achieve monitoring and management of the water quantity and quality at watershed level for both surface water (rivers and lakes) and ground water resources (aquifers). The uniqueness of the system is the integrated treatment of the water resources management issue in terms of water quantity and quality in current climate conditions and in future conditions of climatic change. On an operational level, the system provides automated warnings when the availability, use and pollution levels exceed allowable limits pre-set by the management authorities. Decision making with respect to the apportionment of water use by surface and ground water resources are aided through this system, while the relationship between the polluting activity of a source to total incoming pollution by sources are determined; this way, the best management practices for dealing with a crisis are proposed. The computational system allows the development and application of actions, interventions and policies (alternative management scenarios) so that the impacts of climate change in quantity, quality and use of water resources could be evaluated and managed.

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HIGHLIGHTS

- Development, and application of a telemetric network for the collection of meteorological parameters and parameters of surface and ground water resources
- Assessment of the quantity and quality state of the water resources and spatial integration of results
- Assessment of water needs and demands and water budget of the watershed.
- Evaluation of the impacts of climatic change on water resources, water use and socio-economic activities

SPATIAL ESTIMATION OF WATER FOOTPRINT OF CROPS AND AGRICULTURAL PRODUCTION– THE CASE OF MAGNESIA PREFECTURE, GREECE

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ABSTRACT

During the last decades, Magnesia, located in central Greece, faces a very large reduction in the availability and degradation of groundwater and surface water resources. Cultivation of crops and production of agricultural products account over 90% of the total water demand in the study area. Taking this into consideration, as well as the fact of a great need for water conservation, the Water Footprint (WF) was spatially calculated for the agricultural crops and products using GIS technologies. The methodology used estimated the agricultural water requirements for each crop in each basin of the Prefecture of Magnesia. The model was based on the meteorological data regarding rainfall and temperature, the efficiency of water transportation and irrigation of crops, the estimation of soil moisture and evapotranspiration and finally, the determination of the water balance of all watersheds.

The results show that by estimating WF components for every crop and agricultural product, it is possible to determine crops that consume significant amounts of fresh water that are not used elsewhere or crops and areas that significantly contribute to environmental burden of an aquatic system. The study shows that the average water consumption of crops in the period 1996 - 2002 reached the value of 510.141,04 M^3 / ton / year of which approximately 48% is blue water, 28% is green water and 24% is gray water. These figures show a very lager percentage in the use of blue water for almost all crops, against green water usage, because there are no self-sufficient rural crops in green water as well as in areas with low rainfall rates, and where irrigation is carried out by surface irrigation methods. The large percentages of blue and gray water use are also noticeable in areas with large arable land and low productivity areas.

HIGHLIGHTS

- Water Footprint spatially estimation for all crops and agricultural products in Magnesia Prefecture, Greede
- GIS technology provides spatial analysis of Water Footprint

- Water Footprint indicator of spatial variation of water use for the different crops
- Large use of blue water in the study area
- Large percentages of blue and gray water use in areas with large arable land and low productivity areas.

DETERMINATION OF BASIN CHARACTERISTICS AND OBTAINING SYNTHETIC UNIT HYDROGRAPHS BY USING GIS

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ABSTRACT

Reliable development of hydrographs is required for proper management of water resources. Elements of hydrographs such as peak discharge and time to peak are essential in the planning and design of hydraulic structures. Development of hydrographs is necessary for every watershed. However, there are few number of gauged streams because installation and management costs are expensive. There are also difficulties with hydrograph development resulting from the absence of the precise estimation of runoff from rainfall and determination of flow paths. In a developing country, such as Turkey, suitable data to determine the unit hydrograph of a basin are not easy to find, therefore unit hydrographs are usually determined synthetically. In this study, watershed boundaries were identified for Cankiri-Sabanozu and Tokat-Akdogan small watershed areas in Turkey by using ArcGIS software. Physical and network characteristics of these basins such as area, perimeter, minimum, maximum and mean elevation, aspect, mean slope were calculated with the help of the same software. Then, synthetic unit hydrographs are obtained for these basins using results of ArcGIS. The Snyder, the Mockus and the SCS synthetic unit hydrograph methods were used in this study. Calculated unit hydrographs have been validated by using the observed unit hydrographs. There were two goals of this study. The first goal was to compare the unit hydrographs obtained synthetically to observed data. The second goal was to use GIS techniques in determining geomorphological characteristics of basins and show their effectiveness.

HIGHLIGHTS

- This study has demonstrated that GIS can be successfully used in order to define basin characteristics.
- GIS is a quick and efficient approach for water research.

USING TRMM SATELLITE BASED PRECIPITATION PRODUCTS FOR FLOOD MONITORING OVER RIYADH CITY IN KINGDOM OF SAUDI ARABIA

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ABSTRACT

Floods are among the most common disasters that harm humanity. Flash floods in particular cause hazards to life, personal property, and structures of any type. Regions with plentiful rainfall, as well as arid and semi-arid regions, are equally vulnerable to high hazard risk due to sudden flash floods. Kingdom of Saudi Arabia (KSA) has an arid/semiarid climate. Despite the fact that intensive and frequent rainfall events are rare over the region, occasional flash floods occur and bring large water amounts that can be very damaging. The recent flooding observed on 16 November 2013 in Riyadh, the capital city of KSA, resulted in killing some and led to much property damage. In this study, the Tropical Rainfall Measuring Mission (TRMM) Multi-satellite Precipitation Analysis (TMPA) Real time (RT) data (3B42RT) was used and proved to be good supplement for flash flood forecasting. Preliminary studies indicated that 3B42RT detected high intense rainfall events that match with the distribution of observed floods over KSA. Past flood events were compared with 3B42RT data and a threshold of 3 mm/h rainfall was found enough to trigger floods over Riyadh. Floods observed on November 2013 were of this type. February 2005 and May 2010 floods were not due to high intensity; however, they resulted from rainfall having milder rates with prolonged duration; both of which could be detected by the accumulation of rates. Thus, for future flood events, it is recommended to utilize both approaches for flash flood forecasting.

HIGHLIGHTS

- TRMM 3b42RT images can detect high intensity rainfalls over KSA.
- Distribution of high intensity rainfall events over KSA match with the floods observed in previous years.

SPATIAL DOWNSCALING OF TRMM PRECIPITATION USING SATELLITE REMOTE SENSING PRODUCTS

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ABSTRACT

Precipitation plays an important role in energy exchange and material circulation in the surface system of the Earth. Nowadays, there are two main sources of precipitation estimates: rain gauge stations and remote sensing technology. However, a large number of studies have demonstrated that traditional point measurements based on rain gauge stations cannot reflect the spatial variation of precipitation effectively. On the other hand, satellite remote sensing can potentially solve this limitation by directly providing spatial rainfall over large areas. The Tropical Rainfall Measuring Mission (TRMM) was the first space-borne precipitation radar to provide a range of rainfall products but at coarse resolution (0.25°). For that reason the improvement of its resolution is a fundamental task.

The statistical relationship among precipitation and different spatial, topographic and environmental parameters was tested in the western part of the island of Crete/Greece. Thus, a digital elevation model (DEM) of 30 m for depicting the topography of the study area was incorporated in the study. Furthermore, different auxiliary environmental data were developed from MODIS satellite imagery such as albedo, VWSI drought index with the use of MODIS land surface temperature (LST) and MODIS NDVI data.

At the next step, multiple linear regression models were established and statistical analysis was performed for searching the correlation of different environmental parameters to the precipitation regime and downscaling the TRMM products. The downscaled precipitation estimates were subsequently validated using an independent precipitation dataset from a network of gauging stations. The downscaling procedure resulted in significant improvements in average monthly precipitation estimation in the western part of the island of Crete/ Greece.

GIS - BASED DRASTIC MODEL FOR ASSESSING THE VULNERABILITY OF GAZA GROUNDWATER AQUIFER TO FERTILIZERS

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ABSTRACT

The intended goal of research is the prediction of vulnerability of the coastal aquifer under the given circumstances in Gaza strip. The aquifer vulnerability depends on the spatial variation of the aquifer properties which - in our research- are " Depth to water", " net Recharge", "Aquifer media", "Soil media", "Topography", Impact of vadose zone", and Conductivity. All of them called DRASTIC parameters.
The variability in parameters can be described in terms of deterministic distribution field of each parameter. Therefore, the efficiency of the model depends on the accuracy of the input parameters. Since the input regarding the DRASTIC parameters are estimated from bore-holes tests of some well distributed around Gaza Strip semi uniformly, the question is how far is that estimation from the true value ?
Certainly it is so difficult to answer this question since the information describing these parameters are very often incomplete. Arc GIS is an appropriate way to simulate the parameters along Gaza Strip. Arc GIS has a lot of advantages since it deals with spatial layers to get the need result in relatively short time according to manual work.
This study proposes an empirical approach that can lead a comprehensive understanding of an aquifer, delineates areas that are more susceptible to contamination from anthropogenic sources (mainly fertilizers), and recommends a set of operational activities for region of the aquifer. The study focuses on the Coastal aquifer of the Gaza Strip region. The approach also involves on-going monitoring of the quality of aquifer, and can be considered as an empirical tool to provide preliminary guidelines for vulnerability assessment of Gaza aquifer.

HIGHLIGHTS

- The study reveals that the majority of Gaza strip areas are of high fertilizer contamination vulnerability.
- The study shows that the high risk imposed on the aquifer is due to the high pollution potential of intensive vegetable cultivation, excessive use of either fertilizers and/or irrigation without any control.

- The Sensitivity analysis indicated that the vulnerability index is highly sensitive to the removal of “hydraulic conductivity”, “soil media”, and “depth-of-water” layers.

USING GIS AND DEM TO IDENTIFY SUITABLE RAINWATER HARVESTING SITES IN RIYADH REGION OF SAUDI ARABIA

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ABSTRACT

This paper presents a procedure for selecting potential rainwater harvesting sites in the arid central region of Riyadh, Kingdom of Saudi Arabia (KSA) using Geographic Information Systems (GIS) and Digital Elevation Model (DEM). Isohyetal maps were constructed based on rainfall data of various rain gauges, after processing the data using Inverse Distance Weighting (IDW) interpolation method and their conversion to grid raster. This method was found most accurate among five other methods; these are: Kriging, Spline, Natural Neighbor, Modified Shepard and Triangulation with Linear Interpolation (TIN). The choice of the interpolation method was based on minimizing the residuals between estimations for rainfall at the rain gauges and the observed measurements. 10 potential water harvesting sites were identified after overlying the areas of maximum monthly rainfall on the DEM, detecting the wadis and delineating the watersheds. While identifying potential water harvesting sites depends on many factors; such as watershed area, topography, morphology and rainfall, the results of this study relied primarily on rainfall being the most important factor.

HIGHLIGHTS

- The study presented procedures for using GIS, DEM and rainfall data to detect suitable sites for water harvesting.
- The Inverse Distance Weighting method of interpolation proved most successful compared to the other three methods: Kriging, Spline and Natural Neighbor, for generating the isohyetal maps.
- The use of DEM enabled detecting two sample water harvesting sites within the study area.

FLOOD HYDROGRAPH MODELING STUDIES BY USING GIS AND HEC-HMS FOR DAKAR, SENEGAL

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ABSTRACT

Water is the most basic requirement of human being. The demand for water includes; municipal, hydropower, navigation, industrial, agricultural and recreational use of water resources. The problem about these requirements is that water is not always available in the desired quantity and quality. In the other side, excess of water may lead to the undesired results like floods. Uncontrollably abundance of water especially for short time periods causes loss of human lives and great damage. Therefore most important requirement of human being, water, should be used without waste and precautions should be taken for disasters that water may cause. Water resources management is closely related to the river basin characteristics. Basin is a dynamic and very complex system which has mainly two types of characteristics; geographic and hydrologic. In this study, Dakar, the capital city of Senegal, is selected for the application of basin and hydrologic modeling studies. The hydrologic characteristics of the Dakar Basin were determined by using Geographic Information System (GIS). In sub-basin and stream network delineation HEC-GeoHMS software is used and for the hydrologic modeling studies HEC-HMS software is used. Modeling studies consist of three items: event-based hourly simulations, daily runoff forecast using numerical weather prediction data, and runoff scenarios using intensity-duration-frequency curves. In this paper, subjects mentioned above will be tried to discuss.

A SPATIAL ATTEMPT FOR CONSTRUCTING RESTRICTION ZONES AROUND WATER RESERVOIRS FOR PROTECTING WATER QUALITY

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ABSTRACT

Developing water protection strategies to prevent drinking water sources from contamination is a high priority throughout the world. As a significant policy measure, the segmentation of the delineated watershed areas into several zones is implemented by defining areas closest to the intake and more distant areas. Article 8 of the Directive 80/778 relating to the quality of water intended for human consumption in the European Union for example, forces Member States to take measures for securing the quality of water while in some connected policy documents the rationale behind constructing safeguard zones with land-use restrictions are referred to this end. Due to the requirements set out in legislations, authorities responsible for protecting the water quality similarly apply some restrictions on collective settlements, industrial and agricultural developments particularly in the protection zones. Such restrictions have direct impacts on the social and economical activities of the population residing in the basin. Besides, descriptive differences between legislations from different levels or different practices performed by the different authorities lead to disparities between the basins that are subject to quite different protective measures and zoning systems in spite of their analogous basin characteristics. All such challenges and disputes in protection mostly relate to the lack of scientific basis of protection regulations that limits its qualification for being widely acceptable by and easily verifiable to the general public. The spatial approach presented in this study addresses the above challenges arising from the current practices of reservoir protection and aims at providing guidance for an alternative strategy to achieve a practical solution.

HIGHLIGHTS

- The study provides a comparably practical methodology for deciding upon an optimum protection distance in a watershed.

- The approach can be considered in relation to the constant zoning system that is advised and even ruled by the regulations.
- Through the use of the land utility index, the approach turns out to be a compromise between the protection issue and the total utility of the land.

REMOTE SENSING (RS) AND GEOGRAPHICAL INFORMATION SYSTEMS (GIS) USAGE FOR CLIMATE CHANGE EFFECTS

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ABSTRACT

Global warming becomes a critical and dominant global environmental problem in the last three decades, resulting from global climate change. The subject of climatic change has received increasing attention especially in scientific literature and in the popular press. The earth's climate is dynamic. An understanding of its variability is vital in today's advanced society. Climate change will mainly stand out from sea level rise and more frequent and intense rainfall as well as extended dry periods. GIS with updated data helps people to know what happens in our planet, how climate takes place and where impacts of climate change affect people. Remote sensing was also identified as an institutional technology. Tying remote sensing technologies and data with GIS is a powerful combination of understanding spatial patterns in the earth's changing surface. RS and GIS are applicable in climate change analysis and adaptation. Using GIS and Remote sensing techniques allows us to utilize complex statistical methods to view trends and change at specific times or over periods of times. The aim of this study is to describe terms such as climate change, remote sensing (RS) and geographical information systems (GIS) and to give examples about climate change with the application of RS and GIS and to explain the role of RS and GIS in climate change management.

MANAGEMENT OF A SEWER NETWORK BY COUPLING GIS AND HYDRAULIC MODELING: A CASE STUDY OF THE NEW UNIVERSITY IN TLEMCEN, ALGERIA

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ABSTRACT

The way in which problems of sewerage management are growth, has continued to change more and more rapidly. The reasons are numerous: development of the urbanization, climate context, increased water consumption by individuals and industries. The complexity of these tasks shows today that the traditional management of sewerage becomes more and more difficult; this is why there is a need of methods allowing the use of computer tools. The use of new investigative tools such as digital mapping GIS has become vital, even compulsory. The new Tlemcen university center, located in the northwest of the city of Tlemcen offers 24000 seats and 12000 beds for students. Due to the importance of the realized infrastructures, a model giving the opportunity of sanitation in a sustainable way must be made for this pole. The objective of this work is not only to establish a computational model for the sewerage system of the new university center but also to ensure its management using a GIS. Mapbasic subroutines are developed for the simulation of the network behavior for different return periods, based on the model of Caquot (surface method). This model will generate strategies for managing rainwater flux taking into account the weather conditions, topography and land use. The simulations done helped to highlight the influence of rainfall events on the network. This tool can help managers for decision-making by addressing the shortcomings identified and may therefore provide a performance level of the optimal network operation.

KARST GROUNDWATER INVESTIGATION, EXPLOITATION AND PROTECTION: THE ROLE OF REMOTE SENSING AND GIS

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ABSTRACT

Current research in karst hydrogeology shows the need to dedicate more attention to the study of karst geomorphological and hydrological processes including its overall structure and function both at regional and local scale. This is to answer such questions as from and where to is the groundwater movement. Similarly, it is also to define the governing hydrogeological conditions such as recharge zones and infiltration processes owing to the complex and unique geological framework of conduit networks, sinkholes and other speleological features. Over the last three decades, a lot has been achieved in monitoring karst groundwater flow, origin and quality using spring hydrographs, isotopes, tracer tests and other hydro-chemical techniques. But these methods are usually conducted independently taking long periods and requiring large research teams at a high cost. This paper discusses some of these techniques and the challenges so far as well as the need for a systematic approach using satellite remote sensing (RS) and geographic information systems (GIS) to complement them. High resolution satellite images can provide a collage of geo-thematic derivative data sets such as lithology, vegetation, water and topography. These derivatives coupled with in situ acquired data sets on a GIS can provide an efficient approach in developing very accurate and highly informative karst conceptual site models which are imperatives for any meaningful water resources investigation. Furthermore, an integrated approach of this nature affords us to perform geospatial analyses and run different models as well as the power of visualization where complex results are represented in a simplified manner for efficient management of groundwater resources.

HIGHLIGHTS

- Current karst investigation methods, their advantages and limitations.
- The spatial and temporal advantages of satellite remote sensing and GIS towards developing a conceptual site model for karst water resources.
- Highlights from karst water resources projects in South China.

EVALUATING MULTI-TEMPORAL HIGH RESOLUTION SATELLITE CHLOROPHYLL– α MAPS IN SENSITIVE SHALLOW INLAND WATER SYSTEMS: THE CASE OF LAKE KARLA

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ABSTRACT

In this paper multitemporal, multispectral, remote sensing Landsat data have been exploited towards the establishment of a standardized, cost-effective, monitoring process of key water quality parameters in shallow lake ecosystems. Based on concurrent field and satellite data acquisition campaigns, multiple in-situ, analytical, hyperspectral and satellite observations were processed and fused towards the establishment of concrete relationships between remote observations and physico-chemical parameters.

The emphasis in the present study was given in chlorophyll-α concentrations i.e., a photosynthetic pigment present in all freshwater algal groups. The comprehensive analysis and quantitative evaluation was based on the production of several high-resolution, multi-temporal chlorophyll-α maps in the sensitive, shallow Lake Karla, Greece. The spatio-temporal analysis revealed a gradual slight decline in average chlorophyll-α concentrations from the beginning of 2011 and onward. Along with this decrease in mean chlorophyll levels a similar gradual decrease was detected on the peak concentration levels, as well. The established relation between remote sensing and in-situ data was based on linear regression models with high correlation rates (i.e, r^2>89% for chl-a), while certain mismatches were due to frequent cyanobacterial blooms and observed mainly on the quite shallow parts of the lake.

The spatio-temporal analysis indicated, moreover, that a revision on the location of current sampling stations will contribute to a more efficient and representative in-situ monitoring system. High resolution, multispectral satellite data can, thus, form the core of a low-cost water monitoring system and feed continuously a water quality geospatial database. Such an integrated system is the essential part of a water management plan towards the efficient protection and restoration of sensitive aquatic ecosystems such as the shallow lakes in the greater Mediterranean basin.

CLASSIFICATION OF DRAINAGE BASINS BASED ON READILY AVAILABLE INFORMATION

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ABSTRACT

Classification of drainage basins into groups with similar response to meteorological forcing is very useful in cases of transfer of hydrological information in space such as in streamflow prediction in ungauged basins. This kind of data processing is critical for the implementation of the Water Framework Directive and related legislative tools of the EU such as the Flood Directive. The paper focuses on testing the ability to classify drainage basins using climate-based variables and geomorphometric characteristics as predictors. Precipitation was selected as the climate-based variable, since this is commonly measured in the majority of basins. Geomorphometric characteristics include, among others, statistics of ground slope and the height above the nearest drainage point known as HAND. These are derived from a Digital Terrain Model. The employed methodology involves two steps. In the first step we perform unsupervised classification through using the fuzzy *c*-means method to identify basin classes that serve as reference classes in the second step of analysis. A set of hydrological signatures is used in the first step, which include the runoff ratio, the baseflow index, the slope of the flow duration curve, and the snow day ratio. In the second step we perform supervised classification through using the *k*-Nearest Neighbour method which maps predictors to basin classes. Last, the success rate of the obtained classification is assessed through using jack-knife re-sampling. Investigations were carried out on data from 24 gauged basins in mainland Greece. These were classified into four classes which are hydrologically meaningful. The employed methodology proved to be successful in more than 95% of cases of recognition of the class for an ungauged basin.

HIGHLIGHTS

- Classifying ungauged drainage basins is critical for the application of WFD.
- Classification of gauged basins via hydrological signatures was successful.
- Precipitation and geomorphometric characteristics suffice to successfully classify an ungauged basin.
- The availability of hydrological data proved to be the limiting factor.

TREND ANALYSIS OF METEOROLOGICAL DROUGHT INDICES IN CATCHMENTS OF BELGIUM

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ABSTRACT

Natural or human induced factors may gradually affect the hydrometeorological regime of an area influencing drought conditions. Trend analysis can identify whether successive values are increasing or decreasing. A non-parametric approach is generally selected when there is a need to lessen the underlying assumptions, such as the knowledge of the data distribution for testing a hypothesis. Non-parametric tests are mainly interested on the relative values or ranks of data and not on the magnitude of data. The present study performed a trend analysis on a fifty seven-year hydrometeorological data record for two drought indices, SPI (Standardized Precipitation Index) and RDI (Reconnaissance Drought Index) in Dijle-Demer catchments in Belgium. The two-tailed Mann-Kendall non-parametric test for trends was chosen to assess the tendency of the above indices and also the tendency of rainfall, maximum temperature and minimum temperature. The analysis was conducted for 3 reference periods: Annual, semester and trimester (over the entire period 1954-2011). Two significance levels were considered: a=0.1 and a=0.05. For the grid cells where the Mann-Kendall test revealed the existence of a trend, the Sen's Slope was evaluated to produce the median slope and identify whether the trend is positive or negative. Both RDI and SPI indices agreed in general on selected grids/locations where a positive (wetter) or negative (drier) slope can be identified. Furthermore, it was observed that the RDI index is more sensitive to the identification of decreasing trends.

HIGHLIGHTS

- Tmax and Tmin present a small positive trend in all cases
- Rainfall trends are mostly positive with some exceptions during the spring Trimester

- SPI trends follow almost precisely the rainfall tendency showing a wetter trend in several grid areas
- RDI trends are additionally affected by temperature, depicting the tendency of areas to become drier with the rising temperature

REMOTE SENSING METEOROLOGICAL DATA FUSION FOR EFFECTIVE FLOOD MITIGATION AND FORECASTING OVER MEDITERRANEAN

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ABSTRACT

The development of high-impact climate systems over the Eastern Mediterranean is often associated with extreme weather conditions that cause flood disasters. The proposed research will include the use of state of the art hydro-meteorological and remote sensing products towards an innovative and effective forecasting and mitigation of flood events over Eastern Mediterranean. High resolution METEOSAT satellite imagery, ERA Interim products, as well as historical forecast of the ECWMF Ensemble Prediction System will be used in order to assess the connection of large scale circulation and cyclone evolution with current and historical flood incidents in the island of Crete. The Melbourne University cyclone finding and tracking scheme will be used for the detection and definition of closed and open systems on ECMWF data. On a shorter temporal and finer spatial scale, data from the TRMM satellite and the Global Lightning Network sensors will be used to provide effective warning against extreme weather phenomena. Remote sensing observations will be calibrated and correlated with a network of 10-minute precipitation gauges that will be enriched during the course of the project. Furthermore, hydrological and hydraulic simulations from state of the art models will be performed to study rainfall-runoff processes. These simulations will be assisted by the use of the most up-to-date earth observation products such as high resolution stereo-pair derived DEMs and land cover properties based on VHR satellite image classification. The fusion of the proposed state of the art products will fill many gaps in the understanding of rainfall properties and their variation during the development of extreme weather conditions and their evolution into flood events. The expected scientific outcomes of this project will be disseminated to the international community and applied in the island of Crete with the collaboration of the local authorities.

Conference III

Technological Advances in Water Distribution, Purification and Desalination

AUTOMATED IRRIGATION SCHEDULING IN DRIP IRRIGATION SYSTEMS: OPTIMUM SOIL MOISTURE SENSORS POSITIONING

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ABSTRACT

Proper irrigation management requires a sound basis for making irrigation decisions. Recent advances in electromagnetic soil moisture sensor technologies have greatly facilitated the automation of irrigation scheduling. However, sensors positioning and characteristics (e.g. control volume, accuracy) are important factors affecting irrigation efficiency. Many of the available guidelines for sensor placement were empirically determined from site and crop specific experiments. The main goal of this study is to investigate how soil moisture sensor positioning influences the representativeness of its readings regarding to the average soil water content in the root zone in the case of a soil moisture based drip irrigation scheduling system under various conditions. For this purpose several numerical experiments were carried out using a mathematical model, incorporating a system-dependent boundary condition in order to simulate soil moisture based irrigation scheduling systems. The results of this study provided clear evidence that the positioning of soil moisture sensors driving automated drip irrigation scheduling systems, considerably affect the representativeness of their readings hampering proper irrigation management. Furthermore, sensors' representativeness varies according to the existing conditions (soil hydraulic properties, meteorological conditions etc.) and the irrigation systems characteristics. Based on the numerical experiments results, recommendations for the optimum sensor positioning are provided. Lastly, a significant outcome of this study is the ability of computer models to serve as efficient tools for the detailed investigation of sensors positioning or other automated scheduling system characteristics under various conditions in order to provide a sound basis for improved irrigation management.

HIGHLIGHTS

- Positioning of sensors driving automated drip irrigation scheduling systems considerably affect the representativeness of their readings.
- Time stable representative positions (TSRP) for mean soil water content estimation were identified.
- General recommendations for the optimum sensor positioning are provided.
- Computer models are efficient tools for the investigation of sensors positioning or other automated irrigation scheduling system characteristics.

INCLUDING LEAKAGE AS PRESSURE DRIVEN DEMANDS IN OPTIMAL DESIGN OF WATER DISTRIBUTION NETWORKS

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ABSTRACT

The loss of some part of water through leakage is inevitable in a water distribution network (WDN). Regular maintenance and upkeep of the system keeps these losses within a permissible limit. Therefore, WDNs are designed for the projected demands including some permissible leakage losses as the fixed percentage of nodal demands in the network. However, the leakage losses are pressure dependent and increase with the increase in pressure in the pipeline. A network designed by considering leakages as volume based demand (i.e. fixed percentage of nodal demands) may become pressure-deficient when leakage losses are considered to be pressure-driven. A methodology is proposed to include leakage losses as pressure driven demands along with normal volume based demands in the optimal design of WDNs. The proposed iterative optimization methodology considers link diameters as continuous variables. It starts by assuming the nodal heads at all the demand nodes such that they are above desired pressure heads. These assumed heads are successively corrected until network cost reduces, or the difference in cost in two successive iterations is found negligible. The non-commercial pipe sizes are converted to commercial sizes by splitting it into two sizes. The versatility of the methodology is shown by its application on various types of networks. The higher amount of leakages are properly accounted when they are considered as pressure driven and thus selects higher pipe sizes.

HIGHLIGHTS

- Development of optimal design methodology for including leakage as pressure-driven demand.
- The increase in network cost due to higher losses.
- Versatility of the methodology for its application to both branched as well as looped types of networks.

SENSOR PLACEMENT FOR INTERMITTENT WATER DISTRIBUTION NETWORK SECURITY

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ABSTRACT

Intermittent water supply is very common in developing countries. Limited water resource and bad condition of network primarily force operational intermittency. Intermittent system is more prone to contaminant ingress as compared to that operated on continuous mode. Water leaks through joints and cracks, and the zone of contamination is formed into the soil nearby broken sewers and open drains. During non-supply hours, contaminants ingress into the water distribution network due to lower pressure inside the pipeline. Integrated risk assessment is a methodology to identify risk prone areas of contaminant ingress using the geospatial databases of the water supply network, sewer network, open drains, ground water table and soil with number of system specific attributes. The pipes and nodes of water supply network are classified as high, medium and low risk pipes. In the present study, a Genetic Algorithm based methodology is suggested to locate the sensors to maximize the detection likelihood of the contamination events within the acceptable time from the risk prone areas to improve network security. The performance objectives are evaluated considering behavior of WDN under pressure-deficient condition. A comparison of sensor network design is made by considering contamination events: (i) occurring with equal probability at all the nodes; (ii) occurring with equal probability at nodes on risk prone areas; and (iii) probability of occurrences based on quantified risk. Identification of risk prone area results in reduction of computational work and more sensible placement of sensors.

HIGHLIGHTS

- The identification of risk prone area to select more vulnerable nodes and pipes to contamination.
- Development of optimal sensor locations based on the risk analysis of water supply system.

- Comparison of different sensor network designs based on the weights to contamination events based on risk.

LOCATIONAL VARIABILITY OF EMERGING DISINFECTION BY-PRODUCTS IN DRINKING WATER

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ABSTRACT

Past studies have shown that trihalomethanes (THMs) and haloacetic acids (HAAs), disinfection by-products (DBPs) regulated in various industrialized countries, vary considerably within municipal water distribution systems, both seasonally and spatially. However, very little information is available in the literature on changes in concentration of emerging DBPs (not regulated). In this study, we carried out sampling campaigns to compare levels of various emerging and regulated DBPs in drinking water in small, medium and large systems of Canada. Monitoring was conducted in three systems using chlorination (one small, one medium and one large) and one system using chloramination at various periods of the year, and at various locations between the water treatment plant (WTP) and the distribution extremities of each system to take account of spatial variability. The study focused on the following compounds found at very low concentrations in drinking water (from ng/L to few µg/L): haloacetonitriles (HANs), haloketones (HKs), one halonitromethane species (chloropicrin (CP) and one *N*-nitrosamine species (nitrosodimethylamine (NDMA)). Results highlighted that the pattern of spatial variability (in terms of variation direction, i.e., decrease or increase, and not in terms of absolute concentration variation) of some DBPs was comparable for the small, medium and large systems that use chlorination, but not for all DBPs. Results also showed that regulated DBPs may be used as surrogates for the occurrence of total HANs, total HKs and CP in the small system using chlorination. This was also the case in the medium system using chlorination, except for CP. However, in the large system using chlorination, regulated DBPs were not good indicators for emerging DBPs, except for HANs. Then again, correlations between regulated DBPs and NDMA showed that regulated DBPs were not a good proxy for NDMA in the one small system using chloramination. Globally, the results of this study contribute to a better understanding of the population's exposure to DBPs in municipal drinking water.

HIGHLIGHTS

- Seasonal variations of emerging DBPs were high
- Locational variations of emerging DBPs were high
- Emerging DBP levels were higher in small systems than in large systems
- Emerging DBP levels are correlated in some way with regulated DBP levels

A COST-SIMULATION APPROACH FINDING ECONOMIC OPTIMALITY IN COMPLEX SUPPLY SYSTEMS RENOVATION STRATEGY

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ABSTRACT

When negotiating optimal decisions considering complex multi-centre (or multi-district) supply systems, subject to reduced water resources and reduced funds, the optimal economic level in renovation strategy for leakage reduction must be defined. The optimal economic conditions will be reaching the equilibrium between the marginal benefits of saving water and assuring the service and marginal costs of renovation of the system. This concept is here specifically used to deal with the question of what the target for reducing leakage should be and how related costs can be justified. Nevertheless, the problem can be much more difficult to define and analyses, particularly if the system is constrained by reduced water resources and reduced funds. Mainly, in this situation, the optimal economic problem can be modified in order to find the investment priorities for renovation strategy between the centers in the supply network. This study is related to these aspects; it focuses on defining a reliable and correctly justified cost function for the water in multi-source and multi-centre systems. A cost-simulation procedure is then developed in order to define the incremental behavior of the water-cost along the paths connecting each demand node to the supply nodes. WARGI-SIM decision support system was used in order to find the optimal flow configuration retrieved from the DSS model. The incremental cumulative water costs were then estimated at each demand node. Moreover, the incremental benefit and benefit/cost ratio in saving water were defined in order to find the investment priorities in renovation strategies for leakage reduction between the served centers. A real case application will be presented in the paper.

CALIBRATION OF WATER DISTRIBUTION NETWORKS WITH FIRE FLOW TESTS

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ABSTRACT

In many fields of engineering, mathematical models are used to represent complex processes. The behaviour of a water distribution system can be well understood mathematically with a calibrated hydraulic model. Water distribution system models must cover accurately static and dynamic information of a pipe network system. A water distribution hydraulic model, in order to be reliable, must be calibrated. Calibration of hydraulic models is a procedure of determining individual unknown parameters of a hydraulic model, which minimizes the differences between the measurements performed on a real water distribution system and the calculated analysis results of the hydraulic model. This study examines the use of data from hydraulic fire flow tests to calibrate a model for a small utility. Hydraulic model of the system and calibration was performed by using the MIKE URBAN program by DHI consulting and research organization. The system used in this study is in a small utility located in 19 Mayıs District in Samsun-TURKEY. The applied calibration approach is consisting of the "macro" and "micro" calibration level. At macro calibration level, all major possibilities of the water distribution system model discrepancies should be uncovered and resolved. Afterwards the micro calibration procedure is applied to identify the model parameters by using the optimization method of genetic algorithms. It can be concluded that the calibration approach was successfully applied to small utility with the use of fire flow tests.

HIGHLIGHTS

- Genetic algorithm automatically generates and evaluates hundreds of thousands of possible solutions, which is not possible by conventional trial-and-error method. Thus the search process effectively improves the calibration accuracy.
- Water authorities should take care of their networks and perform a hydraulic model for efficient usage.

- Elements of networks should be checked regularly and their maintenance should be carried out without delay.
- Locations of fire hydrants used to collect calibration data should be recorded precisely and they should be prevented against deformations.
- Any construction, connection, and change in water distribution systems should be considered in computer models

ECONOMIC LEAKAGE LEVEL ANALYSIS IN A WATER DISTRIBUTION SYSTEM

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ABSTRACT

The high Non-Revenue Water (NRW) as a percentage of System Input Volume (SIV) is a common phenomenon observed in several countries, including Greece. It is very significant and complex for water utilities to calculate the components of NRW and then develop the best strategies for the reduction of NRW and especially of Real Losses. The most important component of a leakage control strategy is target setting in terms of economic level of leakage (ELL). The ELL is an economic indication depending on individual network conditions, operating system pressures, demands, marginal cost of water, and operating practices. This paper investigates the water network of Kozani city, located in Northern Greece. Short-Run ELL (SRELL) and Long-Run ELL (LRELL) are calculated throughout the network. Regarding the SRELL, the economic level of service of repairs is determined, due to utility's current data analysis. The optimal frequency of Active Leakage Control (ALC) is defined with the help of Economic Frequency of Intervention (Rate of Rise) Method. Regarding the LRELL, the Pressure Management strategy with the simultaneous implementation of District Metered Areas (DMAs) was analyzed. The latter was implemented by running different hydraulic and leakage scenarios of the network's model, which was created using Bentley WaterGEMS software. The usefulness of the new concept of Medium-Run ELL (MRELL) in the utility's decision making was investigated taking into account factors such as the water's price-elasticity of demand and the Full Water Cost (FWC). The research will help utility managers understand different aspects of the leakage economics and will lead to a better management of their WDS.

HIGHLIGHTS

- The definition of MRELL facilitates companies to take a decision, because it brings the objective very closely.
- The impact of conducting ALC and Service of Repairs to Pressure Management and vice versa are defined

.

- The impact of the change in water price as a measure of conservative demand to LRELL and MRELL is examined.

PRACTICAL APPLICATION OF PENALTY-FREE EVOLUTIONARY MULTI-OBJECTIVE OPTIMISATION OF WATER DISTRIBUTION SYSTEMS

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ABSTRACT

Evolutionary algorithms are a commonly applied optimisation approach in water distribution systems. However, the algorithms are time consuming when applied to large optimisation problems. The aim of this paper is to evaluate the application of a penalty-free multi-objective evolutionary optimisation algorithm to solve a real-life network design problem. The optimization model uses pressure-dependent analysis that accounts for the pressure dependency of the nodal flows and thus avoids the need for penalties to address violations of the nodal pressure constraints. The algorithm has been tested previously using benchmark optimisation problems in the literature. In all cases, the algorithm found improved solutions and/or the best solution reported previously in the literature with considerably fewer function evaluations. In this paper, a real-life network with over 250 pipes was considered. The network comprises multiple sources, multiple demand categories, many fire flows and involves extended period simulation. Due to the size and complexity of the optimization problem, a high performance computer that comprises multiple cores was used for the computational solution. Multiple optimisation runs were performed concurrently. Overall, the algorithm performs well; it consistently provides least cost solutions that satisfy all the system requirements quickly. The least-cost design obtained was over 40% cheaper than the existing network in terms of the pipe costs.

HIGHLIGHTS

- The penalty-free multi-objective optimisation approach is efficent in solving real-life network with large solution space succesfully
- Significant reduction in computation time achieved using high performance computer

SECURING WATER SUPPLY IN ADELAIDE OVER THE NEXT CENTURY BALANCING DESALINATED AND MURRAY-DARLING BASIN WATER

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ABSTRACT

This paper assesses the two major water supply options for a growing but relatively dry metropolitan Adelaide – desalination and expanded trading of water from the Murray-Darling Basin (MDB). What we present in this paper is a portfolio approach suggesting a mixed strategy of desalination and water trading to meet growing demand over the hundred year period from 2014. Crucially, the scope for expanding water trading keeps average costs down, for as long as the political agreements work and drought does not prevent the use of allocations. However, our modelling shows that in the long run water trade in combination with modular augmentation of desalination capacity can achieve a mix of security and cost that avoids spikes in market prices of MDB allocations during drought. The strategy also avoids the real business and household costs, loss of garden value and inconvenience of water restrictions.

NIREUS: APPLICATION OF THE NEW SOFTWARE FOR THE ANALYSIS OF PRESSURIZED COLLECTIVE IRRIGATION NETWORKS OPERATING ON-DEMAND

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ABSTRACT

On-demand collective irrigation networks are hydraulic systems designed to deliver and distribute irrigation water from the water source to the irrigation perimeter, while providing users with the flexibility to decide on the time, the duration and the frequency with which they intend to use their hydrant. This paper presents the application of the newly developed software NIREUS, which is developed for implementing the operation analysis of such networks. The application analysis is made to an existing on-demand pressurized collective irrigation network. The application aims to highlight both the weak and the strong parts of the network in terms of their hydraulic behaviour. On the one hand, operation analysis with NIREUS gives an overview of the operational status of the network under study by implementing the model of the indexed characteristic curves, and on the other hand, NIREUS determines the pipes/hydrants of the network that present (or are most likely to present) operational problems, by implementing the analysis at hydrant level. This information is particularly useful for networks under study, for the management of existing networks as well as for the planning of future interventions and rehabilitation. The paper also describes the main functions of NIREUS and the characteristics that differentiate it from other existing software (ICARE, COPAM). Finally, a comparative application of NIREUS and COPAM is made on a Greek on-demand irrigation network.

HIGHLIGHTS

- This paper presents the newly developed software NIREUS for which the source code was developed from scratch at the Agricultural University of Athens.
- Unlike existing software which function as a "black box", NIREUS allows to intervene at any point of the analysis, differentiate the model's parameters and examine their impact on the operation analysis.

- NIREUS was applied for the operation analysis of an on-demand irrigation network, for which the parts of the network that are most likely to present deficiencies are presented.

PERFORMANCE INDICATORS FOR DAMAGED WATER DISTRIBUTION SYSTEMS

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ABSTRACT

Water distribution systems are one of the most vital lifelines of urban areas. A water distribution system consists of pipes and other hydraulic appurtenances like valves, pumps, connection fittings and storages. Pipes are the main elements of a water distribution system and they may be damaged after natural disasters (earthquake, landslide etc.) or operational errors (waterhammer etc.). A water distribution system is expected to serve at a certain level after some pipes are damaged during a natural disaster. Pipe damages may be grouped as break and leak. A break is defined as the complete separation of a pipeline, such that no flow will pass between the two adjacent sections of the broken pipe. On the other hand, a leak is defined as a gap in pipe, such that water will continue to flow through the pipeline, while some loss of pressure and flow through the leak. Performance of a water distribution system depends on the available flows and pressures in the damaged system. Performance indicators may be collected in two groups as system and component. Earthquake may be the major destructive phenomenon on the water distribution systems so in this study post-earthquake performance of a hypothetical water distribution system will be examined in detailed. Existing performance indicators for the water distribution systems are presented and they are compared for the hypothetical water distribution system. Graphical Iterative Response Analysis for Flow Following Earthquakes (GIRAFFE) computer program was used with EPANET to perform deterministic and Monte-Carlo probabilistic simulations of the system.

HIGHLIGHTS

- Performance assessment is very important study for water distribution systems.
- As regards earthquake Monte-Carlo probabilistic simulation is useful than deterministic simulation.

MULTI-DIRECTIONAL SEARCH STRATEGY TO OPTIMAL DESIGNS OF WATER DISTRIBUTION SYSTEMS

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ABSTRACT

There is a growing body of evidence that, on average, hydraulic capacity of water distribution systems increases in line with entropy of flow directions. Motivated by the existence of large sets of flow directions in looped water distribution systems along with the computational simplicity of the informational entropy function, a multi-directional search approach that aims at maximizing the entropy of water distribution systems in the vicinity of both feasible and infeasible solution spaces is proposed. The approach simultaneously searches in multiple directions for minimum cost designs each characterized with having the highest theoretical entropy of the corresponding set of flow directions. The performance and efficiency of the proposed approach are demonstrated by designing a real network from literature. The results obtained achieve an appropriate balance between feasible and infeasible solutions. *Inter alia*, the significance is that in cases where there is a shortfall in funding, a good range of infeasible solutions would also be available for consideration from the Pareto optimal front. In addition to the global maximum entropy minimum cost solution, a number of minimum cost designs for different, smaller, local maximum entropy values were produced also. A *local* maximum entropy value is the maximum entropy value for a given feasible set of flow directions. The *global* maximum entropy value is the maximum value for all feasible flow distributions for the network. Excellent results were achieved for the sample network considered in this article.

HIGHLIGHTS

- A new multi-directional search strategy preserving local optimal solutions while proceeding towards the global optimal solution has been proposed.
- An excellent compromise between cost and reliability of water distribution systems has been efficiently achieved using the suggested approach.
- A new definition of infeasibility to facilitate solving cost minimization and reliability maximization of water distribution systems has been introduced.

- Reducing the complexity of solving the optimization problems of cost minimization and reliability maximization of water distribution systems.

HYDROLOGICAL CONTRIBUTION TOWARD SEA WATER INTRUSION PHENOMENON IN TERENGGANU, MALAYSIA

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ABSTRACT

A study was conducted at Paka River, Terengganu on determination of hydrological characteristics of Paka River at seven sampling stations. Sampling was started from the estuary of Paka River, and ended about 14 km away from the estuary as each station was 2 km apart from each other. Sampling was carried out at two different water tides (low and high water tides) and two durational variations which represented by the Northeast Monsoon (wet period) and the Southeast Monsoon (dry period). Hydrological measurements of river velocity, river width and river depth were measured by using specific equipment. River width was measured by using a rangefinder (model Bushnell 20-0001), river depth was measured by using a depth meter (model Speed tech SM-5) and river velocity was measured by using a flow meter/current flow meter (model FP101). Water quality parameters such as conductivity, salinity, pH and total dissolved solids (TDS) were directly measured in the field by using a multiparameter YSI 556 meter. Analyses of sodium, sulphate and magnesium ions were performed according to the standard method of analysis by APHA and HACH. Primary data which consist of hydrological measurements and physicochemical properties of Paka River were measured and analysed for each sampling stations. Physicochemical parameters which consist of pH, total dissolved solids, salinity, electrical conductivity, sodium, and sulphate and magnesium concentrations were applied in order to determine the correlations with the influence of seawater movement and other factors to the water quality of Paka River. Overall, station 1 was showing the highest readings for most physicochemical parameters at both water tides during the first and second samplings. Stations 1 that were located at the downstream identified by high readings of most physicochemical parameters as compared to stations 7 which located at the upstream, is related to the effect of seawater movement during high tide. Higher readings of physicochemical parameters were also shown during dry season since freshwater flow from the upstream due to less rainfall intensity.

WATER LOSSES DURING DISTRIBUTION AND APPLICATION IN COLLECTIVE IRRIGATION NETWORKS

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ABSTRACT

The present paper is a part of a doctoral research on the plain of Thessaloniki, Greece about irrigation water losses. Reducing application losses of irrigation water is an integral part of good water management. Water volume consumed for crop irrigation at the plain of Thessaloniki, was estimated and compared against the volume reported by the General Land Reclamation Organisation (G.L.R.O.) of Thessaloniki – Lagadas. For the estimation of net crop water requirements, the crop evapotranspiration was taken into account and also the contribution of the effective precipitation. Estimates were performed for fourteen collective irrigation networks, located at the plain of Thessaloniki and for year 2002 to 2010 inclusive. Rivers Aliakmonas and Axios are the main sources of these networks. Results reveal considerable losses of irrigation water that are related to the management, operation and maintenance of the networks by the Local Land Reclamation Organizations (L.L.R.O.).

USE OF CLAY MINERALS TO REDUCE AMMONIUM CONCENTRATION IN GROUNDWATER

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ABSTRACT

The results indicated that halloysite exhibited fast adsorption rates and high removal capacity from solution in respect to the NH_4^+ ions concentration at pH=7.0. The removal efficiency of the treated halloysite depends on the mass/volume ratio and also on the initial concentration of NH_4^+ ions in solution. High mass/volume ratios (0.4g/20mL, 0.4g/50mL) exhibit up to 30% of the halloysite's removal efficiency, when the initial NH_4^+ ions concentration is low (<40 mg/L). By contrast, low mass/volume ratios (0.4g/100mL, 0.4g/200mL) indicate lower removal capacity with respect to low NH_4^+ ions concentration in solution. The Langmiur adsorption models were applied to describe the equilibrium isotherms. In addition natural abundance constitutes halloysite clay mineral as a low cost effective material. Thus it can be considered as a promising technique in large and/or industrial scale applications for water and waste water purification purposes.

HIGHLIGHTS

- Ammonium contamination of groundwater in Zacharo basin has both organic and inorganic origin.
- The high ammonium values of groundwater are associated with the redox environment.
- The clay minerals palygorskite and saponite from Ventzia deposit (Western Macedonia, Greece) were successfully used as adsorbents for ammonium removal in groundwater.
- The proposed methodology for ammonium removal was proved as a very promising cost-effective technique.

REVIEW OF PIPE DETERIORATION, FAILURE, CONDITION ASSESSMENT TECHNIQUES IN WDS

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ABSTRACT

The Water Distribution System (WDS) is a complex technological system, working continuously and requiring a high safety level. The objectives of an urban water system are to provide safe, potable water for domestic use, adequate quantity of water at sufficient pressure for fire protection and water for industrial use. Urban water distribution systems around the world are becoming older and hence more prone to failure. Therefore, an efficient failure management strategy becomes important. The structural deterioration of water mains and their failures are affected by a number of factors, including pipe material, pipe size, pipe age, soil type, climate, and pressure zone changes. The main focus of this study is the deterioration and failure of pipe assets in urban water distribution systems (WDS). Due to the different topology and hydraulic characteristics of the transmission (pipelines) and distribution (network) components of a water supply system, separate failure detection and location techniques are proposed. In this study pipe deterioration, pipe failure (is a part of the deterioration process), different failure mechanisms and causes were outlined. A brief overview of existing deterioration modeling and failure prediction techniques were also given. Direct inspection and monitoring, also called non-destructive testing (NDT) and the indirect indicators, such as soil properties and historical pipe breakage rates were reviewed as evaluation techniques.

USING CLAY-SUPPORTED NANOSCALE ZERO-VALENT IRON FOR REMOVAL OF Ni FROM CONTAMINATED WATERS

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ABSTRACT

Application of zero-valent iron nanoparticles (ZVINs) for remediation of contaminated groundwater can potentially be a promising approach. However, co-aggregation of ZVINs decreases the durability and effectiveness of nanoparticles surface area. Locally available soil clays mineral with a stable structure could potentially be used as a porous-based material to support ZVINs for the removal of heavy metals from aqueous solution. Therefore, this study was conducted to synthesize the clay supported-ZVINs and to test its performance for Ni removal from aqueous solution. Soil sample were collected from a 0-30 cm depth and subjected to a series of pre-treatment steps that remove aggregating agents (carbonates, organic matte Al and Fe oxides) to isolate the clay fraction. The synthesized clay supported-ZVINs and non-supported- ZVINs was tested for the removal of Ni2+ ions in aqueous solution at various concentration of Ni in aqueous solution. Results showed that the potential of clay supported- ZVINs for removal Ni2+ was significantly higher that non-supported materials. Moreover, the synthesized clay supported-ZVINs had great reactivity. The obtained results demonstrated that clay supported-ZVINs can promisingly be used as an efficient sorbent for Ni2+ removal from contaminated waters.

Conference IV

Water Pollution and Eco-systems Conservancy

DETERMINATION OF CLEANER (SUSTAINABLE) PRODUCTION OPPORTUNITIES IN METAL PROCESSING (COATING) INDUSTRY

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ABSTRACT

In this study, It is aimed that production steps be evaluated within the scope of Cleaner (sustainable) Production approach and Best Available Techniques and Technologies (BATs) (especially in coating parts) to reduce the amount of water, chemicals, energy and the pollution load in the current waste water treatment plant be determined in a manner in which eco-efficiency of a metal processing (coating) company would be increased.
In line with this objective, a study was conducted in a company. As a result of the detailed environmental inventory study, a project was designed and Cleaner Production opportunities (bats and literature) were investigated. Water consumption is approximately 40.000 m^3/year in the plant. As a result of the preliminary studies and experiments, it was detected that the water (gray water and reusable water) can be separated in this phase, and the separated water can be reused within the system. By this means, load of existing wastewater treatment plant decreases. In addition, examples relating to waste reduction and/or recycling have been reviewed and the suggestions related to this issue have been made.
This study is expected to be a reference for metal processing (coating) industry in Turkey. By this means, while environmental performance increases through simple managerial and technical/technological measures, the economic gain is ensured.

HIGHLIGHTS

- We were investigated "Best Available Techniques" (BAT) for the most effective "Cleaner Production" (CP) opportunities to a metal processing (coating) industry
- It was detected that the water (gray water and reusable water) that"Cleaner Production" (CP) opportunities for different production steps to the company
- The study was supported by 19 Mayıs University

METAL WORKING FLUID RECYCLING AND WASTE REDUCTION OPPORTUNITIES IN METAL PROCESSING INDUSTRY

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ABSTRACT

Many different procedures are performed in the metal finishing industry. These are surface treatment, surface coating, surface finishing, painting, and other procedures. Although Metal finishing industries in European have many Cleaner Production and pollution prevention activities, it is very limited in Turkey side. In this study, metal surface treatment used in the coolant and has been exposed to metal chips were integrated with Cleaner Production approach within the framework and evaluated in this section Best Available Techniques (BATs) for determining the economic and ecological efficiency. In line with these objectives, the entire production to reflect the implementation study was conducted in four units of CNC machine tools. All metal parts processed in production for two months were studied. As the coolant using two different companies provide technical and environmental performance of these chemicals have been examined. The parameters monitored in the study were cooling oil concentration, pH value, temperature, conductivity, nitrite, external oil concentration and total bacteria. Nitrite levels towards the end of the month, 30 mg/l was observed. External oil contaminated coolant during metal processing and concentration of the coolant with low suspended solids has increased steadily according to the time of use. No microorganisms is required prevent coolant. Microorganisms breed in stagnant conditions and anauxite. Therefore during metal working fluid supply the mixture and ventilation is important. All parameters of the coolant recovery and re-use and life extension planned to be formed for the purpose of treatment and the supply line will be decisive. The best technique/technology for related sectors examining the most appropriate proposals for determining are presented in this research.

CLIMATE CHANGE IMPACT ON HEAVY METAL RELEASE IN A RECLAIMED COASTAL AQUIFER

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ABSTRACT

The low-lying coastal areas and especially the delta areas, are prone to saltwater intrusion due to sea level rise, which may lead to a loss of ecosystem services brought about by salinization of already limited freshwater reserves. Despite the acknowledged importance of climate change impacts and land use practices on water resources availability there is still a lack of studies on the issue of climate changes induced alteration of water quality. To understand the hydrogeochemical processes occurring within the shallow groundwater system of the Po river delta (Italy), the contribution of local water-sediment interaction and the anthropogenic influence on groundwater quality were quantified. High resolution multi-level sampling was used to capture chemical gradients within the aquifer. Data were employed to calibrate a density dependent multicomponent reactive transport model implemented with PHT3D code along a flow line. The reactive network accounted for redox driven organic matter oxidation and cation exchange. Finally, a series of numerical scenarios were run following the projection of IPCC 2014 on sea level rise and climate change. Results of the predictive model highlight an increase of arsenic, vanadium and lead in the shallow portion of the aquifer, drained by the reclamation network. The increase of heavy metals export toward surface waters could be of serious concern, since the drainage network deserves also for irrigation purposes. Thus, the surface water quality could be negatively affected by climate changes.

HIGHLIGHTS

- A multicomponent reactive transport model was calibrated in a coastal aquifer along a flow line
- The heavy metal release mechanisms were driven by organic matter degradation and ionic strength of the solution.

- Large amount of organic phosphorous released by organic matter outcompeted arsenic for surface complexation sites.
- An increase of heavy metals is predicted in the surface drainage network following climate changes forecast by IPCC.

IRRIGATION-INDUCED GROUNDWATER NITRATE POLLUTION IN MEDITERRANEAN AGRICULTURE

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ABSTRACT

Fertilization and irrigation both are playing an increasingly major role in productivity of the common crops in the Mediterranean countries. Their importance is even more recognized in the recent years because of the global warming and water scarcity. However, irrigation together with nitrogen (N) fertilization induces nitrate (NO_3) losses to groundwater bodies and drainage especially during the rainy season in winter and irrigation season in the summer months. Therefore, irrigation-induced NO_3 leaching in groundwater was assessed during the hydrological years (HY) of 2012 and 2013 in Akarsu Irrigation District (AID) of southern Turkey. The research in irrigated land sought to determine spatial and temporal variability of groundwater NO_3 concentrations and loads. The research was conducted in a hydrologically well-defined 9,495 ha area in the AID where 108 shallow drainage observation wells were monitored during these two years and 4 times a year representing the status in irrigation and non-irrigation seasons (IS, NIS). Additional soil, plant and climatic parameters were either measured or recorded locally. The monthly average NO_3 concentrations were higher in Feb. (27 mg L^{-1}) as the rainy season and in July (15 mg L^{-1}) as the peak irrigation season, and lower in Sept. (10 mg L^{-1}). The nitrate load in the groundwater was also higher during the irrigation season and was as high as 0.7

Mg ha^{-1} in certain points under intensive water use during the irrigation season. These concentrations and also the load values in general were not only related to the water supply but also to the cropping pattern and fertilization practices. Consequently, well-established fertilizer and water management plans in macro and meso-scales may help to reduce NO_3 pollution/leaching risks in shallow groundwaters.

HIGHLIGHTS

- Nitrate concentrations in shallow groundwaters are spatially and temporally variable.
- Groundwater NO_3 concentrations were high in rainy and irrigation seasons.
- Water either by rainfall or irrigation and nitrogen fertilizer amount has effect on groundwater NO_3 concentrations.
- Nitrate concentrations in the most part of the District were below threshold level.

AN EMPIRICAL RELATIONSHIP BETWEEN BULK ELECTRICAL CONDUCTIVITY OF SOIL SATURATED PASTE AND THE ELECTRICAL CONDUCTIVITY OF SATURATED PASTE EXTRACT

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ABSTRACT

During the first 50 years of previous century, soluble salt contents for soils were estimated from the electrical conductivity of saturated soil-pastes. A 50 cm^3 cylindrical conductivity cell was used to measure electrical conductivity and this cup became known as the "Bureau of soil cup". As the understanding of saline soils progressed, the electrical conductivity of saturated soil-paste extract (ECe) was advocated as the preferred index of soil salinity.

The introduction into agricultural sciences of Time Domain Reflectometry (TDR) which measures soil water (θ) and soil bulk electrical conductivity ECa simultaneously and in the same soil volume, revolutionized electrical conductivity of pore water (EC_W) evaluation. In response to the success of TDR, several commercial soil water sensors have been developed that use soil dielectric properties but are less expensive than TDR for many applications and do not require waveform analysis.

A useful application work is presently needed, which could relate ECe with bulk electrical conductivity of saturated paste (ECp) as this can be obtained by a dielectric sensor (e. g the WET sensor). One such method eliminates the need of aqueous extractions, though it still requires the collection of soil samples and the making of saturated soil pastes.

In our investigation WET-ECp values of saturated paste are compared with ECe values obtained conventionally. This is attempted for various soils where a linear relationship is established with quite a large number of R^2. Also the comparison of the ECe values with the respective values estimated according to the model of Rhoades et.al., (1989), showed that this model predicts reliably ECe values, although the calibration of the model was based on data obtained from other soils of different clay mineralogy and texture.

3D NUMERICAL MODELLING OF WIND DRIVEN CIRCULATION AND HORIZONTAL DISPERSION IN A RECONSTRUCTED SHALLOW LAKE

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ABSTRACT

The reconstruction of lakes with unique natural and cultural values that are under threat from anthropogenic pressure, consists a very important section in the Mediterranean freshwater resources management. Lake Karla, located in the eastern part of Thessaly in Greece, is an example of a lake ecosystem, which was dried in the 1960s to provide additional agricultural land and was reconstructed during the last 2 years. The aim of the present paper is to simulate the hydrodynamic characteristics of the lake under wind and inflows using a three dimensional hydrodynamic model. Action of winds of different directions has been tested on the lake, while in addition to winds other parameters like actual bathymetry, inflow, meteorological factors and Coriolis force have been accounted for. Conservative numerical tracers were used to assess the rate of horizontal dispersion from various location in lake Karla. The simulations show that winds blowing from north create a cyclonic gyre at the south part of the lake. In the coastal strip the direction of the current corresponded to the wind direction. The horizontal dispersion rate is higher in the central region of the lake. The research in this paper would be useful to determine the horizontal transport of waterborne materials in lake's body which plays a major role in determining its biochemical properties.

HIGHLIGHTS

- Winds blowing from north create an anticyclonic gyre at the southwestern part of Lake Karla.
- In the coastal strip the direction of the current corresponded to the wind direction.
- The dispersion rate is higher in the southwestern region of the lake which is affected by the permanent inflow discharge from the irrigation trench T2.

CHLORIDE TRANSPORT PARAMETERS PREDICTION IN A CLAY LOAM SOIL COLUMN

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ABSTRACT

As human actions increasingly dispose quantities of pollutants in the environment it is necessary to evaluate the fate of these chemical compounds. Soil is the major recipient of these chemical compounds. The followed pathways are due to four processes which are the advection, dispersion, phase changes (sorption, volatilization, etc.) and reaction (chemical, physical or microbial degradation or production). The resultant of these processes determines the compounds fate and so the risks of passing the solute through the soil profile (under saturated or unsaturated conditions) intrude the aquifer and pollute the groundwater. In the aquifer the same processes dominate in differing scale. Many models have been developed to predict this fate or to predict factors involved in this phenomenon based on laboratory or field experimental results. In this work an effort has been made to predict the factors governing the movement of chloride through a 47.5cm long repacked clay loam soil column. Chloride (a conservative pollutant) is present in the disposed or reused for irrigation treated municipal wastewater. As a non-reactive compound it is crucial to know its behaviour in the soil profile. The measured solute breakthrough curves (BTCs) were analysed with the one-dimensional Advection-Dispersion Equation (ADE) using the CXTFIT code to obtain estimates of the solute transport parameters. The comparison between experimental and calculated results is satisfactory. This could guide our efforts to study and understand soluble substances transport processes in an olive grove in Laconia, irrigated with treated municipal wastewater.

HIGHLIGHTS

- Chloride breakthrough curve through 47.5cm long clay loam soil column
- CXTFIT (STANMOD) code used for transport parameters prediction
- Comparison of experimental and calculated results is satisfactory

GROUNDWATER CONTAMINATION BY HEAVY METALS DUE TO STEEL INDUSTRIES IN PLAIN OF ARDAKAN – YAZD

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ABSTRACT

Yazd-Ardakanplain is a part of SiahKuh desert inYazd province, central Iran. In this area, groundwater resource is extracted by well. The zone that consists of suitable water quality is located in the west and south west, where some steel industries are located. Geological formations affect water quality (by increasing dissolved minerals and salinity) and quantity (due to restricting recharge sources) at several locationsin south, southwest to west and northwest. Charkhab area in the west of plain is the best point for water extraction. Inorganic contamination of steel industrials, including Yazd steel plant, Meybod steel plant and alloy steel plant could influence groundwater chemical quality. Regarding to the contamination index and behavior of heavy metals in groundwater and concentration in soil, important heavy metals such as Zn, Pb, Ni, Cr and Cd were selected for further analysis. These elements were analysed by method of standard addition in a flame atomic absorption spectrometer for 23 samples taken from different zones (upstream and downstream of steel industries plants) in an assumed direction based on topographic slope of the plain and groundwater hydraulic gradient. The results indicatethat the concentration of Pb and Cr ions beyond exceed drinking water quality standards and US EPA in Yazd steel zone. The contamination by Alloy steel zone is increasing while groundwater Meybod steel zone has not been contaminated.

HIGHLIGHTS

- The obtained results show Pb and Cr ions concentrations were beyond of drinking water quality standards in Yazd steel zone.
- Steel plants could influence groundwater chemical quality in Yazd plain.
- Important heavy metals were selected for analysis including Zn, Pb, Ni, Cr, Cd.

EVALUATION OF WATER QUALITY INDICES FOR LAKES IN THE MEDITERRANEAN

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ABSTRACT

Water quality indices (WQIs) are efficient and powerful tools for evaluating, organising and communicating the information on the overall quality of surface water bodies, assisting thus in the monitoring and management of the body. Several water quality indices have been proposed in the literature over the years; using the most efficient one is currently a real challenge worldwide, and particularly in the Mediterranean region where studies on this subject are limited. Furthermore, the use of these indices may be very helpful in evaluating the water quality of aquatic systems in relation to the EU Water Framework Directive (WFD). In this study, two well-known water quality indices have been selected for evaluation: the CCME (Canadian Council of Ministers of the Environment) and NSF (National Sanitation Foundation). These WQIs were applied in the Polyphytos Reservoir-Aliakmon River in Greece where monthly water quality data were available for the period June 2004 to May 2005. The data included: water depth, water temperature, dissolved oxygen, electrical conductivity, pH, transparency (Secchi disk depth), BOD_5, COD, total phosphorus (TP), chlorophyll-a (Chl-a), ammonium, nitrite and nitrate and total Kjeldahl nitrogen (TKN). The application of the two WQIs was made using specialized software-tools freely available. A comparison of their performance and a qualitative judgement on their suitability on expressing the quality of a surface water body is presented. The classification results are compared with those obtained by the WFD-ECOFRAME approach of the EU. Based on the applicability and drawbacks of the examined indices, useful conclusions are derived and discussed. Among those, it is concluded that the NSF-WQI is a more robust index and produces a classification nearer to the WFD-ECOFRAME approach when compared to the CCME-WQI.

HIGHLIGHTS

- Suitability of water quality indices in classifying lake water quality in relation to WFD
- Evaluation and ranking of NSF-WQI and CCME-WQI using measured data in an artificial lake
- Presentation of limitations, drawbacks and strengths of each index

ASSESSMENT OF POLLUTANT LOADINGS FROM WASTEWATER TREATMENT PLANTS IN KAVALA GULF

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ABSTRACT

Worldwide coastal waters are affected by pressures derived from populated areas such as large urban complexes. Population increases in these areas produces large volumes of discharged domestic and industrial wastewater, considered as one of the major significant stresses impacting the coastal environments.
This study describes the assessment of treated wastewater loads and its pollutant content, aiming to evaluate the prevailing situation and provides accurate information on the water quality in Kavala Gulf. The work focuses on wastewater treatment plants loads, based on the analysis of systematic pollution indicators, such as carbonaceous material, suspended solids and nutrient time-series and its association. The data sets used are long-term, relatively consistent, and available in public.
Results show that, although the wwtp's effluent contains low concentrations, it delivers continuously and at a constant rate large amount of pollutant loads, which contribute significantly to the pollutant increase in the water column, thus affecting the benthic system of the gulf.
Proper reusing of effluent discharges from wwtp's should lessen the environmental impacts at the coastal water regarding the suspended solids, organic matter, nutrients, heavy metals and micro pollutants. Reduction of the discharged volumes could be achieved through reclaiming wastewater reused for industrial use within the plant, urban and suburban concentrated watering green areas, groves and forests, firefighting system, street cleaning, agricultural and landscape irrigation.

HIGHLIGHTS

- Land based wastewater pollution sources identification and location
- Carbonaceous, nutrient and suspended solids inputs of wastewater effluent to gulf of Kavala
- Water column and benthic system impacts of wastewater effluent
- Wastewater treated effluent reuse benefit

"WHAT IFs" IN LAKE KARLA

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ABSTRACT

A formerly productive, valuable, natural ecosystem, Lake Karla, Thessaly, Greece was artificially drained in 1962 and the land was given to local farmers. Since then, groundwater over-abstraction and intensive farming, mostly of water-intensive monocultures, resulted in a drop of the aquifer level and a rise in soil salinity. The plan in the 1990s was the re-establishment of a water-body that could act as a multi-services reservoir for providing the region with drinking and irrigation water and as a tourist attraction. In 2010 the lake reconstruction was done. A few years later, the lake is already hypertrophic, shallow and polymictic, with water retention time close to infinity, situated in one of the most fertile and productive plains in Greece. The lake faces various problems, such as water level drop, cyanobacterial blooms, fish kill incidents and constant water quality deterioration. A series of failures in design, construction, but mostly operation, along with its results, are thoroughly investigated in this article. Soil remediation before inundation, inflow water quality and quantity control, as well as flora and fauna initial enrichment alternatives are examined, in order to highlight the gravity of the previous maltreatment of this ecosystem. Actual measurements of biotic and abiotic parameters, which can be used as indicators of Lake Karla's current status, are being compared to modelled scenarios of an alternative management plan, so as to confirm and quantitatively describe the hypothesis.

HIGHLIGHTS

- Listing of the failures during the design, the construction and operation of the plan along with their results.
- Description of the present status of the lake with several biotic and abiotic factors.
- Modelling of alternative scenarios and projections in 2015.

TREATMENT OF UNIVERSITY CAMPUS WASTEWATER WITH THE USE OF PILOT-SCALE VERTICAL FLOW CONSTRUCTED WETLANDS

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ABSTRACT

Vertical flow constructed wetlands (VFCWs) are becoming very popular nowadays since they can receive and treat heavy loads of wastewater. For the needs of the present study, three VFCWs operated for almost three years treating wastewater from a university campus. The objectives of this study were to evaluate the overall performance of VFCW systems, and test different feeding regimes. Another objective was to investigate the influence of vegetation, temperature and seasonal variations in CW system performance. Finally, the produced results were compared to those of a previous study conducted using the same units and under the same operation conditions but with the use of synthetic wastewater. Results underline the unit capacity in removal of several pollutants and their satisfying performance as a first treatment stage even when receiving high hydraulic loads. The two planted units demonstrated higher removal capacity and better performance than the unplanted one. Units also appear to operate better under warmer conditions.

HIGHLIGHTS

- Treatment of wastewater from a university campus.
- Overall performance of pilot-scale VFCWs was satisfying, indicating high removal rates.
- Influence of several parameters, such as vegetation, feeding strategy, temperature etc., in treatment efficiency.

EFFECTS OF DAMS ON THE WATER PARAMETERS OF THE DOWNSTREAM REACH

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ABSTRACT

The last century witnessed an increased demand of water for human consumption as well as for industry and agriculture. This pressure on water resources is enhanced by surface water quality issues caused by different pollution sources. Problems like eutrophication due to the excess of nutrients in river or lakes are common. One of the solutions found to cope with water demand is the construction of dams and the creation of reservoirs. Intakes at several levels allow the capture and distribution of water for different purposes. Due to the characteristics of these water masses, the water quantity and quality processes are changed at the catchment. Point and diffuse pollution sources can directly flow to reservoirs and the processes within the water mass control the quality of the released water. The purpose of this work is to contribute to the understanding of the impact of dams in the water quality of the downstream reaches. It is based on 2 cases studies including 4 dams constructed in the last 25 years in Portugal. The analysis is supported by the existence of a national online database with hydrological and water quality monitoring data. Conductivity (Cond), BOD5, COD, Dissolved Oxygen, temperature (T) and Total Suspended Solids (TSS) data from 1988 to 2000 was used to evaluate changes in water quality downstream after the construction of these four dams. The evaluation showed some clear trends for T, Cond and TSS for both case studies. The methodology used proved to be suitable to the objectives and the results should contribute to the prediction of the water quality impacts after dam construction and to the management of reservoirs operation.

HIGHLIGHTS

- Dam construction leads to a reduction of downstream water temperature variability.
- TSS concentrations in the streams downstream a dam are changed significantly after the construction of the dam.
- Both dissolved oxygen and conductivity are reduced by the dam construction.

DEVELOPMENT OF AN IMPROVED METHODOLOGY FOR POLLUTION SOURCE IDENTIFICATION BY USING ANN-MT3DMS-GA BASED SIMULATION-OPTIMIZATION MODEL

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ABSTRACT

Pollution source identification problem is one of the important and challenging tasks for groundwater management. The location and magnitude of unknown groundwater pollution sources can be identified using inverse optimization technique. In this studywe have presented an improved methodology which is computationally better and more efficient in predicting unknown groundwater pollution sources in an aquifer. The methodology incorporates both numerical and approximate simulation models simultaneously. This is a GA based methodology where the fitness values of the few best individuals of the population are calculated using numerical aquifer simulation model and the fitness of the other individuals are calculated using approximate simulation model. Artificial Neural Networks model is used to develop approximate simulation model. This technique has drastically reduced the computational time of the model compare to numerical simulation based simulation-optimization model. The performance and field applicability of the model is evaluated using illustrative study areas.

HIGHLIGHTS

- A new simulation-optimization model has been presented for optimal identification of unknown groundwater pollution sources.
- This is a hybrid model which is composed of numerical and approximate simulation models and is optimized using genetic algorithms.
- The model can save computational time up to 75% compared to numerical simulation based simulation-optimization model.

IDENTIFICATION OF UNKNOWN GROUNDWATER POLLUTION SOURCES AND SIMULTANEOUS DESIGN OF MONITORING NETWORK USING ANN-GA BASED SIMULATION OPTIMIZATION MODEL.

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ABSTRACT

Identification of pollutant sources is a difficult task but the remediation processes are found to be even more challenging. Source characteristics like location, disposal duration and solute mass flux are the major factors which will assist in the identifying the contaminant sources. But considering the budgetary constraints, an optimum number of monitoring wells can be installed for designing an effective monitoring network which will efficiently identify the pollutant sources. Therefore, a methodology is developed by linking simulation-optimization model for optimal identification and monitoring of pollutant sources. The complex physical processes such as groundwater flow and pollutant transport can be solved using MODFLOW and MT3DMS respectively. But due to large computational time, the approximate simulation model Artificial Neural Network (ANN) can be used, which requires less simulation time. The optimization model is solved using Genetic Algorithm (GA). GA is considered as one of the most effective and robust non-classical optimization algorithm. The optimal design limits on the number of monitoring well installed making economically efficient. The developed methodology is evaluated in a hypothetical illustrative study area and proves to be an effective measure in the groundwater management system.

PARTICIPATION OF FARMERS IN THE MANAGEMENT OF DUCKWEED IN THE JORDAN VALLEY

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ABSTRACT

Jordanian farmers indicated that duckweed plants have been seen to grow naturally in their farm irrigation ponds. Their explosive reproductive capacity can cause a dense cover of this plant and pose a serious problem to irrigation ponds. Farmers used to add herbicides to irrigation ponds to get rid of duckweed plant but this treatment is useless. Farmers are unaware of its nutritional value around the world. Therefore, this paper focuses on the water sources that feed farm irrigation ponds with nutrients. It also focuses on the need for the involvement of Jordan's farmers towards aquatic plant duckweed growth management. The source of the water ponds is the flow from King Abdullah Canal in which its water analysis showed that the heavy metals; Zn, Cd, Pb, and Cu are within Ideal Detection Limits. The management at farm level lies within the involvement of farmers by doing frequent harvests on regular basis throughout the year, and sun drying the plant to be utilized as a new source of forage. A feeding trial was conducted on broilers to replace part of soybean with percentage of duckweed since it has a good percentage of protein, and proved its efficiency. But more research is needed to detect it on layers and egg production.

THE PROTECTION OF GROUNDWATER DEPENDENT ECOSYSTEMS THAT ARE EXTERNAL TO GROUNDWATER BODIES IN SPAIN

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ABSTRACT

Spain has now identified 777 groundwater bodies and a total of 118 types of habitats of community interest in its territory. The dependency between ecosystems and groundwater has been subject to recent studies within the implementation of the Water Framework Directive (2000/60/EC) and Groundwater Directive (2006/118/EC). As a result of this work, a number of groundwater-dependent ecosystems that are outside the boundaries of the groundwater bodies themselves have been identified. This means that they could fall outside the areas officially protected under the terms of European water policy. In this context, this paper focuses on the analysis of the geological and hydrogeological characterization and the hydrochemistry of three Spanish wetlands included in the Ramsar List: Humedales de la Sierra de Urbión, Lagunas del Sur de Córdoba and Humedales del Macizo de Peñalara. The results show that ecosystems are highly dependent on the type of land on which they sit, the presence of groundwater and surface water, water-rock interactions that determine the hydrochemistry of the waters, and the porosity and permeability of the ground, which determines the type of aquifer. We are thus dealing with specific cases of aquatic ecosystems that have a close relationship with groundwater without being located on any groundwater body.

SPECIATION OF METALS IN AWALI RIVER SEDIMENTS: RISK ASSESSMENT

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ABSTRACT

Recently Lebanon started facing serious problem in water shortage and it is highly aggravated in the overpopulated capital city Beirut. One of the solutions to this problem is in the direct exploitation of Awali River, south of Beirut. Previous works tackled the quality of the water and the total metal levels in sediments of the river. The determination of only total metal concentration in sediments is inadequate for predicting the bioavailability, mobility and toxicity of metals. Studies of metal speciation in sediments are important for understanding the potential risks of metals in aquatic systems. The risk assessment code (RAC) which is based on the percentage of total metal associated with exchangeable and carbonate phases has been used to predict the metals' potential threats. The objective of this study was to assess the distribution, mobility and potential risks of Zn, Cu, Cr, Sb, Pb, As, Hg, and Cd in Awali River sediments. To address this objective, sequential extraction protocol was used to sediments from 10 sampling sites. Metal content in each fraction was determined using thermal AAS and ICP-MS techniques, in combination with risk assessment code. The mineral of some sites were determined by XRD. Results indicated highest percentage association with Fe and Mn oxides hydroxides with an average (As: 39%, Cr: 38%, Sb: 37%; Zn: 30%), with organic for (Cd: 46%, Cu: 32%, Hg: 29%), high in residual for Pb with 54%. The risk assessment code derived from percentages in exchangeable and carbonate sediment fraction revealed an average value for (Cr: 17 %, Cd: 20%, Sb: 22%; As: 28 %) which constitute medium risk threats to aquatic organism, but at some sites risks were high), those of high threats were for (Zn: 31 %, Cu: 32%, Hg: 38%, and at some sites very high), Pb was very low (9.5%, low risk). The XRD data of many sites indicated the presence of high amounts of carbonate and several clay minerals in sediments which supports these findings.

IMPACT OF BORÇKA DAM ON TOTAL SUSPENDED SOLIDS CARRIED BY THE ÇORUH RIVER AND THE MURGUL STREAM, NORTHEAST TURKEY

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ABSTRACT

Considering its economy and population, Turkey is a rapidly developing country and in need of many energy investments, which resulted in engineering and management modifications in its river and stream systems, due to its large and ever increasing energy demand. The Çoruh River having a main branch length of 400 km, a catchment area of 19,872 km2, and a mean annual surface water potential of 6.3 billion cubic meters within Turkey's borders is of high economic importance to Turkey because of it is largely undeveloped but economically exploitable hydropower potential. The Çoruh River Basin, where a lot of dams are constructed and operated (e.g. Borçka Dam), is one of the basins being exposed to severe erosion and the river carries sediment and deposits of 5.8 million cubic meters.
This paper investigated the effects of Borçka Dam Lake having a reservoir area of 10.84 km2 and reservoir volume of 419 million cubic meters, the Lower Çoruh River Basin, on the total suspended solids carried by the Çoruh River and the Murgul Stream by studying its variation versus nephelometric turbidity. The effects of discharge from the copper mine to the Murgul Stream draining into the Borçka Dam Reservoir were also evaluated. In situ turbidity measuring and the surface water sampling were done monthly at 3 monitoring stations selected in the Çoruh River, Artvin Province, in the Murgul Stream, Murgul Town, and at the HEPP outlet of the Borçka Dam, Borçka Town, respectively, from December 2010 to November 2011.

HIGHLIGHTS

- On the annual basis, it was determined that the suspended sediment concentration (SSC) carried by the Çoruh River was 375 mg/L and the turbidity (T) was 339 NTU while the SSC carried by the Murgul Stream was 15,693 mg/L and the T was over 664 NTU.

- Based on the SSC of 39.4 mg/L and the T of 43 NTU measured at the outlet of the Borçka Dam and HEPP, it was concluded that the Borçka Dam could trap great part of the SSC and could remove the T considerably thanks to its long hydraulic residence time, and so reduced the possible silting in downstream reservoir, the Muratlı Dam having a dead storage of 55 million cubic meters.

METHODOLOGY AND APPLICATION OF THE COMBINED SWAT-HSPF MODEL

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ABSTRACT

This paper shows the output of a research study that involves developing a new model for diffuse source pollution requiring the integration of a complex distributed catchment model with a model of contaminant transport. It explains in details the various model components, modifications and assumptions that been used in the constructions of the new combined model (NCM) based on Hydrological modules of Hydrological Simulation Program FORTRAN (HSPF) and Phosphorus transformations modules of soil and water assessment tool (SWAT) model as well as the approach adopted. Three Irish catchments have been tested namely Oona, Bawn and Dripsey. The model performance for both calibration and validation periods and model parameter sensitivity analysis and uncertainty results were conducted and examined extensively with the outputs of SWAT model and HSPF. The NCM showed promising potential for better estimation of Phosphorus losses from catchments for the Irish conditions with some drawback for base flow dominant catchments. It gives good results in terms of flow and phosphorus modelling and is generally better than SWAT or HSPF alone for most of the cases tested. An uncertainty analysis based on model parameters was conducted using the PARASOL method implemented in SWAT 2005 and uncertainty bounds for the flow and the total P load predictions were compared with the observed values for each catchment.

HIGHLIGHTS

- Developing of new combined model SWAT-HSPF and tested for Irish catchments
- Parameter uncertainty was analysed using PARASOL method
- The new model is better than SWAT and HSPF in general with some drawback for base flow dominant catchment

ASSESSMENT OF ECOLOGICAL RISK BASED ON PROJECTED HYDROLOGICAL ALTERATION

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ABSTRACT

It is widely accepted that changes in river flows, namely flow regularization due to dams, may result in several impacts on the ecosystems. Climate Changes (CC) contribute to the global pressure upon such modifications. Therefore, to be able to project the influence of CC on river flow's regime, it is crucial to understand the related risks for aquatic ecosystems. The main goal of this paper is to define the ecological risk associated with projected/future flow alteration in the Portuguese Guadiana River Basin. Thus, five climate change scenarios were defined based on bias corrected and globally downscaled climate projections. These projections were used to run a hydrological model (Temez) for the assessment of potential hydrological impacts. This work builds upon a research project called "Development of a Methodology to Integrate Climate Change Effects in Water Resources Management on a Portuguese River Basin". Ecologically relevant hydrological indicators were calculated for the baseline hydrological situation and for each of five hydrological future scenarios, for each of the selected future periods. Through the evaluation of the potential hydrological changes (based on the comparison between baseline and future metrics) it was possible to assess the likely ecological risk due to flow alteration. That was done based on the ecological risk due flow alteration (ERFA) screening method. This methodology was developed based on the Range of Variability Approach (RVA), a technique used to define ecological limits of hydrological change. The ERFA methodology enables the aggregation of information as colour-coded risk classifications, which permits the assessment of the locations with higher or lower ecological risk.

HIGHLIGHTS

- A methodology (ecological risk due to flow alteration, ERFA) to assess the likely ecological risk due to projected flow alteration was applied. Through the application of this methodology it was possible to assess the locations, in the Guadiana River Basin, with higher ecological risk.

- Ecologically relevant hydrological indicators were calculated for baseline and future hydrological scenarios enabling the assessment of hydrological change.
- A methodology to assess water hydrological impacts of climate change was applied.

A METHOD FOR DETERMINING ENVIRONMENTAL FLOWS BASED ON INDICATORS OF HYDROLOGICAL ALTERATION

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ABSTRACT

The conservancy of natural bio-ecological conditions downstream a water diversion in rivers, such as a reservoir or an intake, should be ensured by the release of environmental flows. At the same time, the degree of preservation of the natural flow regime, on which natural bio-ecological conditions depend, can be measured by indicators of hydrological alteration, based on the comparison of the current hydrological river flow regime with the supposedly natural (unaltered) one. In this work, we firstly present the experience of application to Sicily of a part of WFD Italian implementation guidelines to assess hydrologic alteration for rivers in Italy, which is based on the computation an indicator denoted as IARI. Thus the possibility to define environmental flows based on indicators of hydrological alteration is investigated, with applications to different river sections which resulted in a "not good" hydrological status. In particular, simulations are carried out to compute the alteration and the potentially available water resource corresponding to increasing levels of environmental flows. Afterwards, based on the analysis of the trade-off between hydrological alteration and a proxy of the potential water resource available after the release of environmental flows, optimal instream flow requirements are then computed according to hydrologic status targets, given by fixed values of the IARI.

HIGHLIGHTS

- An hydrological method for the computation of environmental flows based on indicators of hydrological alteration is investigated
- The hydrological alteration corresponding to the release of environmental flows computed by different hydrological methods is analysed
- The proposed method has a good flexibility and it enables to differentiate environmental flows based on the ecological importance of the river

LANDUSE IMPACT ON THE ECOLOGY AND ENVIRONMENT

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ABSTRACT

Ecology gives the scientific basis how to utilize the nature. Ecology and environmental sciences are essential for engineering activities, especially in Civil Engineering projects. The use of natural resources by engineers requires the basic ecologic knowledge. The forecasting of the responses from the land, natural resources and the environment mainly depends upon the basic ecological understanding of interaction between the factors and the natural resources are given by the ecology. Environmental deterioration, erosion, pollution and global warming are the major problems of the man-kinds of the century. Solutions of problems mainly are engineering duties. Misuse of the land and the natural resources (Water, soil, plants, air) destroy and abuse the ecosystem and environment which we are living in it. As a result of misuse of nature environmental problems are started. Sometimes problems become unsolvable. The environment and natural resources are existed without any human effort; therefore they are gifts of the Creature for man-kind. We are trustee of the nature and environment or we are temporary steward of them in this world. Nature should be used according to its nature, such as land use should be done according to land capability classification. One of the mottos for utilization and use of natural resources is: "Use wisely, don't waste, don't pollute, don't deteriorate, keep the productivity, save the resources with same amount and quality for the future generations as for sustainable development." In this paper, multiple land use will be tried to discuss with relation to ecology and environment.

A NEW APPROACH FOR DETERMINING THE ENVIRONMENTAL FLOW REGIME IN A GREEK RIVER

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ABSTRACT

The ecological integrity of freshwater lotic ecosystems depends on the flow regime which has a pronounced natural variability in the natural Mediterranean streams. The increasing human demands for water resources has led to the adoption of the environmental flow concept which focuses on an integrated management of water for long-term sustainability by coupling anthropogenic and environment demands. This has been poorly researched and applied in Eastern Mediterranean rivers. In Greece, management actions usually focus on prescribing minimum acceptable flows estimated by hydrological methods according to summer mean monthly flows. This study applies a combination of different approaches for the estimation of an environmental flow regime in a Greek montane river, which includes fish habitat hydraulic requirements and a temporal variability of minimum flow. The proposed method integrates the results of a hydrologic and a fish habitat simulation procedure in a temporal scale that takes into consideration the natural hydrologic seasonality. The results highlight the advantages of using different policy-relevant methods to estimate environmental flow regime and not just a static minimum flow requirement. Finally, this preliminary application promotes the need for further science-based eco-hydrological approaches that respect the local biodiversity with respect to distinctiveness and holism but also to the current EU Water related policies for water management.

HIGHLIGHTS

- The method integrates the results of a hydrologic and a fish habitat simulation method considering the natural hydrologic seasonality.

- The integration of biotic elements, habitat hydraulic requirements of certain fish species, for estimating the environmental flow regime.
- The attempt to estimate an environmental flow regime and not just a minimum flow requirement which is usually the case.

HABITAT BANKING IN SWEDISH RIVERS AND WATER BODIES: A CONCEPT PAPER ON IMPLEMENTING THE EU WATER FRAMEWORK DIRECTIVE

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ABSTRACT

The European Union (EU) Water Framework Directive entails extensive environmental improvement goals for lakes and rivers throughout the Union. Realising these goals in countries such as Sweden, which has tens of thousands of water bodies, many of which are used for commercial activities such as hydropower, presents a considerable challenge for policy. In this paper, habitat banking – where environmental improvements in one location are used to offset measures that reduce environmental quality elsewhere – is discussed as a potential way forward. The conclusion is that although this would likely be limited to banking within individual river systems rather than across the entire country, it would nonetheless be an interesting option to consider. Although habitat banking is more complex in aquatic than in terrestrial systems, because of the migratory nature of many of the keystone species improvements in the downstream parts of a river system can potentially generate enough environmental benefits to offset the impacts of measures further upstream.

HIGHLIGHTS

- Habitat banking represents an interesting option for implementing the WFD.
- The paper discusses this option for Sweden and finds that habitat banking could be used within individual river systems.
- Environmental improvements downstream in a river system can potentially generate enough benefits to offset damaging measures upstream.

HYDROCHEMICAL GROUNDWATER STATUS IN LAS TABLAS DE DAIMIEL NATIONAL PARK WETLAND (CENTRAL SPAIN) AFTER A LONG OVEREXPLOITATION PERIOD

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ABSTRACT

Las Tablas de Daimiel National Park, located in the centre of the Iberian Peninsula, is one of the most representative Mediterranean wetland linked to groundwater dynamic. In natural conditions, the wetland system was a mixing of: brackish surface water came mainly from Gigüela River in the North, and freshwater inputs from the Guadiana River (surface and groundwater sources) in the East. Since the mid-1970s, the overexploitation of the aquifer system that fed the wetland and an inadequate management led to its degradation and it has remained mostly dry since 1980s, except for extraordinary floods and water transfers from other basins. In the late 2000s, the groundwater abstraction decreased and an extraordinary wet period happened. As a result, an important rise of groundwater levels occurred, allowing the reappearance of old springs. In fact, from late 2012 to the present (2014), a continuous groundwater input to the wetland through the Guadiana river there has occurred. The strong relationship between surface and groundwater in the area has caused substantial changes in the groundwater chemical quality in the vicinity of the National Park. This work shows the groundwater hydrochemical status in the wetland in two stages during the dry and upward piezometric periods, and compares them to the pre-1980 water quality. The results show a trend towards recovery of the pre-overexploitation piezometry but significant changes of the hydrochemical characteristics in the major components still exist.

HIGHLIGHTS

- Groundwater quality has changed in the PNTD vicinity in the last 4 years.
- The change in chemical quality matches up with the recovery of levels and decreasing of abstractions.
- Groundwater flow has changed and the system acts mainly as a discharge area similar to natural conditions.
- Besides, there is a variation in the chemical composition of groundwater linked to lithological variability in the area

TRANSPORT OF DENSE COLLOIDS IN POROUS MEDIA

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ABSTRACT

The role of gravitational force on dense-colloid transport in porous media was investigated. Transport experiments were performed with colloids in columns packed with glass beads placed in various orientations (horizontal, vertical, and diagonal). All experiments were conducted under electrostatically unfavorable conditions. The experimental data were fitted with a newly developed, analytical, one-dimensional, colloid transport model. The effect of gravity is incorporated in the mathematical model by combining the interstitial velocity (advection) with the settling velocity (gravity effect). The results revealed that flow direction influences colloid transport in porous media. The rate of particle deposition was shown to be greater for up-flow than for down-flow direction, suggesting that gravity was a significant driving force for colloid deposition. Furthermore, A three-dimensional numerical model was developed to investigate the simultaneous transport (cotransport) of dense colloids and viruses in homogeneous, water saturated, porous media with horizontal uniform flow. The dense colloids are assumed to exist in two different phases: suspended in the aqueous phase, and attached reversibly or irreversibly onto the solid matrix. The viruses are assumed to exist in four different phases: suspended in aqueous phase, attached onto the solid matrix, attached onto suspended colloids, and attached onto colloids already attached onto the solid matrix. The governing differential equations were solved numerically with the finite difference schemes, implicitly or explicitly implemented. Model simulations have shown that the presence of dense colloid particles can either enhance or hinder the horizontal transport of viruses, but also can increase the vertical migration of viruses.

HIGHLIGHTS

- Gravity is a significant force for colloid transport in porous media.
- Particle attachment is higher for up-flow than down-flow directions.

- The presence of dense colloid particles can either enhance or hinder the horizontal transport of contaminants.
- The presence of dense colloid particles can increase the vertical migration of contaminants.

IMPACTS OF URBANIZATION, AGRICULTURE AND TOURISTIC DEVELOPMENT ON GROUNDWATER RESOURCES IN THE EASTERN PART OF THERMAIKOS GULF, NORTH GREECE

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ABSTRACT

The eastern part of Thermaikos Gulf is characterized by urbanization, touristic development and intensive agriculture activities. Water resources are characterized by high water demands for agricultural and tourism during the dry period (May- late September) when water availability is low. The main aquifers are within coarse grained Neogene and Quaternary deposits (porous aquifers). This work deals with the impacts of the aforementioned activities on groundwater resources in this area. Therefore, hydrometeorological, hydrogeological and hydrochemical data were collected, evaluated and compared with previous studies. The water demands for domestic and irrigation use are mainly covered by groundwater abstracted from aquifer systems via numerous boreholes. As a result, a total groundwater level decline of 45 m was recorded over the last 30 years and a negative water balance is established in the coastal aquifer favouring sea water intrusion. Degradation of groundwater quality is mainly caused by seawater intrusion and nitrate pollution. The concentrations of chloride range between 400 mg/L and up to 700 mg/L in areas affected by seawater intrusion. Intensified fertilization has been led to nitrate pollution, as showed by the increased nitrate concentration, which locally exceed the maximum admissible concentration of 50 mg/L set by EU Council for drinking water. This state was led to render most of groundwater unsuitable for human consumption. Finally, the approach of the DPSIR (Driver-Pressure-State-Impact-Response) was applied in order to optimize the measures for rational management of water resources and some recommendations are proposed, including the reuse of the treated wastewater for irrigation purposes, the construction of dams for exploitation of surface water, artificial recharge, water efficiency measures and public education.

HIGHLIGHTS

- Nitrate pollution and seawater intrusion were observed in the study area.
- Decline of groundwater level has been observed since the 1980s.
- Negative water balance is established in the coastal aquifer system.
- DPSIR application for sustainable management of water resources.

ANTIBIOTIC RESISTANT BACTERIA FOUND IN MUNICPAL DRINKING WATER

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ABSTRACT

Multidrug resistant bacteria in water supply systems have been emerging as a growing public health concern. Many factors affect the source and fate of these bacteria. However conditions in the distribution systems may contribute in the dispersion of resistance genes among bacterial populations. Through the process of lateral gene transfer, resistance genetic material is exchanged between species in the microbial population, intensifying the problem of resistance genes. The main objective of this study was to investigate the diversity of microorganisms in tap-water in Glasgow, Scotland, and the occurrence of certain antibiotic resistance genes and gene-transfer mechanisms. Results show that antibiotic resistant bacteria exist at the consumers' end of the distribution system, some of which also contain integrase genes, that aids in the dispersion of resistance genes. Presence of resistant microorganisms in tap water supply system is a public health concern and further investigations should be taken to assess the risks.

HIGHLIGHTS

- Water distribution system contains antibiotic resistance bacteria
- sul1 and sul2 genes are found in bacteria
- Integrons are present in bacteria indicating that they could be transferred to other bacteria.

COASTAL DUNES FEATURES OF ENDEMIC IPOMOEO STOLONIFERAE – SPOROBOLUS VIRGINICUS ASSOCIATION

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ABSTRACT

Ipomoeo stoloniferae – Sporobolus virginicus (Géhu, Uslu et Costa 1989) association is endemic for coastal dunes of East Mediterranean of Turkey. This association is identifed in Kumluova and Dalyan of Muğla province, in Çaltıcak, Kemer of Antalya province, in Anamur, Göksu delta of Mersin province, in Akyatan, Seyhan delta of Adana province and in Dörtyol of Hatay province. The association consists of grasses whose lentgh vary between 5-50 cm. The association's dominant species are Sporobolus virginicus, Ipomoea stolonifera, Inula viscosa, Trachomitum venetum and Euphorbia paralias. It is an association of perennial vegetation of the high beach.

"Flora of Turkey" of Davis (1965-1985), Davis et al., (1988) and Güner et al., (2000, 2012) are essentially used in the identification of the plants. The vegetation of the region has been categorized according to Braun-Blanquet (1932). Climate data from General Directorate of Meteorology (1990) and geological information from General Directorate of Mineral Research and Exploration (1963, 1981). Samples of soil which are mostly representative were obtained from the depts of cms 0-30 to establish the relationship of the plant associations with soil and the physical and chemical analysis of these samples were done with related method in Soil Fertilizer and Water Resources Central Research Institute Laboratories (Tüzüner, 1990).

The work area is coastal dunes as the type of land. Mediterranean floristic region of about 60 vascular plants have been identified within the study area. Most of the work place is filled with quaternary type of land. Stations in the study area, The central Mediterranean (WASS) and the Eastern Mediterranean I. Type (WSAS) precipitation regimes show and the work place has "Rainy Sub Soft, Rainy Sub Hot, A Little Rainy Warm, A little Rainy Soft" Mediterranean Bioclimate. Soil analysis results, especially the quantities of water and grain sizes, were evaluated with all data grain distributions vary with sampling location, particularly.

MULTIVARIATE STATISTICAL TECHNIQUES FOR ASSESMENT OF SURFACE SEDIMENT QUALITY AT THE MID-BLACK SEA COAST OF TURKEY

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ABSTRACT

In this study, physicochemical and mineralogical analysis of the samples, collected from Yeşilırmak, Kızılırmak, Mert, Abdal Rivers and Kurupelit sea regions (2007-2008), were carried out to determine the extent of the total metal contamination in sediment layer. Heavy metals concentrations of the solutions were measured by ICP-OES (Perkin Elmer Optima, 4300DV). For the analytical quality control, reagent blanks, standard reference materials (BCR-701), and sample replicates were randomly inserted in the analysis. SPSS 13.0 for Windows was used to perform statistical analysis. In this study seasonal studies were also conducted to determine the extent of heavy metal contamination in the samples collected from the Yeşilırmak, Kızılırmak, Mert, Abdal Rivers and Kurupelit sea regions. The extent of heavy metal contamination was as follow; Yeşilırmak> Kızılırmak> Kurupelit> Abdal> Mert rivers. Principle Component Analysis (PCA) and Cluster Analysis (CA) were used for the contamination sources and/or to explain secret relationship between sample variables. Different sources of heavy metals determined by using PCA and CA analysis and double correlation analysis between physicochemical parameters of sediments and heavy metal concentrations. It was found that there is a positive relationship between metal concentrations (except Al), and some of these metals were found in 95% and/or upper confidence range. In this study, heavy metals were separated in there main sources by dividing sub-groups. It was determined that aluminium is a metal found earth crust naturally, Ni, Pb, Zn and Cr have industrial sources and Cu and Cd have municipal and industrial sources.

Conference V

Multicriteria Sustainability of Water Systems

SCENARIO-OPTIMIZATION OF PUMPING SCHEDULES IN COMPLEX WATER SUPPLY SYSTEM CONSIDERING A MULTICRITERIA COST-RISK BALANCING PROBLEM

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ABSTRACT

The optimization of water pumping plants activation schedules is a significant issue when managing emergency and costly water transfers systems under drought risk. This problem needs specific optimization tools dealing with complex multi-reservoirs supply systems and considering different scenarios alternatives. The effectiveness of emergency transfers alleviating droughts requires early warning and activation, but, on the other hand, high operating costs of pumps stations stress system managers to the need of a robust approach defining activation rules.
The proposed optimization procedure has been based on scenario analysis. Moreover, the model searches for the identification of optimal decision rules by balancing the risk of water shortages and the operating cost of pumping stations. Scenario optimization provides "baricentric" values defining activation threshold by comparing hydrologic synthetic series results in water demand fulfillment. A multi-objective approach is also required in order to balance energy-cost minimization requirements and reduction of damage needs, as can be caused by water shortages. Consequently, a scenario-optimization considering this multi-objective and cost-risk balancing problem has been developed. The optimization model is implemented using the software GAMS-IDE, specifically designed for modeling mixed integer optimization problems. A model application has been developed optimizing water management and energy costs in a real water system with shortage risks in the South-Sardinia (Italy) region.

MULTICRITERA EVALUATION OF COMBINE SEWER OVERFLOW IMPACTS IN COASTAL CITIES

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ABSTRACT

Combined sewer systems are very common in old urban areas. When intense rainfall is happening, the volume of stormwater runoff usually increases and the capacity of wastewater treatment (WWT) facilities could no longer accommodated combined sewerage. In these situations, the plants bypass the sewage, this is known as combined sewer overflow (CSO). This has always adversely impacted the environment. In this study, the impact of flooding on the treatment plant's performance in New York City, as a case study, is investigated. A framework is suggested to differentiate between different impacts of CSOs in term of ecological, social and environmental factors. The method that is used in this study for investigating the impacts is Multi-Criteria Decision Making (MCDM), based on preference ranking organization method for enrichment of evaluations (PROMETHEE) and United Nation Environmental protection (UNEP) for evaluating adverse impacts of CSOs. The result shows the significant value of the proposed methodology to evaluate the impact of CSOs.

HIGHLIGHTS

- Differentiating between different impacts of CSOs.
- Multi criteria evaluation of CSOs impact.
- Reducing the impact of CSOs and improving the performance of wastewater facilities.

SUSTAINABILITY OF AGRICULTURAL WATER MANAGEMENT IN LARGE SCALE IRRIGATION SCHEMES: A CASE STUDY IN TURKEY

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ABSTRACT

Irrigation can vastly increase agricultural productivity, and is crucial to improve food security. Irrigated agriculture uses 70 percent of water withdrawn from surface and ground-water resources worldwide. However, much of that water has been recklessly squandered on notoriously wasteful irrigation schemes. Therefore, irrigation must be managed carefully both to save substantial amount of water for competing demands of other sectors and to avoid on-site and off-site environmental damage, which is already extensive. The objectives of this research were to (1) figure out hydrologic water budget components, (2) analyse and assess the existing water management performance in a large-scale irrigation district. To this aim, the work was carried out in the Akarsu Irrigation District (9 495 ha), located in the Lower Seyhan Plain, Turkey, in the hydrological years of 2012 and 2013. The main inputs (irrigation I and precipitation P) and outputs (irrigation return flows (IRFs) in Akarsu and crop's evapotranspiration ETc) of the water balances were either measured or estimated daily in two-year period. Water balance work was performed for hydrological year (HY), irrigation season (IS) and non-irrigation season (NIS). Irrigation performance indices of district irrigation efficiency (DIE), drainage fraction (DF) and water use efficiency (WUE) were determined for the periods considered. Closure errors of water balance were found acceptably low for this type of study. Drainage fraction (DF) was

over 50% year-round, indicating that WUE and DIE was low (47 and 49%, respectively). In consequence, low DIE and high DF resulted in higher leaching fractions (LF=58-59%) for the whole period and lower water use efficiency (WUE=45-47%) in the IS in these two years. Irrigation management was poor in the District and not sustainable in terms of water saving and environmental concerns of irrigated agriculture. Improvement of district irrigation efficiency by (a) preventing by-pass flows from irrigation, (b) adapting the water conveyance in the water distribution network to crop's water requirements, (c) modifying dilapidated irrigation and drainage infrastructure within the District, and (d) optimising water applications at the farm level should be the key management strategy for decreasing on-site and off-site impacts of irrigated agriculture.

HIGHLIGHTS

- Water balance works were performed with the very low closing errors in the district scale.
- Reliable water budget results enabled us to evaluate existing irrigation management regime.
- Existing irrigation management was poor in the district.
- High drainage fraction indicated that district irrigation efficiency was low jeopardising sustainable use of available waters in agriculture.

MULTIPURPOSE PLANS FOR THE SUSTAINABILITY OF THE GREEK LAKES

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ABSTRACT

Lake Ecosystems have experienced a significant loss of their ecological value due to various human activities. It has been recognized that the continued alteration of freshwater biodiversity is not sustainable and also it has been realized that less modified freshwater ecosystems provide significant economic and social benefits to society. In Greece, changes in land and water management, driven by the increase in agricultural production and the urban expansion, have created multiple stressors on lentic ecosystems that we can no longer ignore. The objective of the present study is to describe some of these stressors and to identify their impacts on Greek lakes. We collected an extensive data set from twelve natural lakes using several metrics, suggested also by the WFD, along with specific ecohydrological characteristics. Our results demonstrate severe impact on water quality and quantity with consequence to the lake's functions, as well as the extended eutrophication phenomenon in almost all lakes. The Greek lakes have been subjected to various hydromorphological alterations, affecting their metabolism and further maximizing the aforementioned effects due to particularities of the Mediterranean climate. The setup of good management practices through multipurpose management plans are also discussed.

HIGHLIGHTS

- The long eutrophication history of Greek natural lakes and the severe impacts of certain anthropogenic pressures cannot easily be reversed.
- The traditional, one-dimensional restoration methods usually fail, highlighting the complexity of the warm Mediterranean lakes.
- Good practices and "out of the lake" measures with local character can address the multifunctional and site specific character of lakes.

REDUCING VULNERABILITY OF ALGIERS WATER SUPPLY: MANAGEMENT CHALLENGES

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ABSTRACT

Algiers, capital of Algeria, experienced in the past recurrent water shortages due to rampant population growth coupled with the relative scarcity of water resources in this Mediterranean city. The current supply system, despite improvement made, shows vulnerability vis-à-vis a number of factors. Indeed, the region is affected by cyclical droughts that significantly reduce the intake of surface water. Over-exploitation of groundwater has led to the phenomenon of seawater intrusion, which if not mastered, can make these aquifers unusable. Water resources are also prone to pollution that threatens water potability. To analyse the balance between water supply and domestic demand, we will use the concept of water resources carrying capacity (WRCC). The latter can be defined as the level of human activity that can withstand the available water resources without major degradation of aquatic environments and maintaining an adequate standard of living. The action must be carried out simultaneously on the determinant factors of supply and demand which are of social, economic and environmental nature. The objective of this study is to reach an efficient and effective integrated management of water resources. The management of water demand as much as on supply is of critical importance to reduce vulnerability of water supply in a country with limited fresh water resources.

SENSITIVITY OF IRRIGATION REQUIREMENTS TO IMPROVEMENT IN IRRIGATION EFFICIENCY IN CLIMATE-INDUCED CHANGES: EXAMPLE OF A TRANSBOUNDARY WATERSHED

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ABSTRACT

The supply of irrigation water in a timely manner and its appropriate allocation, and efficient distribution has become a grand challenge, particularly in transboundary watersheds where competition between riparian parties is considerable. The altered runoff due to the adverse impact of climate change is likely to cause negative implications on water availability and demand for irrigated agricultural land, especially in arid and semi-arid regions. Appropriate estimation of irrigation demands is substantial to shape adaptation measures. In this paper, the Diyala river basin, shared between Iraq and Iran, is used as a representative case study for investigating the sensitivity of irrigation demands of the downstream state to a set of improvements in overall irrigation system efficiencies in the upper and lower riparian states. Several synthetic scenarios are formulated through an incremental development in irrigation efficiency value for a range between 40% and 60% under different operational conditions. The study of these scenarios reveals that there may be significant annual water saving, covering the demand for both riparian countries, if the target irrigation efficiency will be achieved. However, the examination of the climate trends through meteorological and climatic indicators reveals that the area tends to be drier, with lower amounts of precipitation and higher values of potential evapotranspiration. The possible impacts of climate change on water availability are investigated through the simulation of various climatic scenarios with a rainfall-runoff model. Based on two of the probable future scenarios, the simulation results show that the annual runoff may be reduced from 14% to 30%. It is estimated that such reduction can cause considerable water deficits, especially when there are small improvements in irrigation efficiency. This approach can be extended to other irrigated areas, which have similar constraints regarding climate change impact and irrigation efficiency.

HIGHLIGHTS

- Improving irrigation efficiency from about 40% to 50% would save about 19% of the water allocated for irrigation.
- Improving irrigation efficiency from about 40% to 66% would save about 39% of the water allocated for irrigation.

INDICATORS FOR SUSTAINABLE WATER USE WITH A REGRET-BASED DECISION MAKING APPROACH FOR HYDROLOGIC UNITS IN SOUTH KOREA

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ABSTRACT

This study aimed to develop sustainability index for water use over hydrologic units in South Korea. We identified major indicators for sustainable water use with considering multiple aspects of water use: not only physical, biological and chemical aspects but also social and environmental aspects. Furthermore, stressors for sustainable water use were of major interests because they were straightforward and easy to measure in comparison to indicators representing the state- and impact-related indictors. As a result, sets of indicators were identified with a theme-based hierarchical approach. It is comprised of two components of stress and response to sustainable water use and each component includes five sub-components of 1) human water requirements, 2) renewability of water resources, 3) water quality requirements, 4) health of aquatic ecosystems and 5) equitable water use. Then for each sub-component, multiple indicators, i.e., proxy variables were identified. For drainage basins in South Korea, standard hydrologic units with their total number of about 100 across the country, 19 stress indicators and 11 response indicators were identified in this study. Indicator data were collected for concurrent time, 2010 per se, with number of datasets from earlier or later times and integrated. A regret theory-based multi-criteria decision making (MCDM) approach was utilized to integrate individual indicators to an index. At last, we evaluated sustainability index with focusing on the spatial variability of index and indicators and the sensitivity of index to individual indicators. Also the sensitivities of indices to different MCDM approaches were examined.

HIGHLIGHTS

- We developed sustainability index for water use over hydrologic units in South Korea.
- Stressors and responses for sustainable water use were identified.
- A regret-based MCDM was utilized to integrate individual indicators into an index.

AN INTEGRATED MODELLING SYSTEM FOR ASSESSING WATER RESOURCES MANAGEMENT PRACTICES

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ABSTRACT

An integrated modeling system is applied to evaluate the sustainability of water resources management strategies in Lake Karla watershed, Greece. The modeling system, developed in the framework of "HYDROMENTOR" research project, includes coupled components for assessing surface water and groundwater resources, operation of hydrotechnical projects (reservoir operation and irrigation works) and estimation of water demands at several spatial scales. The study area was sub-divided into irrigation zones and water balance analyses were performed for each zone and each control node of the system for a number of water resources management strategies. Two operational strategies of hydro-technical project development (present situation without operation of the reservoir and future situation with the operation of the reservoir) are coupled with three water demand strategies. In total, eight (8) water management strategies are evaluated. The results show that, under the existing water resources management, the water deficit of Lake Karla watershed is very large. However, the operation of the proposed hydro-technical projects in Lake Karla watershed coupled with water demand management measures, like improvement of existing water distribution systems, change of irrigation methods, and changes of crop cultivation could alleviate the problem and lead to sustainable and ecological use of water resources in the study area.

HIGHLIGHTS

- Development and application of an integrated modelling system
- Assessment of surface water and groundwater resources and operation of hydrotechnical projects
- Evaluation of water needs and demands for operational and water resources management strategies
- Spatial integration of the results and water balance at watershed level

ADAPTATION OF WATER RESOURCES MANAGEMENT STRATEGIES TO OVERTURN CLIMATE CHANGE IMPACTS. THE LAKE KARLA WATERSHED CASE, CENTRAL GREECE

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ABSTRACT

The effects of climate change on meteorology, hydrology and ecology have become a priority area for research and for water management. It is crucial to identify, simulate, evaluate and, finally, adopt water resources management strategies to overturn the impacts of climate change. This paper is dealing with the assessment of climate change impacts on the availability of water resources and the water demands and the evaluation of water resources management strategies in the Lake Karla watershed, central Greece and it is a contribution to the "HYDROMENTOR" research project. The outputs of the Canadian Centre for Climate Modeling Analysis Global Circulation Model CGCM3 were downscaled using a statistical hybrid method to estimate monthly precipitation and temperature time series for present and future climate periods. The downscaling method is based on multiple linear regressions of GCM predictand variables with observed areal precipitation and temperature as well as on the application of a stochastic time series model and it has been applied for three socioeconomic scenarios, namely SRES B1, SRES A1B and SRES A2. The analysis was conducted for two future periods 2030–2050 and 2080–2100.The surface water and groundwater have been simulated for present and future climate periods using a modeling system, which includes coupled models for surface water and groundwater simulation, operation of hydrotechnical projects (reservoir operation and irrigation works) and estimation of water demands at several spatial scales. Two operational strategies of hydro-technical project development are coupled with three water demand strategies. Overall, eight (8) water management strategies are evaluated for present climate conditions and twenty four (24) water management strategies for future climate conditions have been evaluated . The results show that, under the existing water resources management, the water deficit of Lake Karla watershed is large and it is expected to become critical in the future, even though the impact of climate change on the meteorological parameters is very moderate. On the other hand, the operation of the proposed hydro-technical projects in Lake Karla watershed

coupled with water demand management measures, like improvement of existing water distribution systems, change of irrigation methods, and changes of crop cultivation could alleviate the problem and lead to sustainable and ecological use of water resources in the study area.

HIGHLIGHTS

- Precipitation and temperature would not dramatically change under future climate conditions
- The largest change in precipitation is estimated for the SRES A2 scenario. All changes range between 0.1%-5%
- Assessment of surface water and groundwater resources and operation of hydrotechnical projects for present and future climate conditions
- Evaluation of water resources management strategies

A NESTED OPTIMIZATION APPROACH FOR THE CAPACITY EXPANSION OF MULTIQUALITY WATER SUPPLY SYSTEMS UNDER UNCERTAINTY

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ABSTRACT

A nested optimization approach is proposed to solve capacity expansion problems of multiquality water supply systems. The problem to be solved consists in determining the infrastructure to be built and/or rehabilitated at a specific time. Necessarily, such decision should be taken with a long-term planning perspective considering how the operation will be performed to satisfy demand and water quality requirements from using multiple sources with different water quality at the source, taking into account the temporal and spatial distribution of the water resources available and being aware of the environmental impacts. In addition, decision processes which do not appropriately consider inherent uncertainties (e.g., hydrological, demographic, and technological) may lead to suboptimal solutions. Here, the uncertainty is handled using scenario planning with the aim of finding expansion solutions that can be expected to perform well under a set of possible future situations (or scenarios). The solution method combines simulated annealing with nonlinear programming to determine the solution to the nested optimization problem.

HIGHLIGHTS

- A nested optimization approach is developed for solving design problems regarding the capacity expansion of multiquality water supply systems.
- The explicit representation of uncertainty in the capacity expansion problem should lead to more robust solutions.

COMBINED OPTIMIZATION OF RESERVOIR-AQUIFER OF LAKE KARLA UNDER ENVIRONMENTAL CONSTRICTIONS

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ABSTRACT

The aim of this study is the simulation and optimization of Lake Karla watershed groundwater use for domestic water supply and irrigation under two constraints of groundwater restoration. This is achieved by using a coupled modeling system which consists of a surface hydrology model (UTHBAL), a reservoir/lake operation model (UTHRL), a reservoir/lake-aquifer model (LAK3) and a conjunctive optimization-simulation model which includes the United State Geological Survey (USGS) MODFLOW groundwater flow model and the USGS GroundWater Management model (GWM). The groundwater flow model simulates the operation of the alluvial phreatic aquifer for both the historical period from 1987 to 2012 and for the 2012-2044 period under different groundwater management scenarios. Then, the management model GWM estimates the optimum pumping rates, number and locations of irrigation and domestic water supply wells by solving an optimization problem under environmental constraints. Optimal pumping rates were inserted into the groundwater flow model and the hydraulic head maps of the aquifer and the volumetric budget is estimated. The year 2044 is a "milestone" set by the Lake Karla reconstruction project for the restoration of the overused and degraded aquifer. Four alternative management scenarios for the location of forty water supply wells for Volos city have been studied and optimized. These water supply wells are part of the Lake Karla restoration project and they will be located at the southern part of aquifer, where the greatest drawdown of the water table is observed. The four management scenarios have been applied to substantiate the effect of the water supply wells operation on the optimum extraction of groundwater for two different constraints for the year 2044: i) a water table level corresponding to that of 1987, which was the last year of aquifer's positive volumetric budget and ii) a water table level equal with the sea water level (i.e. absolute elevation 0 m). The management scenarios were evaluated regarding the two environmental constraints of groundwater rehabilitation and the optimal groundwater use.

HIGHLIGHTS

- Conjunctive use of optimization- groundwater simulation models
- Optimal exploitation of watershed renewable groundwater
- Aquifer's water table restoration
- Simulation and assessment of new water supply drillings
- Development and assessment of alternative management scenarios

SEISMIC DAMAGES IN PIPELINES IN THE LIGHT OF PREVENTIVE MAINTENANCE

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ABSTRACT

Learning from earthquakes has provided substantial progress in most of the engineering fields. The experience from the performance of pipelines during last earthquakes provided invaluable information and lead to new developments in the analysis and technologies. One of the important observations is that the pipe material and joint type are important for the response to earthquake loading. However, pipe compositions of pipeline systems may differ in cities and countries. The comparisons of water distribution networks in various countries show that pipe compositions (including joint types) in the water distribution networks differ significantly from country to country. The history and development of water supply systems in urban areas of countries affect the existing pipe compositions. Especially, asbestos cement and old cast iron pipes are well known for their high damage rates during earthquakes. It is better to put in the most proper pipeline from the start as replacing or retrofitting the pipelines later requires substantial investment. However, for the existing distribution systems, "preventive maintenance" and "proactive management" concept is getting more attraction. The primary goal of PM is thus to prevent the failure of components of the network before they actually occur by using advanced methods of statistical and risk analysis. This paper evaluates the water pipelines and seismic damage to the pipelines from the recent earthquakes in the light of preventive maintenance concept. Especially, the water pipelines performance during Christchurch earthquake in New Zealand is taken as a case study here.

HIGHLIGHTS

- Effects of different pipe material and joint type on the seismic performance of pipelines are discussed.

A METHODOLOGY FOR CLIMATE CHANGE INTEGRATION IN WATER RESOURCES MANAGEMENT. APPLICATION TO THE PORTUGUESE PART OF GUADIANA RIVER BASIN

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ABSTRACT

Many studies that characterize the impacts of climate change (CC) are generally conducted at large spatial scales (global/regional scale), often failing to capture the climate specificities of smaller regions (local scale). This compromises the potential for integration of the results in water resources management (WRM) policies specifically aimed at local scales. In several countries, namely in Portugal, CC impacts have always been assessed using simplistic approaches, which are unable to fully accommodate all the effects that must be characterized for WRM. In order to eliminate these limitations, a methodology was developed for integrating CC effects in water resources management and was applied to a Portuguese river basin. In order to achieve the goals of the study, a baseline and future scenarios for climate and hydrology conditions in the Guadiana Basin were established and applied in defining future required measures, either structural or operational, taking into account the river basin transboundary context. The paper presents a description of the methodology developed and the outcome of its application. The main goal of the present work is the in depth analysis of the results obtained, in terms of (1) the projected, expected water availability/shortage events, (2) the relationship between the meteorological, hydrological and water availability variables and (3) the nonlinearity of water availability and its relevance for water resources management.

HIGHLIGHTS

- Development and application of a methodology for the integration of climate change effects in water resource management.
- Comparison of solutions for climate change assessment (simple observed/projected versus observed/projected plus paleoclimate).
- Projection of future evolution of the occurrence of water shortage events.
- Analysis of the relevance of water resource management modelling in future water availability/shortage forecasting.

EVALUATING JOINT WATER DEVELOPMENT IN THE LOWER JORDAN RIVER BASIN USING MULTI-CRITERIA DECISION ANALYSIS

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ABSTRACT

Conflicts over shared water resources in the Lower Jordan River Basin are associated with scarcity of resources between five riparians and aggravated by the long-standing Arab-Israeli conflict. Bilateral agreements were signed between Israelis and Palestinians and between Israelis and Jordanians; however, to date, no common comprehensive agreement exists between the riparians over the sharing of the basin's waters. While achieving a consensus allocation strategy coupled with effective management of the basin's water may decrease water shortages, the need to augment water supplies remain a priority for all riparians. This paper provides a comparative synthesis of proposed developmental initiatives aiming to increase regional water supply using a Multi Criteria Decision Analysis - Simple Additive Weighting (MCDA-SAW) technique with sensitivity analysis applied to criteria weights. The results indicate that the Red Sea-Dead Sea Canal (RSDSC) constitutes an optimal option within the context of alleviating water shortage and promoting regional cooperation. A surface water pipeline from Turkey emerges as an attractive option when the quantity of delivered water is emphasized. However, the potential for out of basin water transfers are becoming less desirable with population growth, development and climate change challenges.

HIGHLIGHTS

- The Red Sea-Dead Sea Canal constitutes an optimal option within the context of alleviating water shortage in the lower Jordan River Basin.
- A surface water pipeline from Turkey is attractive as a second option when the quantity of delivered water is emphasized.
- Out of basin water transfers are less desirable because of population growth, development and potential climate change challenges.

WATER ALLOCATION MECHANISMS IN SUPPORT OF WATER SECURITY

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ABSTRACT

Within the last two decades, Integrated Water Resources Management (IWRM) is proposed as a solution for water problems and is considered as an essential approach to achieve sustainable development. In this regard, key concepts of the last 20 years have been sustainability, holistic approach to management, integrated water management and protection, and water security. Recommendations for a Global Goal on Water (to be achieved by 2030), based on Post-2015 Development Agenda, foresee water security as a major concept and efficient water allocation as a means to support it. Significant targets in securing sustainable water for all relate to water allocation, i.e., sharing a limited resource between different regions and competing users, achieving universal access to safe drinking water, sanitation and hygiene, and all countries strengthening equitable, participatory and accountable water governance. The traditional approach in water allocation is basically based on the construction of new infrastructure to meet rising demand. In contrast, this paper focuses on the modern approach and foresees: optimizing the use of existing supplies through significant economic, social and environmental analyses and the assessment of tradeoffs between competing users; and adoption of demand management measures. It describes the essential steps of: situation assessment; scenario development; assessment of implications of different scenarios; decision and uncertainty analysis; and final plans and implementation on a case study from western Turkey. This procedure again puts the focus on IWRM, which should be adopted by all nations as a solution to achieve water security and to take the necessary steps to establish the required institutional and legal adjustments.

HIGHLIGHTS

- Efficient mechanisms for water allocation must be developed to achieve water security, and this development requires the adoption of IWRM approaches.
- A modern procedure for efficient water allocation is presented.
- The results are demonstrated on a case study from the real world.

CONFLICT RESOLUTION IN RESERVOIR OPERATION PROBLEMS USING MULTI-OBJECTIVE STOCHASTIC DYNAMIC PROGRAMMING

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ABSTRACT

An attempt has been made to resolve the conflict between non-commensurate objectives of a reservoir operation problem through multiobjective programming technique. In this multiobjective problem, besides this objective of maximization of hydropower reliability, two more objectives, namely, maximization of hydropower generation after full satisfaction of project demands and maximization of annual release target were considered. The trade-off relations between annual release target and hydropower generation at different reliability levels were established from the results. The trade-off relations were presented to the decision maker for final decision. Here the surrogate-worth-trade-off (SWT) method was used as an interactive tool between the decision maker and the analyst to arrive at the best compromise solution. The developed model was used to find out an optimal release policy for the Sardar Sarovar Project (SSP) reservoir, a multipurpose and one of the most controversial reservoirs from ecological point of view on the Narmada river in Central India. The best compromise solution was found at annual release target of 9700 Mcm. The primary objective function was again optimized for annual release target of 9700 Mcm (secondary objective function used as constraint) and the optimal operating policy of the SSP reservoir was presented to the decision maker.

HIGHLIGHTS

- The best compromise solution was found at annual release target of 9700 Mcm.
- For the given project demand of 11681.49 Mcm, MOSDP reservoir operation model produced better results than SDP reservoir operation Policy.

- SDP algorithm produced a canal release of 7089.35 Mcm at 75% reliability level and firm energy (90% reliable) of 185.15 Mkwh.
- MOSDP algorithm produced a canal release of 9749.55 Mcm and firm energy of 212.85 Mkwh at corresponding reliability levels.

RELIABILITY BASED SIMULATION FOR POWER POTENTIAL STUDY OF A HYDROELECTRIC PROJECT

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ABSTRACT

River Brahmaputra, which is considered to be one of the biggest rivers in the world, contributes to about 41.55% of the total hydropower potential of India. However the development of these huge water resources potential has remained limited so far. Based on this importance, optimal operating policy for a reservoir is always considered to be an important aspect, as operational effectiveness and efficiency of the reservoir system can be improved significantly with an efficient operating policy. Therefore, this research aims at evaluating the reliability based performance of a water resources system. The method results in developing a reliability-based simulation (RBS) model to analyse single-reservoir hydropower system. The methodology consists of two phases of analysis. In the first phase, detailed study has been carried out for optimization of project parameters and for evaluation of energy and power benefits. The project has been considered as a run-of-the-river-scheme with peak storage capacity of minimum three hours peaking generation in a 24 hours period for full installed capacity in 90% dependable year. Therefore on the economic basis, the most beneficial installed capacity for the plant has been found out to be 90 MW. In the second phase, simulation technique has been used to obtain the firm power generation at the most economic installed capacity of 90 MW considering the system as base load plant for 24 hours period. From the analysis, the firm power generation has been found out to be 10.25MW at 90% reliable hydro power generation.

ZEOLITITE AMENDED AGRICULTURAL FIELD EXPERIMENT TO IMPROVE WATER SAVING

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ABSTRACT

Intensive agriculture often affects soil and water quality, thus research is devoted to find viable options to diminish nutrient loss, to recover soil quality and to increase crop yield. Only in recent times, natural zeolitites have been used to reduce nutrient leaching and increase irrigation efficiency. In this study, an experimental field site of about 6 ha was divided into parcels and monitored for two years: three control parcels were cultivated and irrigated according to the traditional way; two parcels were amended with coarse-grained natural zeolitite at different zeolitite/soil ratios (5 kg/m2 and 15 kg/m2) and one parcel was amended with fine-grained NH4+-charged zeolite (7 kg/m2). The raw material was a chabazite rich zeolitite sourced near Sorano in central Italy. Soil EC, temperature and volumetric water content were continuously monitored with TDR probes at different depth and routinely checked in the laboratory via gravimetric method. A meteorological station was installed on-site to monitor climatic variables for water balance calculation. Continuous monitoring highlighted an increase of soil water availability in the amended parcels with respect to the control ones. In particular, the parcel amended with 15 kg/m2 of zeolitites showed and average water content always higher than the control ones. Besides, after intense rain events, field capacity was augmented and percolation in the deeper soil horizons was hampered. Finally, the residual water content during summer droughts was improved of 1.4±0.4%. This study has shown the capability of zeolitites to improve soil water content in agricultural lands to save irrigation water.

HIGHLIGHTS

- An open field experimental site amended with natural zeolites was established to quantify the water saving capacity.
- A water balance approach was established for each plot.
- Continuous monitoring of soil EC and water enabled to quantify the water saving capacity.

- Both soil water content increase and decrease of percolation was observed for the parcel amended with zeolites.

INFORMING DROUGHT MANAGEMENT: A NEW APPROACH TO ESTIMATE VULNERABILITY LEVELS IN WATER SUPPLY SYSTEMS

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ABSTRACT

Characterising vulnerability to drought in water systems is a challenge due to the complexity of the systems, their dynamic response to drought conditions and the effect of management responses. There are several useful methods for estimating vulnerability ranging from multiple indicators, to statistical approaches. Drought management actions are then defined in a sequential way after defining the thresholds of vulnerability. However, there is a need to evaluate the vulnerability and potential response in an integrated way, to evaluate the effect of the response actions on the system. The objective of this paper is to provide a new integrated method to define vulnerability to drought linking identification, thresholds and management actions. A meta-multicriteria approach was adopted since the problem itself modulated the multi-criteria method. At first, the indices are divided into sensitivity and adaptive capacity criteria. Based on the extreme values of the above criteria four non -ordered categories are established to characterize the vulnerability to drought. Two fuzzy methods are developed to assess the vulnerability to drought. The first one is the fuzzy pattern recognition and the second is based on logical propositions. The logical proposition is quantified on the basis of fuzzy sets and logic. Each logical proposition describes each category whilst fuzzy implication is used to express algebraically these logical propositions. The proposed two methods lead to similar but not identical results. Furthermore, the quantification of the logical propositions can be modified with respect to the sequence of the drought years. For this purpose the use of fuzzy - union between the fuzzy vulnerability with itself is proposed. The proposed method has been applied to several Mediterranean countries.

HIGHLIGHTS

- Three sequential stages of the water system are considered. The vulnerability assessment process takes into account simultaneously the ability to resist, to reorganize following impacts and to adapt to drought conditions.
- Instead of conventional multicriteria methods, the evaluation of the vulnerability can be achieved on the basis of a logical proposition.
- By using fuzzy sets and logic we can quantify the logical proposition and furthermore, to include the uncertainties in the analysis.
- Fuzzy aggregators can simulate the way of human thinking whilst the fuzzy complement can be used to express the case of multi-year drought.

EFFECT OF GRANITIC BASEMENT RADIOACTIVITY ON GROUNDWATER RESOURCE IN SHIRKOOH AREA - YAZD PROVINCE OF IRAN

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ABSTRACT

Granites are one of the main sources of radioactive elements (e.g. uranium and radium) into waters and soils. Shirkooh granite is of S-type (product of partial melting of metamorphosed sediments) which can be comparatively enriched in radioactive elements. In order to evaluate the potential effect of the Shirkoh granite complex on the local groundwater resource, stream sediment and water samples were collected and were analyzed by HRGS technique. The obtained results show a slightly enrichment of Uranium (on average 2.2ppm) and probably Thorium toward west where leucogranites exposed. Shirkooh aquifer is mainly composed of hard rock formation in which water flows through shallow depth joints and fractures (and probably some major faults). This aquifer is the main source of water of springs, Qanats and wells in the region. In addition, analysis of groundwater samples indicates relatively high concentration of Uranium in two hotspots. The one matches the local drainage basin of Sanij Abad and the other one is in the local drainage basin of Deh Bala. The sources of Uranium are clearly attributable to weathering product of leucogranites (without long migration) and local major faults (probably with longest migration) respectively in first and second hotspot. Based on the results of this research a detailed study is needed to investigate local drainage basin of Sanij Abad and drainage basin of DehBala.

HIGHLIGHTS

- The obtained results show a slightly enrichment of Uranium and probably Thorium, toward west of Shirkooh granite.
- The source of Uranium is clearly attributable to leucogranites which is facilitated by groundwater flow along the faults and fractures.
- Granites are one of the main sources of radioactive into waters and soils.
- Shirkooh aquifer is mainly composed of hard rock formation.

BUILDING RESILIENCE IN THE WATER SUPPLY NETWORK OF MAURITIUS

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ABSTRACT

In Mauritius, with an area of 1860 km2, the water supply network has been divided into 6 main systems to serve 6 regions. The whole network relies on surface and ground water. Surface water is abstracted through rivers and stored in reservoirs across dammed rivers, while groundwater is harnessed through some 120 boreholes. The water requirement of the country is of the order of 180 Mm3 annually for a population of 1.3 million. Gradually, conjunctive use of surface water and groundwater has been introduced so as conserve surface water reserves. Surface water is stored through man made reservoirs, which do not have a capacity beyond a year's supply, unless there are heavy rains. During the same heavy rains, the aquifers are recharged, and unless pumping is carried, the ground water will certainly go to the sea. The idea is to pump heavily during the rainy period so as to abstract a maximum amount of water from underground, thus saving on the amount of water which needs to be extracted from the reservoirs. A further step in increasing the resilience of the network has been to introduce standby generators, in case of electricity breakdown, and a double borehole. Effectively, there are two inherent problems with borehole pumping in Mauritius: water levels may vary widely - as much as 20 metres – during the dry and wet seasons and the risk of a power supply breakdown during cyclones. These two issues have been addressed by installing a second borehole and a standby generator. The latest step is trying to interconnect different networks. Any of the above networks is, in principle, independent. However, previous droughts have brought home the need of possible interconnections. Gradually a few interconnections are being made, so that should a network suffer a shortage of supply for various reasons, there is a possibility of recovering from the shortfall. Thus, the overall water network is acquiring a certain degree of resilience which helps providing water to the population satisfactorily during the whole year.

HIGHLIGHTS

- Interconnections between supply systems increase resilience.
- Resilience has been increased by doubling boreholes.
- The provision of a standby generator provides a safety net in case of power outage during cyclones.

INTEGRATION OF CLIMATIC VARIABILITY AND CHANGE INTO COASTAL WATER MANAGEMENT OF THE ŠIBENIK-KNIN COUNTY – CROATIA

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ABSTRACT

In this paper water related topics of Integrated Coastal Zone Management Plan for the Šibenik-Knin County in Croatia (ICZM Plan) is presented. The ICZM plan has been proposed as an effective tool to address climate variability and change impacts. The plan is focused on the impacts of climate change in the coastal zone and adaptation to the expected changes. The main objective of the ICZM Plan for the Šibenik-Knin County is to offer a platform for sustainable development of the Šibenik-Knin County coastal zone based on water as its fundamental resource, blue economy and smart specialization. The background work for the Plan identified the main climate-related challenges for the area. Based on these challenges and analyses of the existing development plans, strategies and water management plans, possible adaptation measures have been analysed and proposed, as well as solutions. In this work methodology, possible adaptation measures and proposed solutions are presented.

HIGHLIGHTS

- Integrated Coastal Zone Management is an effective tool to address climate variability and change impacts in coastal zones.
- Coping with variable and unpredictable of predominately karst fresh water resources represents a big challenge to climate adaptation.
- The main climate impacts are: temperatures, water scarcity, flooding, sea level rise and droughts.
- ICZM Plan contributes to protection, restoration and preservation of the coastal zone's resources.

Conference VI

Social, Political, Institutional and Legislative Aspects

INSTITUTIONAL CHALLENGES FOR ACHIEVING A WHOLE OF WATER APPROACH – THE CITY OF SYDNEY RESPONSE

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ABSTRACT

Urban water managers and policy makers are struggling with the challenge of transitioning to an approach that considers a whole of urban water approach, where water planning and the urban form are considered in an integrated manner. The recent drive for liveable cities, where water is used to enhance the urban landscape through reuse and storm water management, has seen a shift in focus. This has brought a number of challenges to bear on institutions charged with water planning and management at strategic, tactical and operational levels.

Five central challenges have emerged from the research undertaken by ISF, viz.:

- Legislations and regulations that are prescriptive, overlapping and inconsistent
- Economic and financial systems that are restrictive and traditional
- Planning that is uncoordinated and non-collaborative
- Organisational and professional cultures that are siloed and inflexible
- Citizens engagement that is uncoordinated, technical and uninspiring

Drawing on the approach adopted by the City of Sydney, the paper will illustrate how a number of these challenges were overcome by local council in their attempt to achieve liveability goals, make the city more resilient to climate change, and reduce pollution levels in the water ways and harbour. The City undertook a consultative process to develop a decentralised water master plan that would both drive and guide future recycling, storm water management, and pollution control initiatives. Six transferrable lessons and enabling actions were identified that will have relevance to other cities and urban planners aiming to achieve a whole water approach and liveable cities.

HIGHLIGHTS

- Strong leadership and vision from senior positions is key to driving a Whole of Water approach to service delivery.

- Transparent consultation with the community and stakeholders is key for confirming the vision and to support the implementation of the strategy.
- Changing the current culture and improving the knowledge and capacity of staff and organizations is key to achieving an integrated approach.

THE EUROPEAN FLOOD DIRECTIVE: CURRENT IMPLEMENTATION AND TECHNICAL ISSUES

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ABSTRACT

In 2007 the European Union put into force the Floods Directive (FD) 2007/60/EC. The introduction of the FD was triggered by the fact that more frequent floods were observed in Europe and extreme flooding phenomena have caused many economic losses and in some cases even human casualties. These facts have intensified the need for European cooperation in flood management. The primary goal of the FD is to enact a framework for the assessment and the management of flood risks, targeting at the reduction of the negative effects on human health, the environment, the cultural heritage and economic activities that are connected with floods. The FD is currently in the process of implementation by the Member States and the first technical difficulties have arisen. The present paper examines the current implementation status of the FD across Europe, its weaknesses that have appeared up to now and proposes certain steps that should be taken in order to enhance the preparation of the Flood Risk Management Plans. A major technical issue that needs to be tackled is the uncertainty that characterises flood management, mainly due to lack of reliable data. Moreover, the case of River Evros-Maritsa is presented in relation to the application of the FD on transboundary catchments and the impediments that rise in managing floods across countries.

HIGHLIGHTS

- Current implementation status of the FD in Member States.
- Weaknesses and technical issues that have arisen during implementation.
- Confronting uncertainties due to lack of data.
- Transboundary flooding and common management

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ASSESSING WATER AVAILABILITY IN EUROPE: A COMPARATIVE STUDY

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ABSTRACT

Climate change is likely to alter the hydrologic cycle and modify water supply conditions in many regions. This study presents a regional assessment of current and future water availability in Europe under different assumptions. The study highlights large uncertainties associated with these estimates. It was carried out within the BASE European project and may be used to compare risks of water scarcity across European regions. Water availability is understood as the amount of water that can be supplied at a certain point of the river network to satisfy a regular demand under specified reliability requirements. In this sense, water availability is the combined result of natural processes and policy. Natural processes are conditioned by greenhouse gas emissions and configure the hydrologic regime. Policy determines how water resources are managed and defines the available hydraulic infrastructure to manage water and water supply conditions. Water availability was computed with the WAAPA model. The model was built from the river network inferred from the Hydro1k digital elevation maps. Storage volume for regulation was taken from the World Register of Dams of the International Commission on Large Dams. Hydrologic scenarios were taken from the Inter-Sectoral Impact Model Intercomparison Project (ISIMIP), where several hydrological models were applied using forcing from five global climate models under the Representative Concentration Pathways scenarios. Policy scenarios were devised by identifying several water management practices in different regions of Europe. The main result of the work is a set of local water availability estimates in 1260 sub-basins across Europe and an assessment of associated uncertainties

HIGHLIGHTS

- A methodology to assess water availability at the regional scale accounting for natural and man-made processes
- Sensitivity analyses to time horizon, emission scenario and water management practices

APPROACHES FOR THE DETERMINATION OF MICRO HYDROPOWER POTENTIAL OF TURKEY

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ABSTRACT

Predictions on fossil fuels being in a trend of run-out and recent nuclear disasters have accelerated the disputes about energy generation methods. Hydropower, the clean and renewable energy resource, still represents significance all over the world and small-scale hydropower has a remarkable role for exploiting the hydropower potential totally. After the law #4628 came into force, intensive and chaotic arguments about hydropower and its implementations were initialized by some non-governmental organizations in Turkey, most of which were not sharers of the "subject" actually. Furthermore, the impression existed that license applications for small hydropower plants could not be controlled sufficiently. Turkey has not made the desired breakthrough in the determination of small-scale hydropower potential yet, while they have realized a considerable development on researches for large-scale hydropower potential. The number of small-scale hydropower plants in operation is 153, while 313 are in planning level, as of end of 2013, in Turkey which are estimated to reach at a couple of hundreds in near future. Micro hydropower, one of the important aspects of small-scale hydropower, is widely employed in many countries, although it is a new research and applied field for Turkey. "Unlicensed electricity generation regulations" which came into force on 03/12/2010 and were revised on 30/03/2013 in Turkey obtained newer encouragements to those who would operate any kind of micro cogeneration plants. Aim of this study is to assess the applicability of micro hydropower in Turkey and to discuss how supplementary criteria for the determination of micro hydropower potential in the relatively small rivers of Turkey can be derived and developed. These criteria mentioned in the study can be sequenced as "Hypsographic Curves Method", "Hydraulic Head-Flow Diagram Method", "The Concept of Bifurcation Ratio", and "Artificial Flow-Duration Curve Approach". In consequence of the single and/or combined utilization of these criteria, micro hydro potential of small watercourses might be determined based on bifurcation ratios of various orders.

HIGHLIGHTS

- In the approaches for the determination of micro hydropower potential, some methods can be derived from methods used for larger watercourses besides developing totally unique methods for micro hydropower plants.
- Hypsographic Curves Methods, Hydraulic Head-Flow Diagram Method, The Concept of Bifurcation Ratio, and Artificial Flow-Duration Curve Approach may be counted as appropriate approximations to determinate the micro hydropower potential.
- Turkey has not obtained the desired progress for micro hydropower yet, although it is a convenient energy generation tool under conditions of the country.
- Potential determination methods have to be discussed by considering own conditions of any country for which the studies are carried out.

EVALUATION OF GOLF TOURISM ACTIVITY IN NOTHERN CYPRUS RELATED TO WATER DEMAND

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ABSTRACT

Even though golf tourism satisfies all economic aspects, some environmentalists object to increase its potential because of high water demand to irrigate and other environmental effects.
An effective Golf Course Environmental Management Program can reduce uncertainties and may provide betterment to mitigate environmentalist's hassles. In fact, there are many good examples in continental European and the USA; where reclaimed wastewater is used for golf courses irrigation purposes.
This paper summarizes the environmental impacts of golf courses and discusses their appropriate management practices. Also rehabilitation of CMC Golf Course in Yeşilyurt, Northern Cyprus is analysed from economic and environmental points.

TURKEY'S DRAFT WATER LAW AND WFD IMPLEMENTATION: AN ANALYSIS

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ABSTRACT

After some lengthy processes of preparation and consultation, a new framework water law has now been declared as "ready" for Parliamentary procedures. Since Turkey aspires for European Union membership, harmonization with Water Framework Directive (WFD) is one of the key priorities within environmental negotiations. From the outset, the newly proposed water law has been drafted with an eye on WFD requirements. It also targets to eliminate the so-called "patchwork" of water-related legislation in Turkey through adoption of a single yet comprehensive law. This paper analyzes the recent draft Turkish water law in light of WFD rules and principles. It has been observed that the proposed water law appears to be largely in line with these rules. However, there is room for improvement as well. For instance, although the proposed law mentions the full-cost-recovery principle, which is one of indispensable elements of WFD, there is a degree of ambiguity in the law on whether environmental and resource costs would be calculated and recovered in full. It is anticipated that a number of by-laws would provide full-fledged frameworks of operationalization on issues that are not sufficiently articulated in the law itself.

AMBITIOUS GOALS AND AMBIGUOUS ISSUES: INTEGRATING WATER AND ENERGY CONCERNS IN THE NORWEGIAN HYDROPOWER SECTOR

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ABSTRACT

The EU Water Framework Directive represents a common framework for water policy designed to improve and integrate the way water bodies are managed throughout Europe. This complex and innovative directive engages multiple actors and sectors, involves changes in the institutional, organizational and spatial set-up of water resource management, and calls for the integration of the different interests and policy goals.

Based on secondary data analysis and qualitative semi-structured interviews, the paper investigates how the new EU water policy affects the management of water recourses in relation to Heavily Modified Water Bodies and hydropower in Norway. The illustration of the Norwegian case helps gaining more insight into the implementation process in a country that, besides not being a EU member, relies mainly on hydropower for its electricity generation, hence needing even more effective energy-water policy integration.

Conclusions reveal that, while the complexity of the organizational structure has increased in response to the WFD, the path towards major coherence and integration with the hydropower sector has seemingly not been supported by changes in the legislative framework. Despite the space created by the WFD for institutional reforms, the Norwegian case shows that domestic water quality ambitions and the WFD implementation process are profoundly influenced by broad political and economic conditions. Indeed, the importance of the hydropower sector makes of the implementation of the WFD a highly politicized issue and the country seems locked in a pre-existing path determined by a historical distribution of responsibilities in the water policy field and the established political-institutional structure.

HIGHLIGHTS

- Hydropower is an important renewable energy source that has largely contributed to the world development and can continue assisting in the energy transition.
- The integration between water protection and energy security involves also an action in order to reconcile different environmental concerns.
- The mapping of the different stakeholders' frames shows that the conflict persists within the Common Implementation Strategy.
- The WFD implementation has triggered and legitimized bottom-up pressures which aim at reforming the institutional set-up of water management in EU.

WATER MANAGEMENT IN THE MEDITERRANEAN REGION: CONCEPTS AND POLICIES

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ABSTRACT

The Mediterranean Region exhibits significant contrasts in its demographic and hydrologic features that have shaped the water management policies of the Mediterranean countries. Although awareness is raising with regard to sustainable water management, the extent to which it is applied in practice is debatable. Use conflicts and non-renewable water extraction in water scarce part of the region like the Southern and Eastern rim countries are exposed as overriding management issues. Furthermore climatic variations are superimposed on natural hydro-stress and water dependency on external resources in most of the cases. Decision-making process needs measurable, comparable and reliable tools in order to be able to make trade-offs when facing conflicting issues. Indicators are valuable tools for understanding the trends and challenges encountered in water resources management. The Contracting Parties to the Barcelona Convention adopted, in November 2005, the Mediterranean Strategy for Sustainable Development (MSSD). The first priority field of action of the strategy is integrated water resources and demand management. Increasing efficiency by reducing losses and wasteful use is expected to help stabilize water demand in the Southern and Eastern part of the Mediterranean countries.

In this paper, an assessment of the existing water management concepts and policies in Mediterranean countries will be presented based on sustainable development indicators related to water management.

HIGHLIGHTS

- Water management is presented with highlights on existing constraints and challenges in Southern and Eastern countries, in particular
- Indicators are used to show the trends and challenges in selected countries
- Water resources management policies are debated on regional level based on indicators

MODELLING SECTORALLY DIFFERENTIATED WATER PRICES IN A COMPUTABLE GENERAL EQUILIBRIUM MODEL

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ABSTRACT

This study presents a Computable General Equilibrium (CGE) model, STAGE_W that includes multiple water commodities produced from different water resources as well as several taxation instruments related to the water sector, which allow for a wide range of pricing schemes including price differentiation between consumer groups. With the help of the model economy-wide effects of policy changes in the water sector can be simulated. To demonstrate its capabilities, the model is applied to the case of Israel, where the current water pricing scheme supplies potable water to municipalities at fees above the supply costs and subsidizes water delivered to the agricultural and the manufacturing sectors. Due to limited freshwater resources, climate change and population growth, water scarcity is an increasing problem in Israel. Therefore, pricing systems which lead to a more efficient allocation of water are intensively debated. This study analyzes two alternative pricing schemes under discussion in Israel: price liberalization, which unifies the prices for all potable water consumers at cost recovery-rates, and marginal pricing, lifting the potable water price to the cost of desalination. Both schemes reduce potable water demand at limited economic costs and increase the viability of alternative water sources (desalination, wastewater recycling and brackish groundwater). It is found that price liberalization is the most favourable option from a national welfare perspective, while the marginal pricing allows for larger water savings and, in the long run, independence from fresh water resources.

HIGHLIGHTS

- The study presents, a general equilibrium model, for different types and uses of water including tax instruments allowing for price differentiation.
- The model is applied to Israel, where despite of scarcity low agricultural water prices prevail, cross-subsidized by high municipal water prices.
- For Israel, price liberalization (cost recovery pricing) is the most favourable option from a national welfare perspective.
- Marginal pricing allows for larger water savings and, in the long run, independence from natural water resources.

AGRICULTURAL WATER MANAGEMENT IN DROUGHT CONDITION, CASE STUDY

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ABSTRACT

The Zayandeh-Rud River Basin is the most important basin in Central Iran, which in recent years has struggled to satisfy the growing urban, agricultural, industrial and environmental demand of its residents and ecosystem. Agriculture is a main user of water resources at this basin and optimal crop water allocation has become more challenging in this region. In this way, the objective of conventional irrigation methods which was on the basis of maximizing the yield per unit area by allocating water should be improved to maximizing the water productivity by available limited water resources. For this reason, deficit irrigation could play an important role on conquering the scarcities; while the reduction of yield may be small as compared to the benefits gained through diverting the saved water to cover more cropped area under irrigation.In this paper a comparison between the yields of main crops of the irrigation zones in the Zayandeh-Rud Basin will be accomplished to determine the optimum allocated water for each crop and after that suggesting an appropriate deficit level which could apply on the all types of the main crops which are cultivated. Therefore, at first the main crops of the basin with crop water production function (CWP function) of each of them will be presented and then the total saved water will be calculated according to the optimum deficit level obtained from CWP functions.

HIGHLIGHTS

- In this research an optimum deficit level for the main crops of the case study will be presented.
- The main crops of the basin with the CWP function of each of them will be presented.
- Main cultivated crops on case study's lands will be introduced.

"THINK ABOUT NEW AGRICULTURAL PRACTICES, DRAIN LAKE KARLA": SOCIO-ECONOMIC INSUFFICIENCIES OF A LAKE RESTORATION PROJECT IN THESSALY, GREECE.

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ABSTRACT

The paper focuses on the socio-economic aspects of Lake Karla's restoration in Thessaly, Greece. Its scope is twofold. First, it evaluates whether the lake restoration project is successful, the socio-political processes that lead to it and its effects on the local and regional community. Second, it analyses the fundamentals of a conceptual framework that can be used by climate change adaptation strategies (and strategists) based on the case of Lake Karla. Methodologically, the paper adopts a critical political ecology perspective while draws upon extended field research in the area; specifically, primary material, questionnaires and interviews with key-informants, in agricultural communities located in close proximity to Lake Karla.
The paper brings to front the close interrelationship between society and environment in the case of Lake Karla, and reveals how contemporary crisis in capitalist accumulation along with diachronic institutional insufficiencies may enhance an already existent environmental and societal crisis as well. It also highlights that socio-environmental scholars should fully understand the complexity and dynamic nature of environmental projects in order to be able to protect both waters and local economies. The latter is of great importance in semi-dependent crisis-hit peripheral countries such as Greece.

HIGHLIGHTS

- Diachronic institutional insufficiencies along with contemporary crisis may turn Karla's restoration into a failure.
- Socio- environmental scholars should fully understand the complexity of environmental projects in semi-dependent peripheral countries.

RESILIENCE POLICIES AGAINST FLOOD RISK IN THE PARIS REGION: AN ECONOMIC ANALYSIS USING COBAYE

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ABSTRACT

More than 100 years after the great Seine river rise of 1910, Paris and its region risk regional and national social and economic disasters even more important if such a rise was to happen again today, especially in the housing, energy and transportation sectors (IAU-IdF, 2014). Based on the "EPTB Seine Grands Lacs" studies, OECD then proposed a series of measures – both technical and non-technical to help avoid risk of flood in Paris and its region, among which optimization of existing structures, including dikes, controlling runoff at the source with ecological restoration basin heads, better governance articulation and awareness campaigns (OECD, 2014).
In this paper, we propose a methodology called CoBAYe (Cost Benefit Analysis considering interdependency and uncertainty) to provide an economic *ex-ante* evaluation of this set of policies. Based on some of the traditional cost-benefit analysis (CBA) roots, this new decision-making tool proposes to use a systematic typology based on the consideration of direct, indirect and induced effects of the implementation of a public policy. Therefore, CoBAYe takes into account spatial, temporal, technical and functional interdependencies between public policies and private strategies to assess both the techno-economic constraints and potentialities of the use and application of the new water infrastructure.
Relying on the CoBAYe methodology, the main result presented in this paper is hence an *ex-ante* economic evaluation of resilience policies against a risk of flood in the Paris Region to help identify social, political and governance levers required for an efficient response.

HIGHLIGHTS

- *Ex-ante* multi-sector economic evaluation of resilience policies against a risk of flood in the Paris Region.

- Social, political and governance levers required for an efficient response against the risk of flood.
- The CoBAYe innovative decision-making tool helps identify public policies and private strategies interdependencies induced by the flood policy.

BEYOND YES AND NO: PRIVATIZATION AND PUBLIC RESISTANCE IN JAKARTA'S WATER SUPPLY

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ABSTRACT

Privatization of essential utilities is one of the most urgent yet most intractable public reforms. Many scholars have argued that this intractability lies in public hostility or opposition to the private sector's key interest in making profits out a service that is essential to life. More recently however, there is growing realization that this "public versus private" interests frame does not reflect reality on the ground; that extant narratives are far more complex. There has however, been little attempt to investigate such claims empirically. A large part of the problem is methodological – it is difficult to analyse or compare narratives quantitatively. This paper contributes to this effort by using the Q methodology to outline the stakeholder perceptions of water privatization in Jakarta, Indonesia. It finds that there are seven discourse coalitions - while four are hostile to the private operators, three hold narratives which rely on joint interests. The study was repeated after three years to investigate the apparent intractability of the privatization effort. It finds that joint-interest narratives are becoming stronger, signalling a possible way forward for the management of the water utilities. This study provides a hermeneutic model for understanding water privatization efforts, especially for cities in the advanced global South.

HIGHLIGHTS

- Public resistance to privatization is not well-captured by an intractable "anti-privatization" narrative.
- Even resistant coalitions acknowledge need for private capital in infrastructure
- Findings expose myth of "market turn" – politics should be a key part of the privatization narrative
- Findings point towards a meta-narrative that will ameliorate implementation risks

A NEW INTEGRATED APPROACH FOR WATER EDUCATION IN TURKEY

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ABSTRACT

Water resources are at risk all over the world today. Population growth, changes in land use, pollution and climate change are adversely affecting the quality and quantity of water resources. Today, 80% of the world population lives in water insecure areas. In order to sustain human and ecosystem health, access to safe water resources need to be provided for the communities. Therefore, water security is a top issue at the international agenda. Universities have important role in leading research and providing education for water professionals and cooperate with relevant institutions on water management and policies. In Turkey, Ankara University founded Water Management Institute (Ankara WMI) in 2010 in an attempt to tackle water related problems at local, regional and international levels. The institute aims to conduct research and education activities on sustainable water management, water policy and security issues. Focusing on development of a new graduate programme on water education, Ankara WMI has proposed to establish an inter-disciplinary Master of Science programme on "Water Policy and Security". The programme was developed by analyzing similar international and related national programmes as well as performing gap analysis for existing programmes and the future needs. According to the new curriculum, students will need to take three compulsory courses, namely, Water Science, Integrated Water Resources Management and Water Policy and Security. The remaining credits will be completed via elective courses, such as Adaptation to Climate Change, Decision Support Tools for Policy Analysis, Water Governance and International Law on Watercourses.

HIGHLIGHTS

- Water security is a top issue at the international agenda.
- There is a growing need to adopt an integrated approach on water education in the world and in Turkey.
- Ankara University Water Management Institute was founded to tackle water related problems at local, regional and international levels.

- An inter-disciplinary Master of Science programme on “Water Policy and Security” was proposed to contribute to capacity building in our country.

LEGISLATIVE ASPECTS OF FLOOD HAZARD PREVENTION AND RESILIENCE IN NON-EU MEMBER EUROPEAN COUNTRIES

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ABSTRACT

Floods have been the reason of maybe the most significant disasters in human history. With the recent climate change, the flood events started to become more frequent and more severe. In parallel with the devastations faced, the battle against flood has boosted not only with scientific and technological tools, but also by political and legislative means. Stemming from this need, EU initiated the Flood Directive, which describes the legal and practical framework of the actions that are required to be taken by the governmental bodies against flood related issues. The member countries have declared that they are going to fulfil these requirements within a predefined timeline. However, the non-EU member (or candidate) European countries are not bounded by law with this directive yet. Still, there have been some ongoing efforts, to some extent at least, in order to fit the present legislative framework to EU Flood Directive. This is not an easy task that can be done in an eye blink, but it is a long process of harmonization. In this study, the present legislation and applications on flood issues in some non-EU countries such as Turkey, Ukraine and Moldova is given and a comparison of these with the EU Flood Directive are presented. The ongoing efforts, necessary changes to be made and steps to be taken with a target of "complete harmonization" is discussed. Finally, a number of conclusions are drawn from these discussions including some recommendations for the aforementioned process.

HIGHLIGHTS

- The legislative framework of some non-EU member countries are compared with the EU Flood Directive.
- The differences and similarities in between are discussed.
- Conclusions are drawn pointing out the difficulties of the process of harmonisation and problematic issues on flood legislation.
- Some recommendations are listed to facilitate the process.

WILLINGNESS TO PAY TO IMPROVE WATER SUPPLY SERVICES IN RURAL KAZAKHSTAN: APPLICATION OF CONTINGENT VALUATION METHOD

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ABSTRACT

In the recent decades Kazakhstan has been transitioning from a state planned to a market economy. This transition has affected many facets of life including provision of water and sanitation. For development of market water supply services the willingness of consumers to pay is important. Consequently, the consumers' willingness to pay (WTP) for piped water supply using the contingent valuation (CV) method with different starting point bids was investigated. The experimental Pavlodar region is arid to semiarid with a mean annual precipitation of about 250 mm. Water resources are mainly surface water from the Irtysh River (86%) and to a minor extent groundwater (14%). The WTP was investigated by using questionnaires for major peri-urban areas and by applying CV with open-ended questions and bids format with different starting points. The results showed that households with access to groundwater (well or borehole water users) perceived this as of good quality. Consumers without access to groundwater used open-source, standpipe or delivered water for which they had to travel and spend time or to pay. Open source water and standpipe water quality was perceived as bad or satisfactory. More than 90% of the consumers were willing to pay for better water quality and regular water supply. The response rate for the bids was higher than for the open-ended format questions. The mean WTP was estimated to be about 1,120 in bids and about 1,590 KZT per household and month in open-ended question format, respectively (150 KZT ~ 1 USD as of January, 2012). The bids from CV displayed a substantial influence of the first price in the mean value for the user group that had no charges and used private wells and boreholes as well as open source. For other water user categories, the starting price had no impact. The main influencing factors are the source of water (groundwater or surface water) and the access to private or public water supply, and the fee payment for private connection as an implicit indicator of the household wealth. The results can be used to better identify the proper technological choice and the level of service to be provided making rural water projects both sustainable and replicable at a larger scale.

PERCEPTIONS OF CITIZENS TOWARD WATER MANAGEMENT IN A RESIDENTIAL COMMUNITY: CASE STUDY FROM AL-MAFRAQ – JORDAN

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ABSTRACT

This study aims to investigate the perceptions of the citizens in AL-Mafraq Governate toward the water management. A questionnaire survey in the study area summarized the views of the citizens in AL-Mafraq Governorate on the situation of water quantity and quality. The survey covered socioeconomic information such as educational level, age, and household income in addition to the data concerned with knowledge on water quantity, water quality, water conservation and public perception and satisfaction by respondents. The study recommended performing optimal use of water, maintaining and monitoring the water quality and quantity, promoting measures for increase the water use efficiencies. More efforts should be taken from the Directorate of Water by reducing the water contamination, increasing the efficiency of water distribution networks, changing or repairing the old pipelines to increase the conveyance efficiency from the water sources to the house holders, increasing the public awareness among the policy makers and private sectors through out the media. For conserving water resources, the religious motivation, economical incentives, building sanitation systems, using modern irrigation systems and water harvesting projects should be taken by the water authorities in AL-Mafraq Governate.

DRINKADRIA PROJECT: FROM AN IDEA TO POLICY RECOMMENDATION – A COMMON APPROACH DEVELOPMENT, TOWARDS WATER RESOURCES MANAGEMENT AND SUPPLY, ACROSS ADRIATIC SEA COUNTRIES

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ABSTRACT

Nowadays, Adriatic Sea countries are facing significant cross-border water supply and resources management problems. Cross border water resources management is a complex issue, requiring the adoption of immediate measures, while at the same time it is quite challenging. No common methodologies and tools exist, addressing water quantity and quality issues, water losses and pricing policies, in the Adriatic area. WFD 2000/60 is the trigger of the harmonization of procedures and legislations. Drinkadria project develops a common methodology approach, for efficient and effective cross border water supply and resources management. Stakeholders are called to address three specific objectives. The first one is the promotion of sustainable provision of drinking water, by stabilizing joint cross-border recommendations on drinking water resources management, common code of good practices for water utilities for reducing water losses and wasteful/non-sustainable uses. The undertaking of innovative technologies, through the implementation of pilot actions is the second objective. The third one is stimulating capacity building, through the exchange of know-how and the development of a regional network of water supply experts. A set of standardized protocols on the applicable management of water supply systems and resources, in the Adriatic area is being prepared, tested by

the beneficiaries involved. Pilot actions aim in improving water supply and ground water management. The use of analytical tools for water losses reduction is the road path for sustainable water supply. The measurable outputs and results of Drinkadria are being presented in this paper, supporting decision makers in the adaptation of relevant policies.

INSTITUTIONAL AND LEGISLATIVE STATUS OF SURFACE WATER MANAGEMENT IN TURKEY AS AN ACCESSION COUNTRY TO EUROPEAN UNION

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ABSTRACT

Turkey aims to join the European Union in an unforeseeable future, though the accession negotiations has already benn started in several chapters in 2005. As one of the priority areas "Environment" chapter is opened in 2009. In order to adopt and implement Union's legislature, Turkey has legislated several directives since this date. Regarding the surface water management, Turkey enacted many directives such as "Management of Surface Water Quality Directive" and "Protection of Watersheds and Preparation of Watershed Management Plans Directive". In particular, the Ministry of Forestry and Water Works (MoFW) is carrying out extensive efforts on adaptation to the Water Framework Directive (WFD) of EU. The paper presented aims to demonstrate and compare the current legislative and institutional status of surface waters in Turkey with respect to the WFD's basic aspects and methodology. The paper also aims to create an overlaps and gaps analysis through that comparison.

HIGHLIGHTS

- The legislative framework of WFD are compared with the Turkish legislation for surface water management.
- The differences and similarities in between are discussed.
- Legislative and institutional overlaps and gaps in surface water management are considered.